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Waratah Coal

China First: Groundwater Assessment

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Waratah Coal

Executive Summary

E3 Consulting Pty Ltd (E3) was commissioned by Waratah Coal Pty Ltd (Waratah Coal) to undertake an assessment of groundwater for the Galilee Coal Project – Northern Export Facility Project (China First Project). This technical report assesses the current status of groundwater, the potential impact to groundwater resulting from the proposed works, and outlines management measures to mitigate the impacts on groundwater from the China First Project (CFP). The project includes a:

- Coal mine (Exploration Permit Coal (EPC) 1040 and 1079) located near Alpha in the Galilee Basin, Central Queensland;
- Rail alignment between the mine and a coal terminal located within both the Abbot Point State Development Area (APSDA) and Port of Abbot Point; and
- Coal terminal incorporated within both the APSDA and the Port of Abbot Point.

A review of available groundwater data on the Galilee Basin indicates that little is currently known about the hydrogeological regime in this area. Based upon current data, the water levels measured at the mine ranged between 12 and 55 metres below ground level (mgbl) with groundwater flowing east. Shallow aquifers in Tertiary material were not present during investigations at the mine site. It is believed that the shallow aquifers are not laterally continuous across the Galilee Basin; however, they may occur in isolated areas that are recharged by creeks and/or rainfall. No major aquifer units in the Permian sequences above the coal seams were reported from drilling or geophysical traces. The adjoining units above and below the coal seams themselves represent areas of groundwater aquifers. The water quality from these aquifers varied from hypo to hypersaline with predominantly low yields of <6 L/s. However occasional bores reported yields of 10-17L/s. The water was predominantly suitable for livestock watering or irrigation.

The north and central sections of the rail alignment (KP00-KP230) are located within an undeclared groundwater area. The aquifers in this area are anticipated to include predominantly unconfined and confined weathered and fractured granite/igneous systems. Shallow unconfined and confined tertiary aquifers in shale, sandstone and clay strata are also likely to exist in the southern section of undeclared groundwater between KP200 and KP230. Shallow alluvial unconfined aquifers in alluvial leads may occur in river valleys; however specific data was not found for these aquifers. Yields of between one and 5.6L/s and a range in salinity between 400 and 1,300mg/L Total Dissolved Solids (TDS) occur in the granite aquifers (SKM, October 2009). Limited static water level data for bores within the area indicate that water levels range from five to 30mbgl.

The rail alignment crosses the declared area of the Highlands Groundwater Management Unit (GMU) between KP230 and KP447. The aquifer systems in this area can be categorised into three main groups including predominantly tertiary shale, sandstone (including the Suttor Formation) and clay strata. The depth to the top of these aquifers ranges from 10 to 150mbgl and static water levels range from 10 to 80mbgl. Semi-confined Permian aquifers may exist at greater depth within this area.

The coal terminal is located within the Bowen GMU. Searches of the Department of Environment and Resource Management (DERM) groundwater database indicate bores in the Bowen GMU are mainly in alluvial unconfined aquifers with groundwater at 2 to 20mbgl around the Don River (SKM, October 2009). There are six bores within 5km of the coal terminal. The data from these bores indicates two aquifer systems occur, these being a shallow alluvial aquifer system and deeper saline granite aquifer. The aquifers near the coal terminal are comprised of Quaternary deposits and mud flats interspersed with alluvial deposits (SKM, October 2009). The groundwater flow is likely to be both westerly and northerly from the granitoid intrusive and erosional outwash to the respective sinks of the Caley Valley Wetlands and Dingo Beach. Groundwater at the coal terminal is likely to be <10m below ground level and hosted in both the shallow and granite aquifers. Groundwater within the area is characterised by neutral to slightly acidic pH (6.03 – 7.31) and brackish to saline (GHD, 2009). The yields within the alluvial aquifers range from <1 to 20L/s with salinities ranging from 500 to 1,000mg/L TDS. Yields of up to 40L/s have been observed in the granitic aquifers. Groundwater within these aquifers ranges in salinity from 300 to 20,000mg/L TDS.

Results from the field works and hydrogeological modelling found that the mine has the greatest potential for impacts to existing groundwater. The mine lies east of the boundary of the Great Artesian Basin (GAB) and includes groundwater in the Galilee Basin. The presence of aquitards at the base of the GAB suggests low potential for impacts from the mine to the GAB. Groundwater resources in the area have been identified and a model of the potential impacts has been prepared. The model suggests the mine will impact on groundwater users within 12 to 30km of the mine from drawdown.

The potential for groundwater contamination may occur as a result of impacts from coal rejects disposal; mining; goafing of the coal seam aquifers; leaking tailings storage facilities; and spills and leaks from chemical, fuel and oil storage and handling areas at workshops and mine operations infrastructure. The assessment of potential for acid generation and heavy metals impacts from the mine overburden and coal reject indicate a low likelihood for these impacts. The potential for impacts from surface storages of rejects, waste, tailings and fuel, oil and chemical storages are considered to be low because:

- Groundwater levels around the mine are generally not shallow and will become deeper due to drawdown around the mine; and
- Appropriately constructed storage and handling areas will result in low potential for leakages or spills.

As the rail alignment will carry coal, the main potential impacts with respect to groundwater are related to shallow near surface groundwater that could be impacted by railway construction activities.

Mitigation measures to manage these impacts include further site specific studies of vulnerable groundwater areas, management and containment measures for potential contaminants and a commitment to enter into agreements with landholders regarding groundwater usage (if required) and "make good" requirements if groundwater is impacted by project activities. A monitoring program with trigger levels based on the ANZECC 2000 guidelines will allow for an assessment of the actual impacts from the mine during its development and Waratah Coal will enter into agreements with local land users for monitoring and "make good" arrangements where unacceptable impacts such as dewatering and contamination of neighbouring bores are reported. Further longer term hydraulic testing would be useful to refine predictions of the extent of potential impacts.

1 Introduction

Waratah Coal Pty Ltd (Waratah Coal) proposes to establish a coal mine, railway and coal terminal to export high volatile, low sulphur, steaming coal to international markets. The Co-ordinator General declared the Galilee Coal Project – Northern Export Facility (China First Project) to be a significant project requiring the preparation of an Environmental Impact Statement (EIS).

The project includes a:

- Coal mine located near Alpha in the Galilee Basin, Central Queensland;
- Rail alignment between the mine and Abbot Point State Development Area (APSDA) and Port of Abbot Point; and
- A coal terminal incorporated within both the APSDA and Port of Abbot Point.

The China First Project study area is shown in Figure 1-1 and a full description of the project is provided in the Project Description section of the EIS.

1.1 Terms of Reference

This technical report addresses Section 3.4.2 (Groundwater) of the Terms of References (ToR) for the China First Project. The ToR requires an assessment of the quality, quantity and the local and regional significance of artesian and non-artesian groundwater resources within the project area. The report has been structured to address the three major structural components of the project separately; mine site, rail corridor and onshore coal infrastructure at Abbot Point. The technical report identified the existing environmental values of groundwater within the project area, assesses potential impacts resulting from the China First Project and suggests management measures to mitigate potential impacts. The section of the ToR pertaining to groundwater requirements are listed in Table 1-1. For ease of reference, the respective sections of this report that address the ToR requirements are also provided.

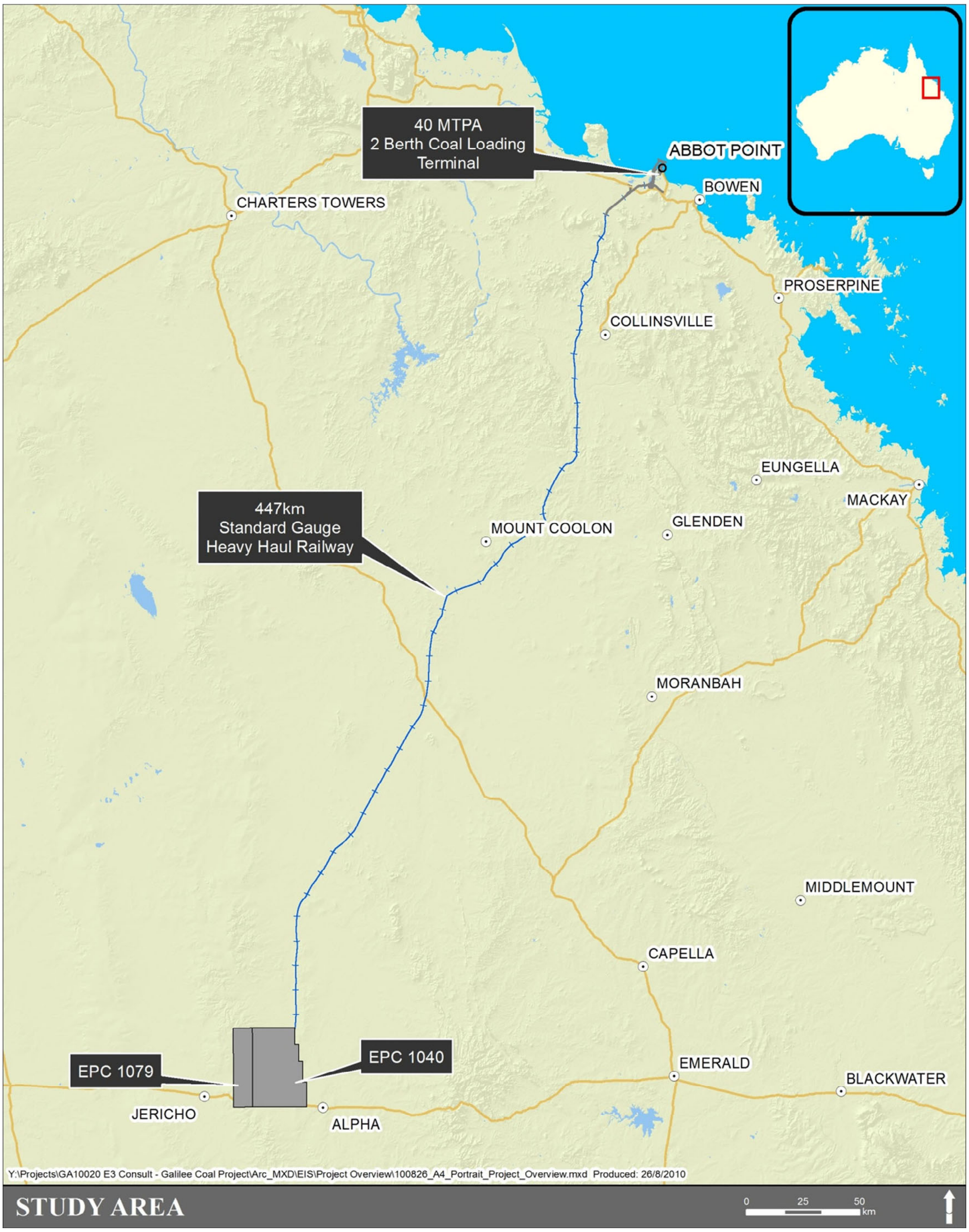

Figure 1-1: Study Area

Table 1-1: Terms of Reference

Terms of Reference	Section in EIS
Location and type of facilities; Pumping parameters; Seasonal variations of groundwater levels. Draw down and recharge at normal pumping rates.	Sections 3,4 and 5
Nature of aquifer(s) including geology/stratigraphy, aquifer type, depth and thickness.	Sections 3,4 and 5
Hydrology of the aquifer(s) including depth to water level and seasonal changes in levels, groundwater flow directions, Interaction with surface water, Interaction with sea/salt water, possible sources of recharge, vulnerability to pollution,	Sections 3,4 and 5
Major ionic species present in the groundwater, pH, electrical conductivity and total dissolved solids.	Section 3.3
The environmental values of groundwater should be described in terms of values identified in EPP (Water), sustainability, including both quality and quantity, physical integrity, fluvial processes and morphology of groundwater resources.	Section 2 and 3.3
Assessment of potential impacts caused by the project to local groundwater resources, including induced salinity.	Section 6
The extent of the area within which groundwater resources are likely to be affected by the proposed operations and the significance of the project to groundwater depletion or recharge.	Section 3.3, 3.4 and 3.5
Specify available management options to monitor and mitigate effects.	Section 7
Response of groundwater to the progression and cessation of the proposed activities.	Section 3.3, 3.4, 3.5, 4 and 5
An assessment of potential impacts on local groundwater caused by altered porosity and permeability of any land disturbance. The potential for groundwater dependent ecosystems to be impacted. Impacts of surface water storage volumes on groundwater pressure and levels in relation to the sea/freshwater interface and associated ecology of wetlands. Assessment of the potential to contaminate groundwater resources and measures to prevent, mitigate and remediate such contamination.	See Land Use and Planning and Contaminated Land Technical Reports
A network of observation points should be developed which would satisfactorily monitor groundwater resources both before and after commencement of operations.	Section 8

2 Methods of Assessment

Desktop and field investigations were undertaken on groundwater over the extent of the China First Project (CFP). Only desktop investigations of the local and regional hydrogeology in terms of regional characteristics and vulnerability for the rail alignment and coal terminal were undertaken, as it is considered that these components will not significantly penetrate the underlying hydrogeology. In contrast, desktop investigations, preliminary studies and field sampling were undertaken of the hydrogeology of the mine to develop a conceptual model to predict potential impacts of mining activities as open cut and long wall mining activities have the most potential to impact on groundwater resources.

2.1 Desktop Assessment

The desktop component of this technical report included a literature review and search of relevant Commonwealth, State (Queensland and Western Australia) and regional databases. Specific information sourced and utilised included:

- Historical groundwater bore records sourced from the Department of Environment and Resource Management (DERM);
- Digital searches for GIS groundwater data sourced from Department of Environment and Resource Management (DERM);
- Sourced mapping in assisting to produce conceptual models for the Galilee Basin from (Phil Ferenczi per comms), Department of Employment, Economic Development and Innovation (DEEDI);
- Review of relevant Commonwealth, Queensland, and Local Guidelines and Standards including the *Environment Protection Policy (Water) (EPP(Water 2009)) and Queensland Water Quality Guidelines (DERM 2009).*
- Review of relevant Stygofaunal Guidelines including the Western Australia Environment Protection Agency of *Methods and Survey Considerations of Subterranean fauna in Western Australia, No.54a (Draft), Technical Appendix to Guidance Statement No.54 (EPA 2007);*
- Published and grey literature including publications sourced from Great Artesian Basin Coordinating Committee (GABCC).

The purpose of the desktop review was to obtain an overview of groundwater quality in the China First Project study area and identify data gaps so that field surveys could be targeted to obtain the relevant information.

2.2 Legislative and Planning Framework

The Queensland *Water Act 2000* vests the use and control of all the State's water to the Queensland Government. One of the tools employed to implement the Water Act are Water Resource Plans. Water resource plans strive to achieve a sustainable balance between meeting human needs and those of the environment.

The Water Resources (Great Artesian Basin) Plan 2006 is the primary legislation for groundwater management of the Great Artesian Basin (GAB) in Queensland. The CFP is within the Galilee Basin and is outside the eastern boundary of the GAB.

The Great Artesian Basin Resource Operations Plan 2007 implements the Water Resource (Great Artesian Basin) Plan 2006. Twenty-five 'groundwater management areas' and associated 'groundwater management units' are identified in the plan. The mine site of the CFP is predominantly within the Highlands Groundwater Management area.

The *Environmental Protection Policy (Water) 2009* (EPP(Water) states that sampling and analysis must comply with the *Queensland Water Quality Guidelines* (QWQG) as these take precedence over other recognised guidelines. The QWQG indicate that the mine falls within the Central Coast Queensland region and the relevant water types are upland streams for which ANZECC 2000 guidelines are to be adopted. The QWQG and ANZECC guidelines are predominantly focused on the protection of surface waters however in the absence of specific guidelines for groundwater quality these have been adopted as a way to assess groundwater quality.

2.3 Field Work

The field work of site specific investigations at the mine was undertaken in September 2009 and May/June 2010. These data were used to input into the conceptual model used to predict potential impacts at local and regional scales.

2.3.1 Bore Survey

A groundwater survey of available bores within the mine project areas was undertaken in order to assess the state of pre-mining regional groundwater. The locations of the bores assessed are shown in Figure 2-1 and detailed in Table 2-1. These sites form a network of observation points for monitoring groundwater quality prior to and throughout mining activities.

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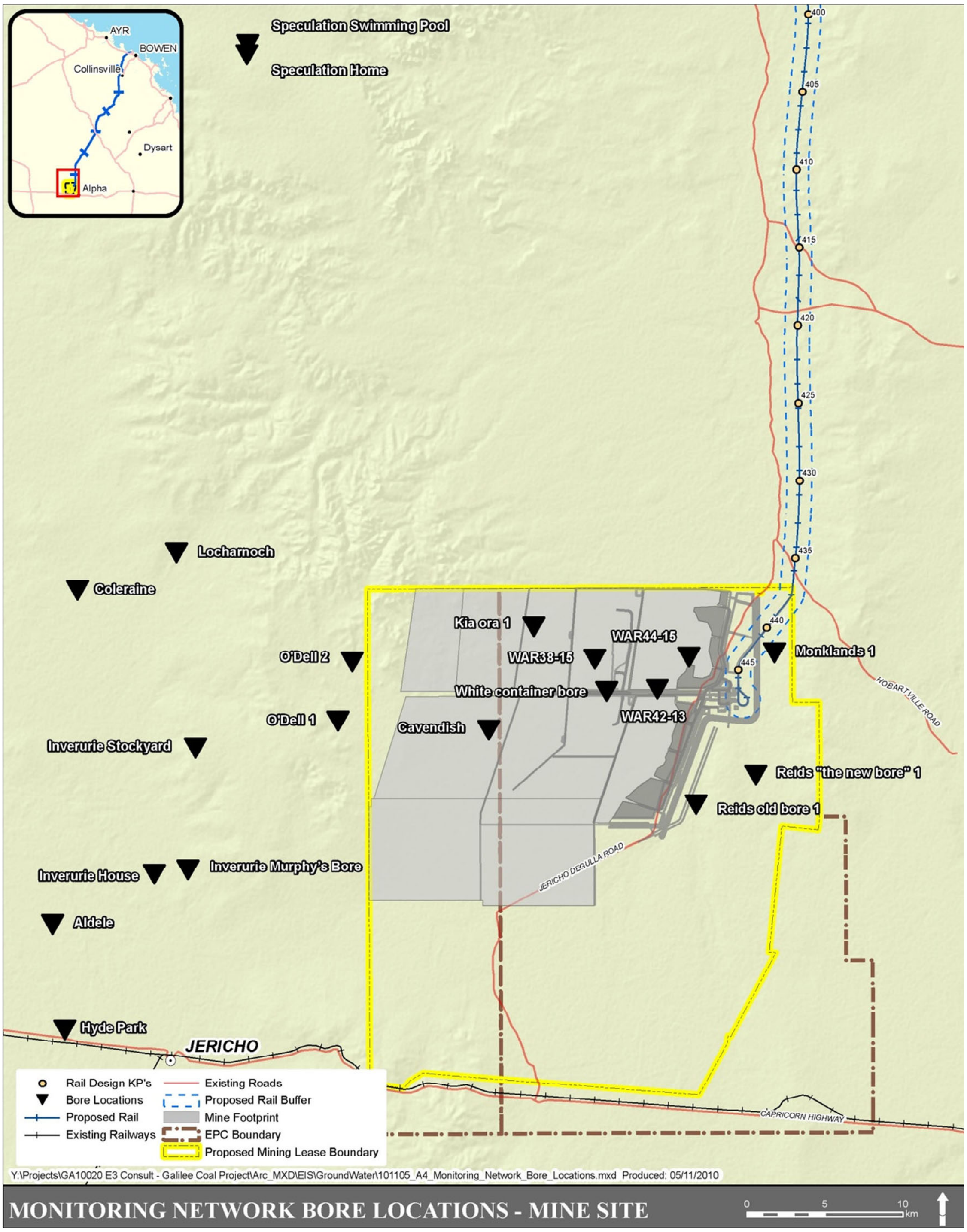

Figure 2-1: Monitoring Network Bore Locations

Table 2-1: Groundwater Bores Surveyed in this Study

	Bore ID	Aquifer
1	WAR38-15(New)	Weathered Permian
2	WAR38-15(80)	Coal Seam B
3	WAR38-15(House)	Weathered Permian
4	WAR44-15(Monitor)	Weathered Permian
5	WAR44-15(New)	Coal Seam DL
6	WAR44-15(Retro)	Coal Seam DL
7	WAR42-13(50)	Weathered Permian
8	WAR42-13(New)	Coal Seam DU
9	WAR42-13(80)	Coal Seam DL
10	White Container bore (DERM RN 14512)	Weathered Permian
11	Cavendish 1 (DERM RN 51682)	Weathered Permian
12	Kia Ora 1 (DERM RN 15405)	Weathered Permian
13	O'Dell bore 1 (DERM RN 103801)	Weathered Permian
14	O'Dell bore 2 (DERM RN 103441)	Weathered Permian
15	Monkland's 1 (DERM RN 44466)	Tertiary
16	Reid's "the old bore" 1 (DERM RN 44467)	Tertiary
17	Reid's "the new bore" 1 (DERM RN 44468)	Tertiary
18	Hyde Park (DERM RN 103171)	GAB and associated aquifers
19	Aldele (DERM RN 3070)	GAB and associated aquifers
20	Locharnoch	GAB and associated aquifers
21	Coleraine (DEM RN 3075)	GAB and associated aquifers
22	Inverurie – Stockyard	GAB and associated aquifers
23	Inverurie – Home bore	GAB and associated aquifers
24	Inverurie – Murphy's bore	GAB and associated aquifers
25	Speculation – Swimming pool (DERM RN (69617)	GAB and associated aquifers
26	Speculation – Home bore (DERM RN 51056)	GAB and associated aquifers
27	Armagh – House bore	GAB and associated aquifers

Note: Bracketed text indicates different bores in close proximity to others

2.3.2 Geophysical Survey

A review was undertaken of available geophysical logs from coal exploration holes to assess the potential aquifer zones and the presence of fresh or saline water in the stratigraphy. In addition gamma resistivity and Spontaneous Potential/Point Resistivity (SP/PR) tools were used on bores from this study in order to identify the likely strata layers containing groundwater and areas of higher permeability material.

The sonde with the geophysical tool is lowered into the hole usually filled with drill fluid or water, with a grounded electrode in the mud pit or a wetted area close to the hole. A spontaneous potential is generated between the electrodes and assists in identifying porous beds and/or fresh/saline waters. Resistivity logs indicate the grain size of any material as sands have high resistivities and clays/shales have low resistivities.

Gamma logs measure the gamma radiation produced by the stratigraphic formations. Clays and shales have high gamma radiation signatures as compared to sands which have lower levels of gamma radiation. A typical SP/PR and gamma trace from sand and clay formations is shown in Figure 2-2 to illustrate the interpretation of down hole logging.

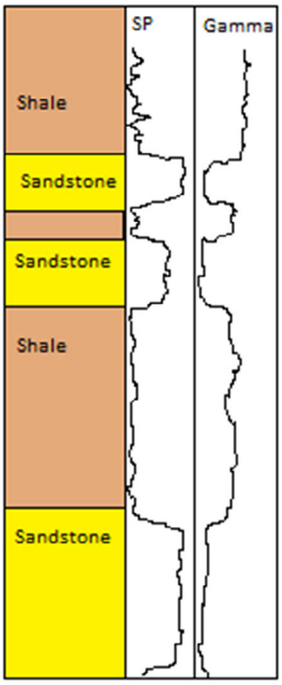

Figure 2-2: Example of Geophysical Trace

2.3.3 Bore Installation

Environmental monitoring bores were installed to assess the hydraulic and chemical parameters of groundwater in the area of the mine based upon ARMCANZ 2003 guidelines "Minimum Construction Requirements for Water Bores in Australia". Water bores were drilled by a licensed driller using an air rotary blade drilling technique with the capability to undertake mud rotary drilling if required. The boreholes were drilled at 150 mm diameter and were cased with either 50 mm or 100 mm diameter Class 18 factory slotted uPVC screen and casing. The environmental monitoring bores were generally screened across the bottom 6 m of the hole. Bores were backfilled with clean graded sand to 3 m above the screened interval, by at least a 1 m plug of bentonite and then grouted to the surface with a bentonite cement mix. Bores were completed with a cement pediment and lockable bore monument. The bores installed by this method included three 100 mm diameter bores and one 50 mm bore.

Further environmental monitoring bores were installed and constructed in existing coal exploration boreholes that had been maintained to monitor groundwater levels.

The environmental monitoring bores constructed in existing coal holes used 50 mm diameter factory slotted screen and casing. The bores were constructed in the same manner as the wells constructed into the drilled holes. Details of the well construction are presented in Table 2-2. The bores indicated in Table 2-2 were installed within 30 m of surrounding monitoring bores to improve the likelihood of pumping induced drawdown effects being observed in these bores.

The depths of these bores and the screened intervals were assessed using the results from the down-hole geophysics, bore logs and site observations. Bore construction details are presented in Appendix A along with drill logs for the three locations. Locations of bores are detailed in Table 2-2.

Table 2-2: Bore Construction Details

Bore ID	Coordinates	Geology	Depth (mgbl)	Screen Interval (mgbl)
WAR38-15(40)	E438016.8, N7415027.2	Weathered Permian	40	34 – 40
WAR38-15(New)	E438040.6, N7415054.1	Interburden B/C	66	60 – 66
WAR38-15(63)	E438037.2, N7415042.9	Coal seam B	62.8	56.8 – 62.8
WAR42-13(50)	E442073.9, N7413136.2	Weathered Permian	50	44 – 50
WAR42-13(65)	E442087.2, N7413141.9	Coal seam DU	65	59 – 65
WAR42-13(80)	E442090.0, N7413147.0	Coal seam DL	85	79 – 85
WAR44-15(Retro)	E444092.9, N7415171.8	Coal seam DL	62	56 – 62
WAR44-15(Monitor)	E444095.3, N7415165.4	Weathered Permian	49	43 – 49
WAR44-15(New)	E444099.8, N7415170.4	Coal seam DL	62	56 – 62

2.3.4 Water Level Monitoring

A survey of bore water levels on and surrounding the mine including the newly installed monitoring bores, and existing landowners bores was carried out in order to assess the piezometric surface and therefore the direction of flow in the aquifers. Water levels were measured using a manual groundwater level probe "dipper" and GPS locations and elevations for each bore were recorded.

2.3.5 Water Sample Collection

The monitoring bores and available landowner bores in the surrounding region were sampled in order to assess the geochemistry of groundwater. Newly constructed environmental monitoring bores were purged using a 50 mm diameter submersible pump for bores with static groundwater levels above 30 mbgl and using a 50 mm diameter pneumatic pump for bores with deeper static water levels. In order to comply with *AS5667.11 1998 "Water Quality Sampling – Guidance on sampling of ground waters"*, four to six bore volumes were purged from each bore prior to sampling. Pump flow rates differed depending on bore depth and static water level. Where sampling of surrounding landowners bores was undertaken, the water samples were collected directly from the bore or where down hole access was not available, the samples were collected from the pump outlet.

The following field parameters were assessed at the time of sampling:

- Electrical conductivity (mS/cm);
- pH;

- Dissolved oxygen (% saturation);
- Water temperature (°C); and
- Turbidity (NTU).

Samples were stored in laboratory supplied sample bottles and placed on ice in a cooler and transported to a National Association of Testing Authorities (NATA) accredited analytical laboratory with chain of custody forms in appropriately preserved sample containers. Samples for heavy metals were filtered on site to assess dissolved heavy metals concentrations. Samples were analysed for the following suite of parameters:

- Metals (arsenic, cadmium, chromium, copper, iron, lead, manganese, mercury, nickel and zinc);
- Nutrients (ammonia as N, nitrate as N, nitrite + nitrate as N, total kjeldahl nitrogen as N, total nitrogen as N and total phosphorous as P);
- Total dissolved solids;
- Alkalinity (carbonate alkalinity as $CaCO_3$ and hydroxide alkalinity as $CaCO_3$);
- Sulfate as SO_4^{2-}; and
- Major anions/cations (calcium, chloride, magnesium, nitrate as N, potassium, sodium, total anions and total cations);

Ionic balance was reported by the laboratory as an indication of whether other major unreported ions are present outside of those tested. The ionic balance for the results were <5%, and indicated no other major ions were present.

2.3.6 Aquifer Tests

Permits for long term pump tests were not received by the time the fieldwork was undertaken as the mining exploration leases over the land did not allow the removal of water for purposes other than environmental (i.e. water quality) sampling. Therefore, water levels were monitored with both pressure transducers and manual water level meters during bore development. Water levels were also monitored during the purging and sampling of the monitoring bores. This monitoring data was used to assess aquifer parameters and in particular transmissivity, storage and hydraulic conductivity. The data were also used to monitor water levels for potential indicators of leakage/connections between bores screened in different aquifers. A v-notch weir was used to assess flow rates during bore development (Plate 2-1).

Plate 2-1: Well Development Setup showing the V-notch Weir Method for Estimating Flow Rates

Constant rate discharge tests were carried out on WAR38-15(New), WAR42-13(New) and WAR44-15(New) with water levels monitored at adjacent bores. Table 2-3 to Table 2-5 summarise the constant rate discharge tests carried out.

Table 2-3: WAR38-15 Constant Discharge Test Details

		WAR 38-15 New	WAR 38-15(63)	WAR 38-15(40)
Test purpose		Pump	Observation	Observation
Owner		Waratah Coal	Waratah Coal	Waratah Coal
Easting		146°23'37.1		
Northing		23°22'24.31		
Depth (m)		66	62.8	50
Diameter (mm)		100	50	50
Casing material		PVC	PVC	PVC
Primary use		Environmental monitoring	Environmental monitoring	Environmental monitoring
Distance from pumped monitoring bore (m)		-	20	20
Static water level at start of testing (mbgl)		53.26	53.51	Dry
Screen details	Type	Class 18 uPVC	Class 18 uPVC	Class 18 uPVC
	Diameter (mm)	100	50	50
Screen 1	Top (mbgl)	60	56	45
	Bottom (mbgl)	66	62	50

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Table 2-4: WAR44-15 Constant Discharge Test Details

		WAR44-15 New	WAR 44-15 Monitor	WAR 44-15 Retrofit
Test purpose		Pump	Observation	Observation
Owner		Waratah Coal	Waratah Coal	Waratah Coal
Easting		146°27'10.66		
Northing		23°22'19.89		
Depth (m)		62	49	62
Diameter (mm)		100	50	50
Casing material		Class 18 uPVC	Class 18 uPVC	Class 18 uPVC
Primary use		Environmental monitoring	Environmental monitoring	Coal core logging and environmental monitoring
Radius from pump bore (m)		-	25	25
Static water level at start of testing (mbgl)		11.07	9.68	11.13
Screen details	Type	PVC	PVC	PVC
	Diameter (mm)	100	50	50
Screen 1	Top (mbgl)	56	43	56
	Bottom (mbgl)	62	49	62

Table 2-5: WAR42-13 Constant Discharge Test Details

		WAR42-13 (New)	WAR42-13(80)	WAR42-13(65)
Test purpose		Pump	Observation	Observation
Owner		Waratah Coal	Waratah Coal	Waratah Coal
Easting		146°26'00.2		
Northing		23°23'25.28		
Depth (m)		80	97	97
Diameter (mm)		100	50	50
Casing material		Class 18 uPVC	Class 18 uPVC	Class 18 uPVC
Primary use		Environmental monitoring	Coal core logging and environmental monitoring	Coal core logging and environmental monitoring
Radius from pump bore (m)		-	25	27
Static water level at start of testing (mbgl)		17.01	17.04	15.76
Screen details	Type	PVC	PVC	PVC
	Diameter (mm)	100	50	50
Screen 1	Top (mbgl)	74	80	65
	Bottom (mbgl)	80	85	70

Table 2-6 contains details of the three aquifer tests. Aquifer tests were carried out in accordance with AS 2368-1990 "Test Pumping of Water Wells". However, as stated in section 2.3.6 permits for long term pumping tests were not received prior to field work, therefore the duration of pumping did not comply with the standards.

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Table 2-6: Aquifer Test Details

Bore ID	Pump time (min)	Pump rate (L/min)
WAR38-15 (New)	10	9
WAR42-13 (New)	220	9
WAR44-15 (New)	184	9

2.3.7 Slug Tests

Slug tests were undertaken on 11 bores around the project site as shown in Table 2-7. A slug of water was introduced into each bore to artificially raise the water level in the bore. Water levels were monitored at one second intervals prior to slug injection, throughout the injection period and throughout the period of recovery.

Table 2-7: Slug Test Summary

Bore	Injection volume (L)	Injection time (mins)	Maximum displacement (m)
WAR38-15(New)[1]	100	2.5	6.3
WAR38-15(60)[1]	50	1.25	10
WAR44-15(Monitor)[1]	40	2	9.8
WAR42-13(50)[1]	40	4.2	14.5
Reid's the new bore[1]	20	2	0.16
Reid's the old bore[1]	20	2	0.35
Hyde Park[2]	40	2	1.91
Aldele[2]	40	22	0.3
Locharnoch[2]	40	2	-
Coleraine[2]	40	1	0.45
Monkland's 1[1]	40	2	1.6

Note: 1 – Bores in proximity to the mine area. 2 – Bores in GAB and associated aquifers.

2.3.8 Stygofauna Sample Collection

Stygofauna samples were collected in order to assess the potential for groundwater ecosystems within the mine lease area.

Stygofauna were collected from the pump discharge of WAR38-15New, WAR38-15(63), WAR42-13(New), WAR42-13(80), WAR44-15(New), WAR44-15(Retro) using a phytoplankton net of 0.45 µm mesh size. Figure 2-3 illustrates the stygofauna net setup. The trap consists of a plankton net (44 mm diameter) with a small collection vial/sump attached to the bottom. A total of 300 L of groundwater was filtered through the net at each sampling location in order to meet stygofauna collection guideline requirements (Western Australia EPA, 2007).

The material that did not pass through the mesh was preserved in 70% ethanol solution for later identification. The methods used for the collection of stygofauna were based upon the sampling methods and guidelines for subterranean fauna in Western Australia (Western Australian EPA, 2007).

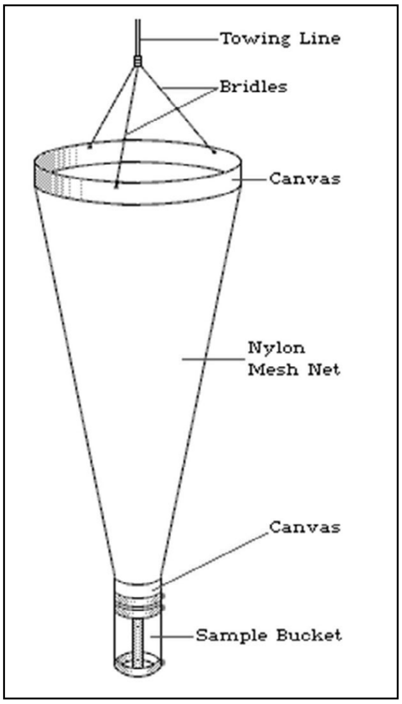


Figure 2-3: Stygofauna Net Setup

2.3.9 Double Ring Infiltration Test

A double ring infiltrometer was used to assess the saturated hydraulic conductivity of shale layers in the Rewan geological formation as the shales of the Rewan Formation are interpreted to be one of the aquitards overlying the mine site geology. The infiltration test was undertaken on a sample of shale not on soil, therefore results were not used to assess recharge.

Plate 2-2 shows the infiltrometer test setup. A suitable section of the Rewan formation was identified within a road cutting at the following location on Durrandella station (Plate 2-3 - Easting 456452, Northing 7340425).

Plate 2-2: Working Infiltrometer Test

Plate 2-3: Rewan Formation Road Cutting

A flat shelf with an area greater than the diameter of the infiltrometer was cleared in the road cutting using shovels and a pick axe. An intact sample of shale was collected as part of fieldworks and an infiltration test was undertaken. The infiltrometer was placed on the shale and a seal around both the outer and inner rings of the infiltrometer was achieved using silicon sealant. Both the inner and outer rings of the infiltrometer were filled to a level of 10 cm and water depth monitored and measured over a time period of 15 minutes. The water level in the outer ring was kept at a constant level throughout the trial. Results were analysed using equation (1) to assess likely infiltration rates (IR) into the shale.

*Equation (1): K = (IR/1000) * 1440*

IR is the slope of the linear regression taken from the plot of inner ring water level versus time and K is hydraulic conductivity.

2.4 Modelling

Predictive modelling was undertaken to assess the impact of the mine on the groundwater regime. The primary modeller was St John Herbert (MSc) of E3 Consult.

The specific goals of the model were:

- Predicting the amount and extent of drawdown around the mining operations;
- Predicting the groundwater inflow rates to the mine void; and
- Identifying areas for monitoring.

Predictive modelling included both numerical modelling and analytical modelling to provide a check on numerical results.

2.4.1 Conceptual Model

The simple conceptual model includes:

- Surficial Tertiary and Weathered Permian overburden sediment (layer 1 and 2);
- Coal seam B (layer 3);
- Interburden (layer 4 and 5);
- C, D, E coal seams (layer 6); and
- Permian sediment underlying coal seams (layer 7).

The water levels measured at the site ranged between 12 mbgl to 55 mbgl. Layers 1 and 5 were placed in the model to allow refined layers for more stable model simulation. Tertiary material was dry at the time of sampling and this unit is not considered to act as an aquifer across the entire region but only in discrete areas where recharge from rainfall and creeks leads to accumulation of groundwater. Depressurisation of the overburden is not anticipated to impact regionally on these water levels. The water levels in the weathered Permian overburden trend generally easterly and may feed the alluvial leads at some distance from the mine. The easterly flow is attributed to pressure of drape folded geology and topographic highs caused by the Great Dividing Range further west of the site.

The western boundary condition reflects the conceptual model of a drape fold in the geologic units that is resulting in an easterly gradient in the water levels of the units monitored. This may also be reflected in the topographic high produced by the Great Dividing Range west of the modelled area. The purpose of the eastern boundary condition is to assist in producing the observed gradient across the model. This was extended further east to minimise potential effects of the boundary condition on focus area of the model. This is similar to other modelling practices reported (ESI 2007, REM 2008, SKM July 2009).

Pit details including boundary locations and depths of each excavation and the excavation sequence were supplied in DXF format by Waratah coal. These were conceptualised by adding pit boundaries to the model and inserting drain cells to the depth of each respective excavation.

Figure 2-4 provides an overview of the conceptual model.

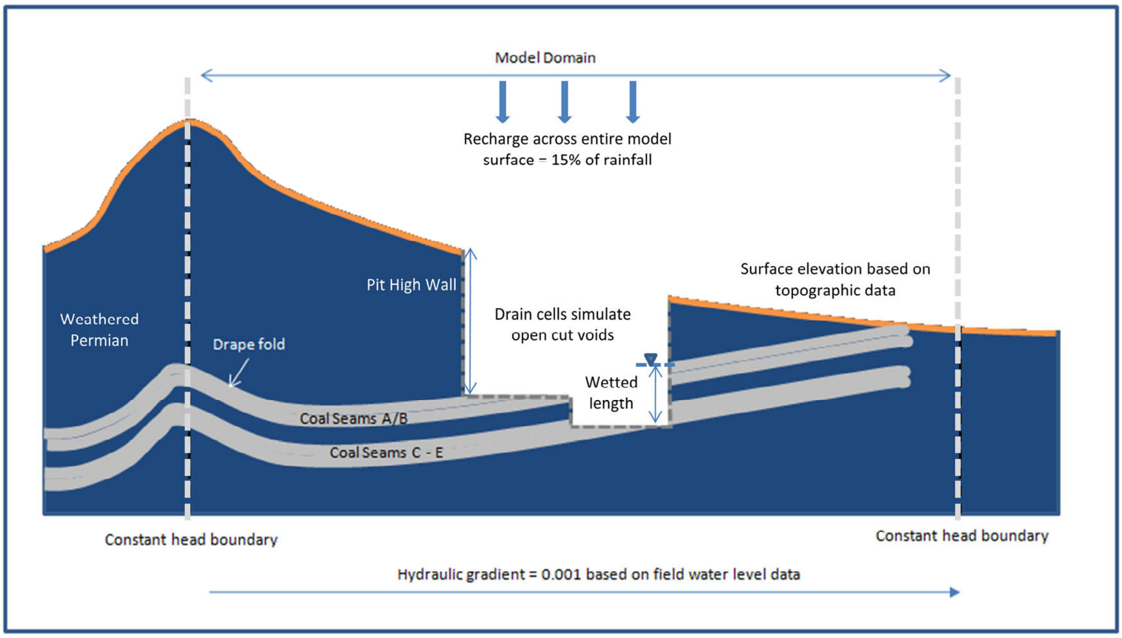


Figure 2-4: Simple Conceptual Model Diagram

2.4.2 Model Code

Numerical simulation of groundwater was undertaken using the Modflow based package Groundwater Vistas using Modflow 2000 code. Modflow code is the most widely distributed code for groundwater modelling and is considered to be an industry standard. The block model is considered suitable for the uniform strata with little or no faulting and a very shallow dip and simulates unconfined and confined aquifers in steady state and transient modes.

2.4.3 Model Geometry

The model consisted of the seven layers described in Section 2.4.1. The model surface was derived from a topographic elevation model (Figure 2-5).

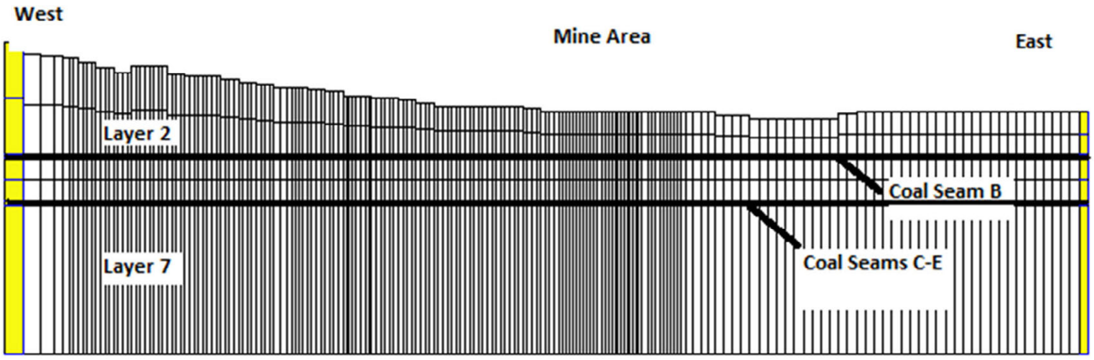


Figure 2-5: Model Cross Section

The model covered an area of approximately 50 km by 60 km with 188 rows and 198 columns yielding approximately 260,000 cells with the mine footprint placed in the centre of the modelled area (Figure 2-6). Cell size ranged from 100 m × 100 m in the mine footprint to 1,000 m × 1,000 m at the edge of the model domain. The size of cells did not change by a factor of more than 1.5 in either direction.

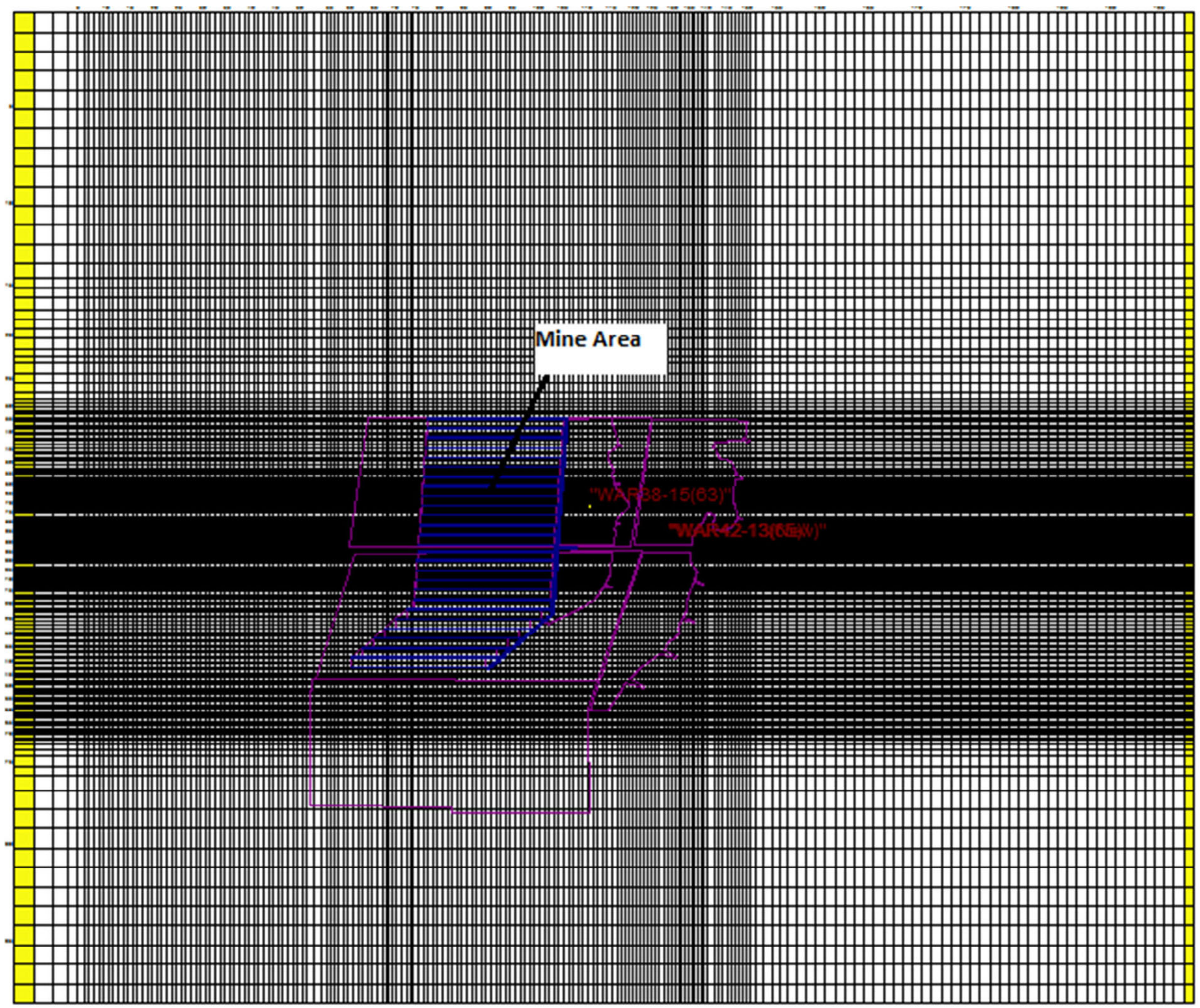


Figure 2-6: Model Grid Plan View

2.4.4 Hydraulic Parameters

The horizontal hydraulic conductivity was initially set based on results from hydraulic testing (section 2.3.6) and adjusted during calibration as summarised in Table 2-8. The vertical hydraulic conductivity was generally set at one order of magnitude lower than horizontal hydraulic conductivity and adjusted during calibration. Specific Storage of the units was estimated from hydraulic testing undertaken and reported above (in the order of 3×10^{-4} to 9×10^{-5}) and allowed to vary up to 5×10^{-6}. Unconfined sand aquifers were given storativities of sand in the range of 0.15-0.25 (Fetter, 1994).

Table 2-8: Modelled Hydraulic Parameters

Layer	Initial Hydraulic Conductivity (m/d)	Calibrated Horizontal Hydraulic Conductivity (m/d)
1	0.001-0.0029	0.001
2	0.001-0.0029	0.001
3	0.25	10.0
4	0.001	0.001
5	0.001	0.001
6	1.8-6.8	2.47
7	0.1	0.13

2.4.5 Boundary Conditions

The model domain is surrounded by constant head boundaries on the western and the eastern boundaries to simulate the generally easterly gradient recorded at the site. The constant head boundary condition is used because it is a simple boundary condition to solve. It is recognised that this boundary condition has the potential to constrain model solutions to the greatest degree compared to other boundary condition types. This was addressed in the model by placing these boundary conditions at a significant distance from the focus area of the model. The northern and southern boundaries were interpolated to be parallel to groundwater flow while the base of the model was a no flow boundary.

2.4.6 Recharge and Evapotranspiration Parameters

Recharge to the model domain was through layer 1 and then the uppermost active layer. The initial recharge was estimated as a percentage of average annual rainfall from the Monkland's rainfall station (site 35164) reported by the Bureau of Meteorology (May 2010). The average annual rainfall was 525.5 mm and initial estimates of recharge were up to 20% of rainfall. The recharge rate used in the model was 15% of annual rainfall. The nearest recorded weather station with evapotranspiration data was Emerald which recorded 1,930.9 mm/year. The evapotranspiration extinction depth was set at 2 m. The extinction depth was based on the typical rooting zone depth of grass and hence the zone of evapotranspiration.

The recharge was applied uniformly across the model and adjusted during model calibration. Initial heads for transient runs were derived from the calibrated steady state runs.

2.4.7 Model Calibration

Model calibration uses an adjustment of model parameters to find a set of simulated parameters that yield a simulated result matching observed results within an acceptable range of error (Anderson and Woessner, 1992). Model calibration was undertaken using the groundwater levels recorded at the environmental monitoring bores installed on-site and water levels recorded at surrounding landowner bores. Calibration included adjusting the following parameters:

- Boundary condition location and water level;
- Hydraulic conductivity both lateral and vertical; and
- Recharge.

The calibration targets comprised the observed water levels from the environmental monitoring bores installed on the site and the water levels measured from the surrounding landowners bores. As the degree of connection and heterogeneity of the hydrogeological regime connecting the surrounding landowners bores that were several kilometres distant from the mine was not known, these data was given less weight than the on-site data when calibrating the model. However, as model calibration accuracy is dependent upon the number and distribution as well as the quality of the calibration targets, they were included in the calibration. In the absence of a long period of time series monitoring data the model was calibrated in a steady state mode.

2.4.8 Calibration Results

The results of the calibration are provided in Table 2-9 and are presented graphically in Figure 2-7.

Table 2-9: Calibration Results

Calibration Target	Observed Water Table (mAHD)	Simulated Water Table (mAHD)	Residual Error (mAHD)
WAR44-15New	314.73	306.47	8.28
WAR44-15Monitor	316.12	312.46	3.68
WAR44-15retrofit	314.50	309.59	4.93
WAR42-13(50)	318.73	314.21	4.52
WAR42-13(80)	317.42	309.64	7.80
WAR42-13(65)	318.70	309.72	9.00
WAR42-13(New)	317.45	309.66	7.79
WAR38-15New	321.10	313.14	7.98
WAR38-15(63)	320.85	316.42	4.45
O'Dell Bore 1	350.81	351.92	-1.11
O'Dell Bore 2	373.49	351.63	21.86
Monklands 1	317.00	317.94	-0.94
Reid's old bore 1	318.00	323.08	-5.08
Reid's the new bore 1	329.40	318.89	10.53

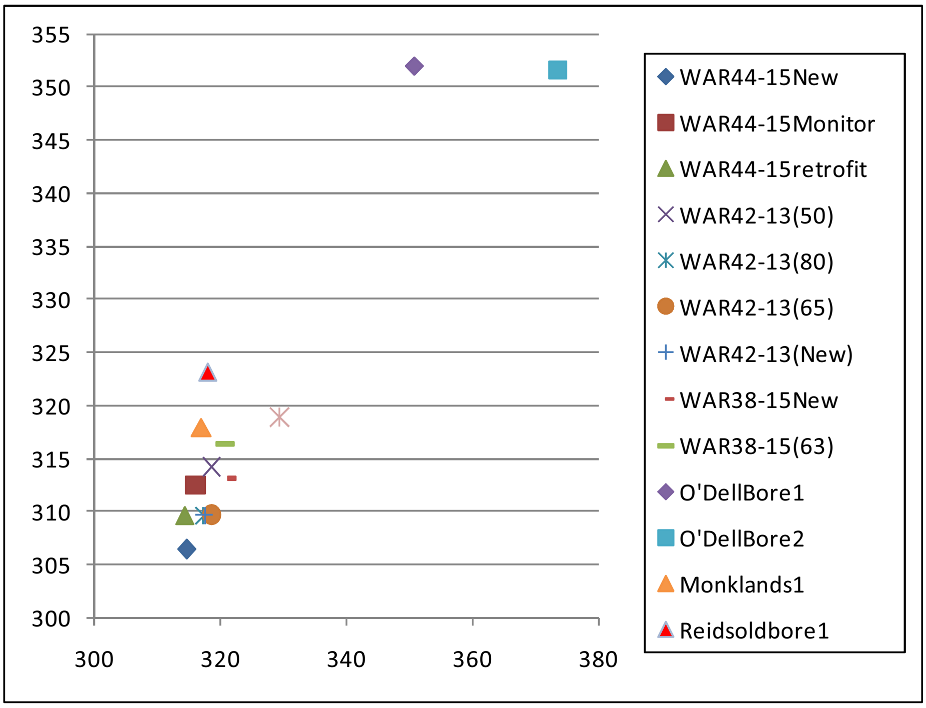


Figure 2-7: Model Calibration Plot

Given the large extent of the model and scarcity of water level data from outlying bores this is considered a reasonable calibration for this simple model.

The predictive scenarios included simulation of mine drawdown and inflows after mining for the following periods:

- 1 year;
- 5 years;
- 10 years;
- 15 years;
- 20 years;
- 25 years; and
- Groundwater recovery after mining.

The depths of the four open cuts between year 1 and year 25 are shown in Table 2-10, while the extent of the pits and underground mining were interpolated from mine plan documents. Detail of the mining sequence is presented in volume 2, chapter 2 of the China First Project Environmental Impact Statement.

Table 2-10: Simulated Pit Depths (m below ground level)

Year	Open cut 1 north	Open cut 1 south	Open cut 2 north	Open cut 2 south
1	50	80	40	38
5	80	95	50	55
10	100	105	61	65
15	115	115	67	67
20	115	138	73	72
25	130	145	80	75

2.4.9 Mass Balance

The model water mass balance (shown in Table 2-11 for year 1) shows that the constant head boundaries balance each other as intended in order to reproduce the hydraulic gradient observed in the field. The drains indicate that 35% of the water left the model via these drain cells.

Table 2-11: Mass Balance Results

Component	Percentage of water balance
Constant head boundary IN	18%
Constant head boundary OUT	22%
Recharge	25%
Drain cells	35%

2.4.10 Sensitivity and Uncertainty

The model has been constructed on the limited available data and the use of the model predictions should be treated with care. Sensitivity Analysis has been undertaken with the model. The analysis attempts to assess the influence that selected hydraulic parameters have on model predictions of Drawdown. The analysis is focussed on the parameters of hydraulic conductivity, recharge, evapotranspiration, and constant head boundaries. The results of the sensitivity analysis are summarised in Table 2-12 in a similar manner as suggested by Anderson and Woessner (1991).

Table 2-12: Sensitivity Analysis Results

Parameter	Variation	Results (observed change in head)
Recharge	×10	15%
Evapotranspiration	×10	1%
Extinction depth	80%	1%
Constant Head Boundaries	10%	5%
Hydraulic Conductivity	10%	2%

The model was most sensitive to changes in hydraulic conductivity, constant head boundaries and recharge.

Sensitivity analysis provides an indication of parameters with greater sensitivity by calculating the change in the Sum of Squared Residuals (SSR) from changes in parameter values. This indicated the parameters with greatest change in the SSR were the constant head boundaries and hydraulic conductivities in upper layers while hydraulic conductivities in lower layers had lower sensitivities.

The model was calibrated in a Steady State simulation and was not calibrated in transient mode due to a lack of transient data. This led to greater uncertainty in predictive runs of mine development under transient conditions and required a reduced conversion and dampening factor in transient runs.

Drain cells were used to simulate the open cut voids and longwalls. The drain cells were placed in the model for the entire mining period they represent (i.e. 1 year or 5 years) at an instantaneous point in the model timeframe. This may result in an overestimate of inflows reported at the end of each stress period. The stress periods were setup around the mining sequence data at 1, 5, 10, 15, 20, and 25 year intervals.

The simulation of mine inflows applied the mine development as drain cells that appear in the model instantaneously at a point in time. This may result in an overestimation of inflows reported at the end of each stress period by the model.

Significant uncertainty in aquifer geometry is present outside the immediate area of groundwater investigations. For modelling purposes media dimensions and parameters have been assumed to be homogeneous and this is likely to lead to over estimation of the extent of drawdown from the mine.

There is uncertainty surrounding hydraulic parameters derived from shorter term hydraulic tests and the absence of transient data for calibration does not allow transient calibration of the model. The model uncertainty can be reduced by incorporation of longer hydraulic test data, hydraulic tests from surrounding landowners bores and engineering study data during mine design studies. The recalibration of the model with this data could assist in refining predictions. These data would enable an enhanced conceptualisation and numerical model setup with regards to model definition and boundary conditions that truly reflect the physical system.

Recent research (Toran and Bradbury, 1988) suggests that data from before, during and after mining is required to reduce uncertainty and that models calibrated to just one or two of these datasets will have larger uncertainties.

Uncertainty and variability analyses were not undertaken due to the simple level of model complexity.

2.4.11 Model Assumptions

The following assumptions were made in the modelling:

- A 5 year time period was sufficient to simulate the mine's development;
- Once an area is excavated and becomes a drain, it remains as an active drain cell for the entire mine life;
- Once a drain cell is active, the storage becomes zero in order to avoid numerical generation of water in the model; and
- It was assumed that cracking due to subsidence will not extend to the surface and will not allow rapid movement of water from rainfall recharge to the goaf.

The model assumes that the entire mine remains dewatered for the entire mine life and that seams remain completely dewatered.

In steady state runs the initial heads from the calibration were used as starting heads for the simulation. In the cells overlying the underground mine, the vertical hydraulic conductivity was increased to simulate subsidence of the mined panel and goaf.

The extent of drawdown from mining operations has been based on a threshold of 5m drawdown.

2.4.12 Analytical Calculations

In order to provide an alternate check on the model uncertainties, analytical calculation of potential mine inflows to both open cut pits and underground long wall mining areas have been estimated based on the Darcy's equation: Q = KiA

Where: Q = flow rate L/s

K = Hydraulic conductivity/Permeability

I = hydraulic gradient

A = cross – sectional area

Aquifer hydraulic conductivities have been taken from field slug tests and constant rate drawdown tests on bores screened in the specified aquifers. Hydraulic conductivities of 1.2 m/d and 1.8 m/d were incorporated in the Darcy's equation for coal seams A-B and C-D respectively, along with a hydraulic gradient of 0.001 based upon field measurements of water level (mAHD).

Estimates of inflows to open cut sections have been calculated assuming both seepage from the entire highwall (height from base of pit to surface) and the saturated length taken as an average of the depth to water from ground surface as recorded in field investigations (pit highwall less an average water table level of 30 mbgl) (Figure 2-8).

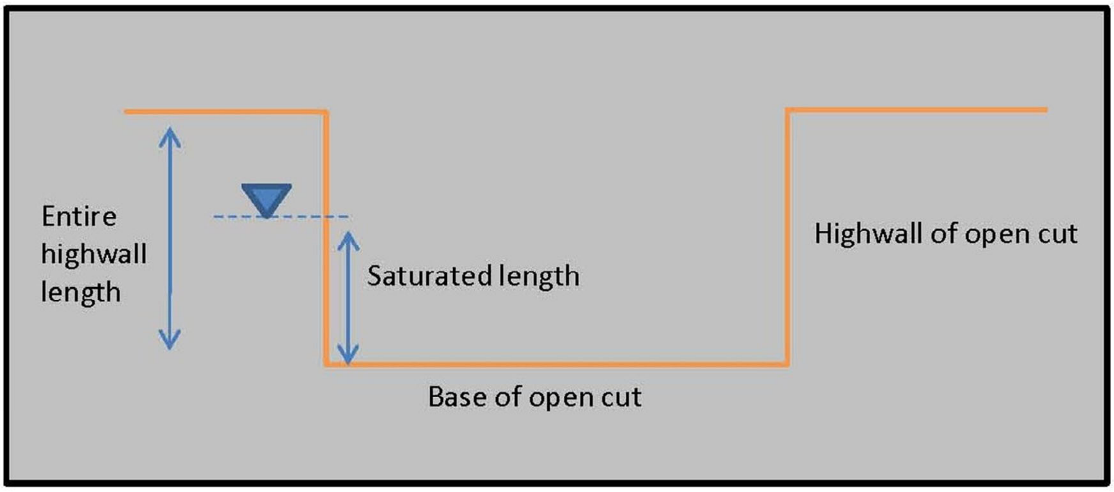


Figure 2-8: Opencut Highwall and Saturated Length

Estimates of inflows to longwall sections have been calculated based on the volume mined per year being one longwall section with dimensions of:

- 7,000 m length
- 500 m width
- 6 m height

Inflows from prior goaf have not been estimated. It is assumed that mining in the four underground mines occurs simultaneously. Table 2-13 and 2-14 contain summaries of predicted inflow calculations and results from mining operations.

Table 2-13: Open Cut Mining Analytical Inflow Summary

Year	Inflow ML/Year (Entire highwall)	Inflow ML/Year (Wetted length)
1	889	416
5	1168	697
10	1376	904
15	1520	1048
20	1680	1209
25	1818	1346

Table 2-14: Underground Mining Inflow Analytical Summary

Mine area	Target coal seam	Total inflow (ML/Year)
Underground 1	Coal seam C-D	2329
Underground 2	Coal seam C-D	2329
Underground 3	Coal seam C-D	2329
Underground 4	Coal seam A-B	1554

Comparison with simulated results (Table 3-16) indicates that the modelled flows are anticipated to be generally lower than the analytical estimates, which may be considered to be higher flow rate estimates.

3 Mine Site

3.1 Location

The mine is situated approximately 30 km northwest of Alpha. Figure 3-2 shows the boundaries of the mining tenement and the location of the rail loop. Topography slopes generally eastwards through the mine. Minor ephemeral streams drain to the north and east. Prior to field work in April 2010, the site was subject to a significant wet season with rainfalls that exceeded the 90th percentile of recorded rainfalls in monitoring data since 1887.

3.2 Previous Investigations

The following discussion is based on:

- A baseline groundwater report (SKM, October 2009);
- Reports undertaken for Waratah Coal summarising Data Gaps (Bradshaw and Bradshaw, 2010);
- Waratah Coal's mines (AMEC, 2010); and
- Data collected during this engagement.

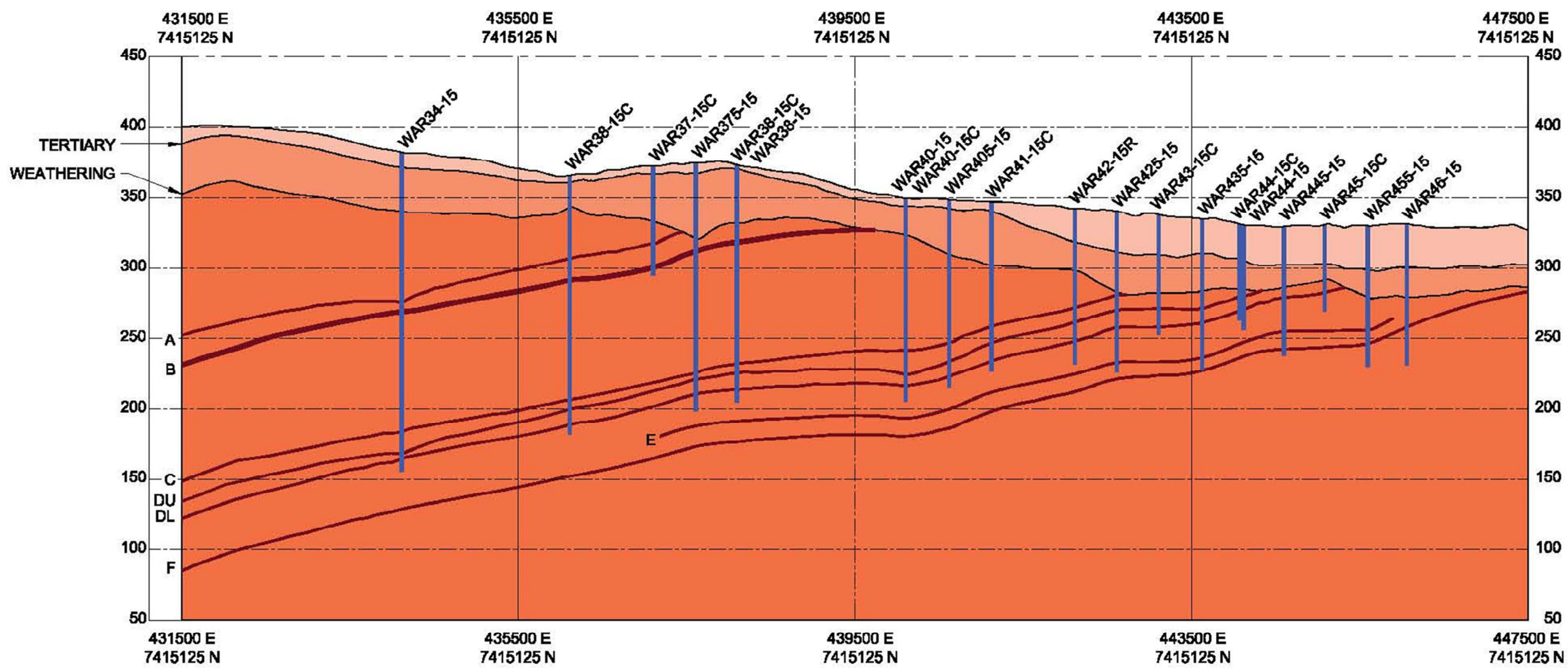
The Galilee Basin contains two major sedimentary layers. The upper layer consists of tertiary alluvial sediments and the deeper layers consist primarily of sediments of Permian age. In general, a shallow unconfined aquifer zone is located within the tertiary sediments and a multilayered semi-confined to confined aquifer system exists within the deeper Permian sediments comprised primarily of sandstone (AMEC , 2010). The aquifers are divided into the five major groups (Base of tertiary, A to B sandstone, C to D sandstone, D to E sandstone and sub E sandstone) (AMEC, 2010).

The majority of the coal seams exist within the Permian sediments. Existing data on landowners bores in and around the mine indicated that the bores predominantly abstract water from the unconfined Tertiary and semi-confined to confined Permian sandstone aquifers. The shallower tertiary aquifers are not found in all areas of the mine area. Groundwater within the mine area can be broadly grouped into the aquifers specified by AMEC (2010), however this investigation indicates the presence of thinner bands of groundwater in and around the various coal seams.

Table 3-1 provides a summary of the type of data and physical parameter results from DERM bore data (SKM, October 2009). A cross section of the geology in the mine area is provided in Figure 3-1.

Table 3-1: Groundwater Quality and Aquifer Physical Parameters (adapted from SKM, October 2009)

Physical Parameters	Range
Static water level (m bgl)	1.9 – 95
Groundwater elevation (m AHD)	300 – 380
Top of aquifers (m bgl)	0 – 170
Yield (L/s)	<1 – 17
Total dissolved solids (mg/L)	170 – 13,400
Inferred flow direction	North – North East



VERTICAL SCALE HAS BEEN EXAGGERATED BY A FACTOR OF >5:1

Figure 3-1: Local Cross Section (after Coffey, 2009)

Predictions of annual mine pit inflows from subsurface aquifers based on a prior conceptual model of the local and regional groundwater systems (AMEC, 2010) was estimated at 4,045 ML per year.

A data gap analysis for the Galilee Basin was undertaken to evaluate the quality and extent of bore and seismic data in the region (Bradshaw and Bradshaw, 2010). The report concludes that very little was known regarding the geology and stratigraphy of the northern portion of the Galilee basin. Data is of very low resolution and a significant amount of the existing data was obtained in the 1960s. Existing data for the southern Galilee Basin is more complete than that of the northern Basin; however, data is still very limited.

Key conclusions regarding groundwater outlined in the report are of limited assistance. However, core logs continually show strata with porosities that indicate potential for reservoir storage within the Triassic sandstone sediments. Log derived porosities of up to 20% were reported for the Bandanna formation, indicating the potential for aquifers within these sediments. The report also suggested that there was evidence of the vertical movement of groundwater between different sedimentary layers and aquifers.

3.2.1 Groundwater Occurrence (Regional)

Registered groundwater bores exist across the majority of the mining lease area (Figure 3-2). A number of bores also exist in the surrounding region. Groundwater elevations range from 300 – 380 m AHD.

3.2.2 Groundwater Occurrence (Local)

Registered bores from the DERM database are shown in Figure 3-2. DERM records can include old bores that have been decommissioned or replaced but DERM have not been notified. Water level data recorded during drilling of 124 coal exploration holes were contoured and plotted as shown in Figure 3-3. Based on the groundwater contouring (Figure 3-3), groundwater predominantly flows east. The potential sinks for shallow groundwater are the upper tributaries of the Tellerenha Creek if groundwater is shallower than the creek bed. This creek is ephemeral and thus may only occur in the peak of the wet season.

Historic water quality data for the tertiary aquifers are limited within the mine. Six bores within the DERM records are noted as intersecting the tertiary aquifers. Table 3-2 contains a summary of the water quality in these bores. Continual water quality data does not exist for the tertiary water bores within the study area.

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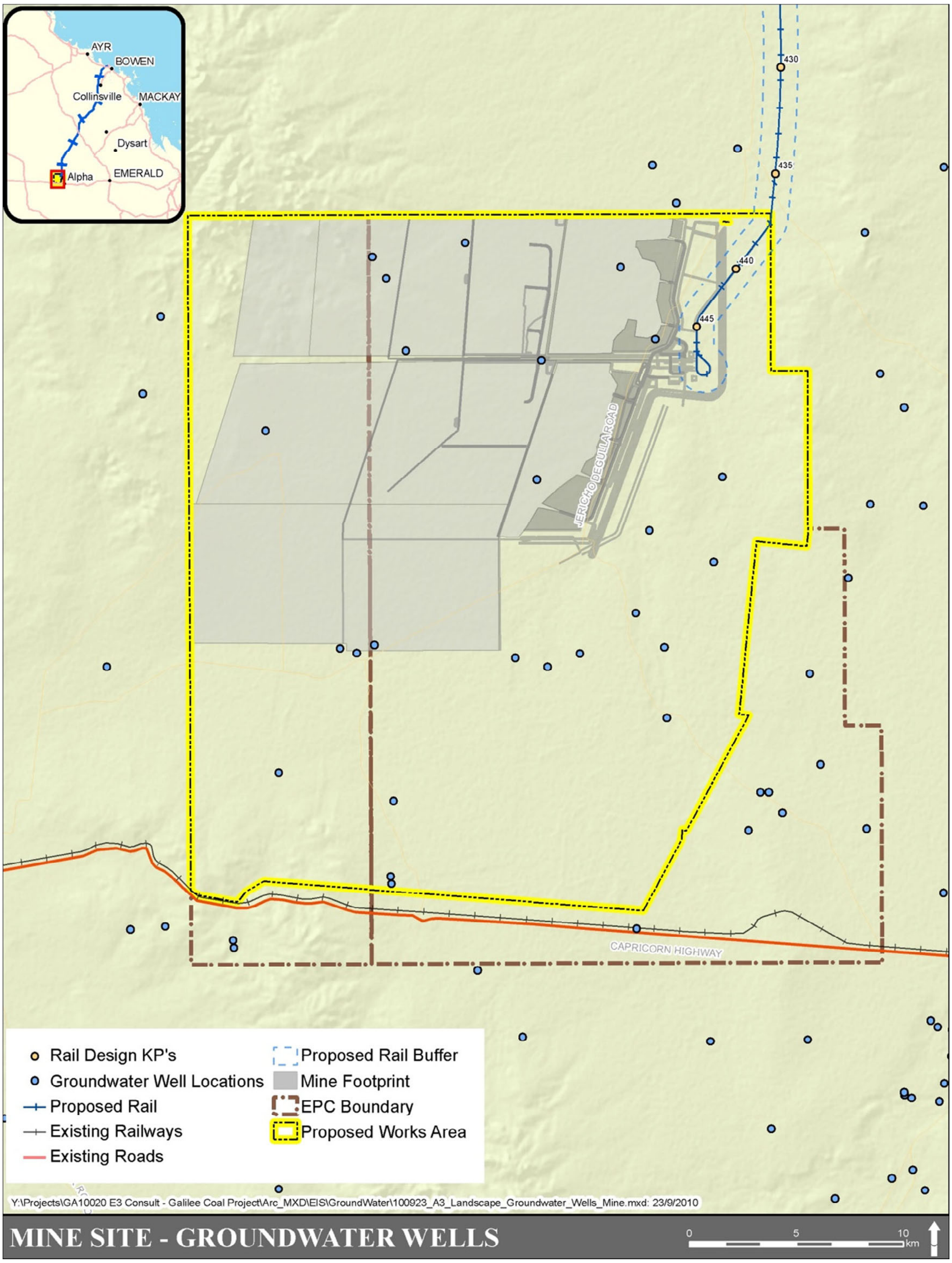

Figure 3-2: Registered Bores in the Mine Area

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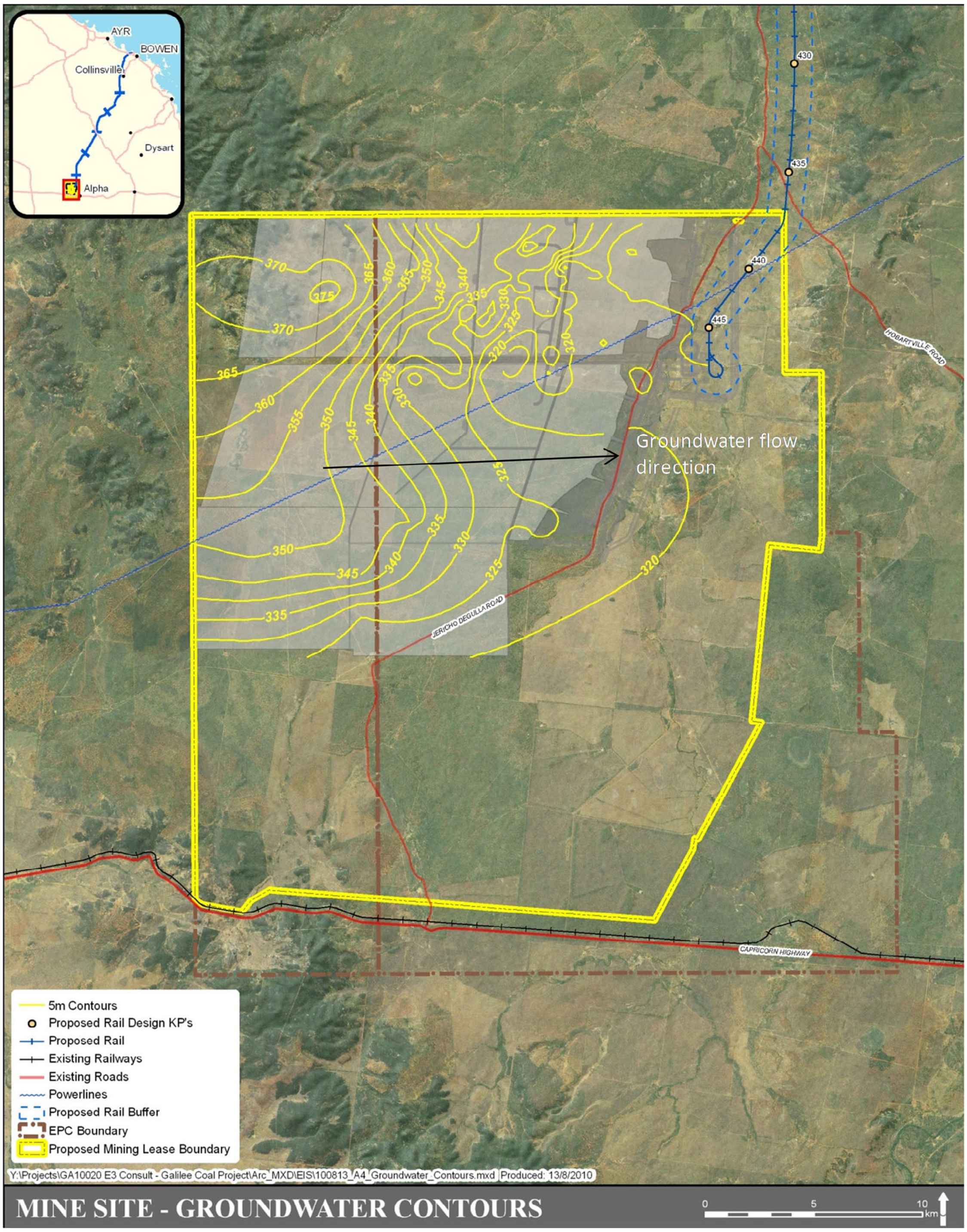


Figure 3-3: Contour Plot of Groundwater Level (m AHD) Data from Exploration Data

Table 3-2: Historic Tertiary Aquifer Water Quality Data

Well ID	Sampling Date	Level (AHD)	Depth to Water (mbgl)	Well Invert (RL)	Depth (RL)	Electrical conductivity (mS/cm)	pH - Field	Electrical Conductivity - Field	Manganese	Iron	Total Dissolved Solids	Hydroxide Alkalinity as CaCO3	Carbonate Alkalinity as CaCO3	Bicarbonate Alkalinity as CaCO3	Sulfate as SO4 2-	Chloride	Calcium	Magnesium	Sodium	Potassium	Nitrite as N
ANZECC 2000 Freshwater		NC	NC	NC	NC	NC	6 - 7.5	NC	1.2	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	0.02
ANZECC 2000 Primary		NC	NC	NC	NC	NC	NC	NC	0.2	0.2	NC	NC	NC	NC	NC	350	NC	NC	NC	NC	NC
ANZECC 2000 Stock water		NC	NC	NC	NC	NC	NC	NC	NC	NC	2000	NC	NC	NC	1000-	NC	1000	NC	NC	NC	1.5
LOR		-	-	-	-	-	-	-	0	0.1	1	1	1	1	1	1	1	1	1	1	0.01
Units		m				mS/cı	pH	mS/cm	mg/L	mg/	mg/L	mg/l	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
12030076	11/08/1977	399.38	9.19	390.19	390.19	20.8	8	-	-	-	13618	-	0	341	890	7200	190	280	4860	30	0
12030076	7/11/1978	399.38	9.43	389.95	389.95	22.7	7.8	-	-	-	14211	-	0	408	980	7700	130	310	4830	30	10
12030076	13/12/1983	399.38	9.45	389.93	389.93	20.5	8.1	-	0.01	0	13315	-	6.6	340	920	7300	130	295	4450	27	0.5
12030076	16/12/2009	399.38	9.6	389.78	389.78	0	-	22.8	-	-	-	-	-	-	-	-	-	-	-	-	-
12030077	11/08/1977	400	2.61	397.39	397.39	0.21	7.5	-	-	-	117.3	-	0.1	44	13	42	3.9	2.9	34	0.2	0
12030077	13/12/1983	400	2.75	397.25	397.25	0.19	7.4	-	0.01	6.1	168.26	-	0.1	36.5	5.1	32	4.5	2.9	30	4	1.5

Note: - = No data NC = No criteria Highlighted values exceed criteria

3.2.3 Great Artesian Basin

The GAB is a large hydrogeological basin consisting of the Eromanga, Surat and Carpentaria Basins. Parts of the Bowen and Galilee Basins are also included in the GAB. The Great Artesian Basin Coordinating Committee (GABCC, 2009) produced a background document that provides a summary of the current knowledge regarding the Great Artesian Basin (GAB). .

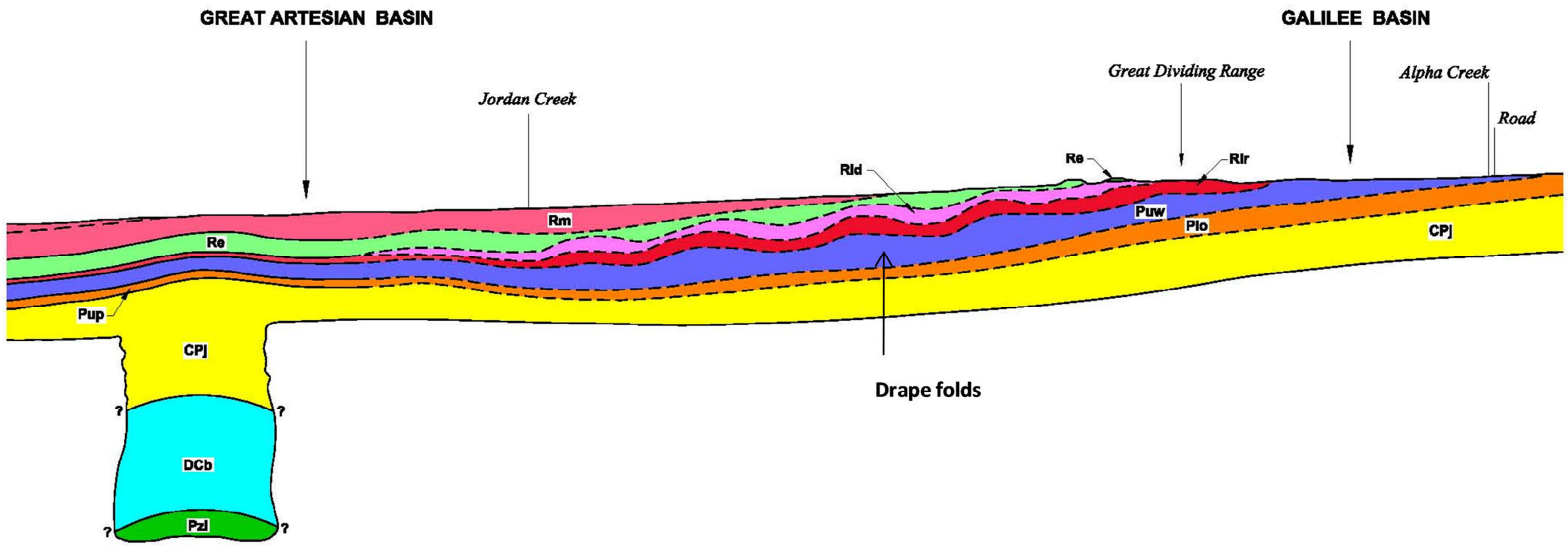
The GAB covers an area of 1.7 million km^2 and crosses the boundaries of New South Wales, Queensland, South Australia and the Northern Territory. The Great Dividing Range forms the eastern boundary of the GAB. An estimated 8,700 million ML of water are contained within the GAB, of which 570,000 ML are used annually via bore extraction.

The GAB consists of confined artesian and sub-artesian groundwater. Natural springs occur where artesian waters emerge at the surface. The GABCC (2009) reports that the confined aquifers of the Basin are bounded by the Rewan group which forms the basement of the aquifers and the Winton formation acting as the upper confining layer. The position of the coal resources which underlie these confining strata and are located east of the great dividing range are illustrated in Figure 3-4.

Aquifer hydraulic parameters range significantly across the GAB as a result of the substantial area of the GAB. The typical range in aquifer parameters are as follows:

- Aquifer hydraulic conductivity, 0.1 – 10 m/d;
- Basement hydraulic conductivity, 0.001 – 1 m/d;
- Transmissivity, 10 – 2,000 m^2/d; and
- Storage coefficients, 10^{-4} – 10^{-5}.

Protection of this significant groundwater resource is a high priority for both local and national government. The coal reserves of the China First mine lease area are outside the GAB as indicated by the GABCC definition of the Rewan Formation as the underlying formation and the Queensland Government map titled 'Geological map of the Barcaldine – Alpha region with coal resource areas' (Figure 3-5).



Key for strata: Rir - Rewan Formation, Rm - Moolayember Formation, Pio - Colinlea Sandstone, Re - Clematis Sandstone, Puw - Blackwater Group, CPj - Joe Joe Formation, Dcb - Buckabie Formation, Pzl - Crystal Tuff, Pup - Peawaddy Formation, Rld - Dunda Beds, Puw - Blackwater Group.

Figure 3-4: Regional Geological Cross Section (adapted from BMR, 1968)

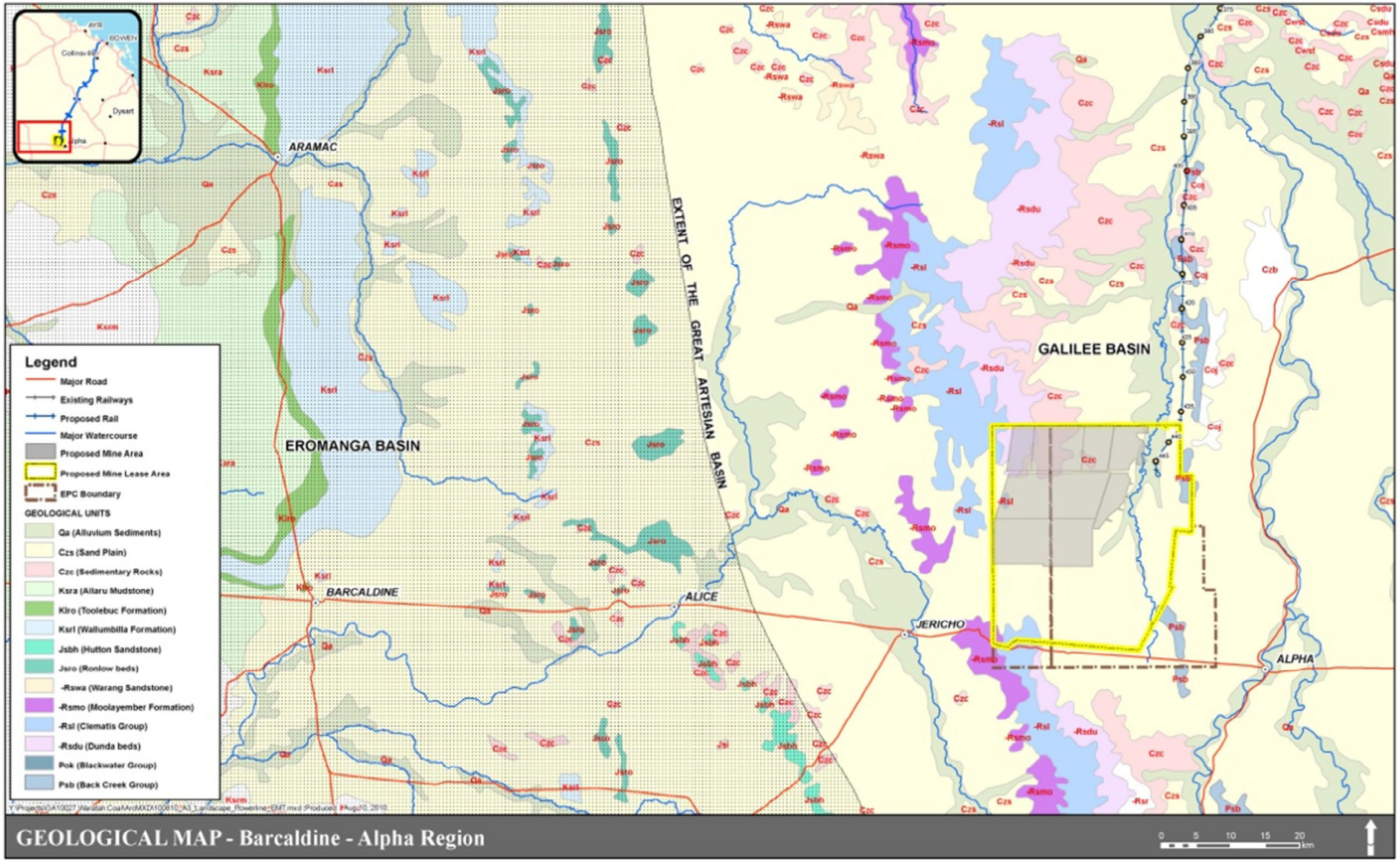


Figure 3-5: Geological Map: Barcaldine – Alpha Region (DERM, Per Comms)

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3.2.4 Geophysical Survey

Results from the geophysical surveys are summarised in Table 3-3 and are presented graphically in Appendix B.

Table 3-3: Summary of Down Hole Geophysical Survey

Bore ID	Coal Seams	Predicted aquifer interval(1)	Coal seam interval (m)(2)
WAR44-15	DU	53 – 55.5	50.8 – 53.1
	DL1	58.5 – 60.4	58.1 – 58.9
	DL2	62.2 – 64.6	59.5 – 61.5
WAR42-13	DU	*	66.5 – 68.5
	DL1	*	81.5 – 82
	DL2	*	83 – 85
WAR38-15	B	51.5 – 60.15	51 – 57.1

Note: 1 – Based on Gamma resistivity plots, 2 - Based on exploration core logs, * - No aquifer indicated.

Results indicate that groundwater primarily flows in the coal seams and within the overburden/interburden immediately adjacent to the seams. This is evident from plots of gamma resistivity with depth. Substantial shifts in the position of the gamma trace in each plot suggest water and or areas of high permeability strata are present. These inferences were proven correct when gamma plots were compared with the drill logs for each core hole. Only minimal variations in SP/PR values were evident from all attempted logs and this suggests an absence of widespread Permian aquifer units across the mine beyond those associated with the coal seams.

The monitoring bores in the area surrounding WAR38-15 were screened at intervals of 30-40 m, 51-57 m and 60-66 m in order to obtain water quality samples and aquifer parameters from coal seam B, coal seam B overburden and the interburden between coal seams B and D. WAR42-13 bores were screened at intervals of 40-50 m, 65-70 m and 80–85 m in order to obtain aquifer parameters and water quality samples from coal seam D, coal seam D overburden and below coal seams DU and DL. WAR44-15 was screened at intervals of 40–50 m and 58-62 m to obtain groundwater samples and aquifer parameters from the overburden of coal seam DU and from coal seam DU (Table 3-3).

3.3 Results of Water Quality Sampling

3.3.1 Water Quality - Tertiary Aquifers

Tertiary groundwater within the study area is dominated by sodium cations and chloride anions. Based upon Hem (1992), the water is classed as sodium calcium and chloride sulphate bicarbonate waters.

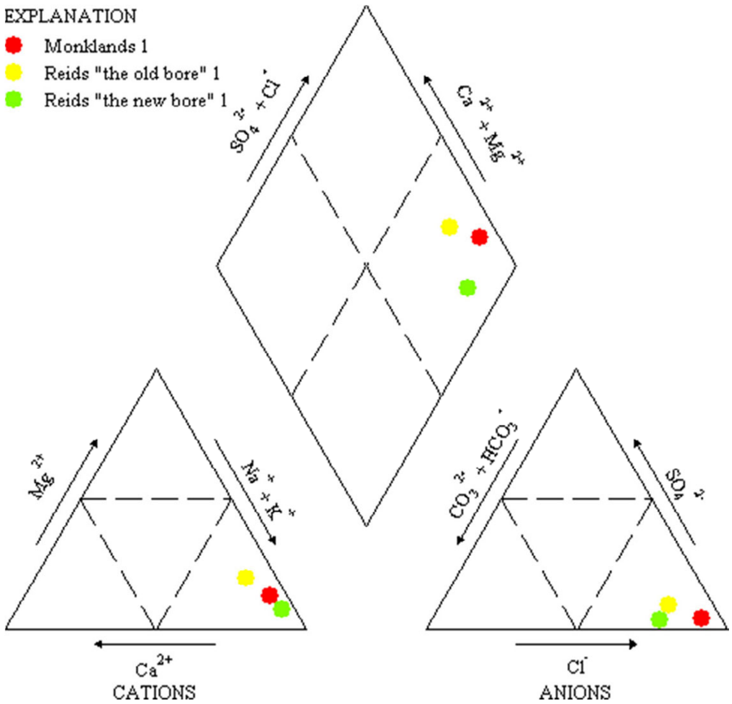

Figure 3-6 illustrates the trend in groundwater chemistry along the likely groundwater flow paths perpendicular to the Tallarenha Creek.

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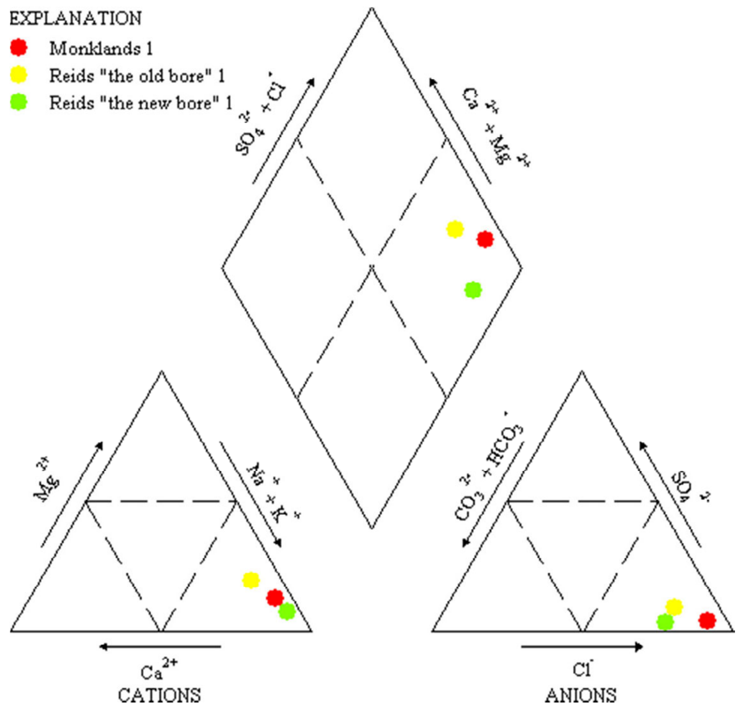

Figure 3-6: Piper Diagram of Tertiary Aquifer Geochemistry

A tertiary aquifer geochemistry map of the region is provided in Figure 3-7.

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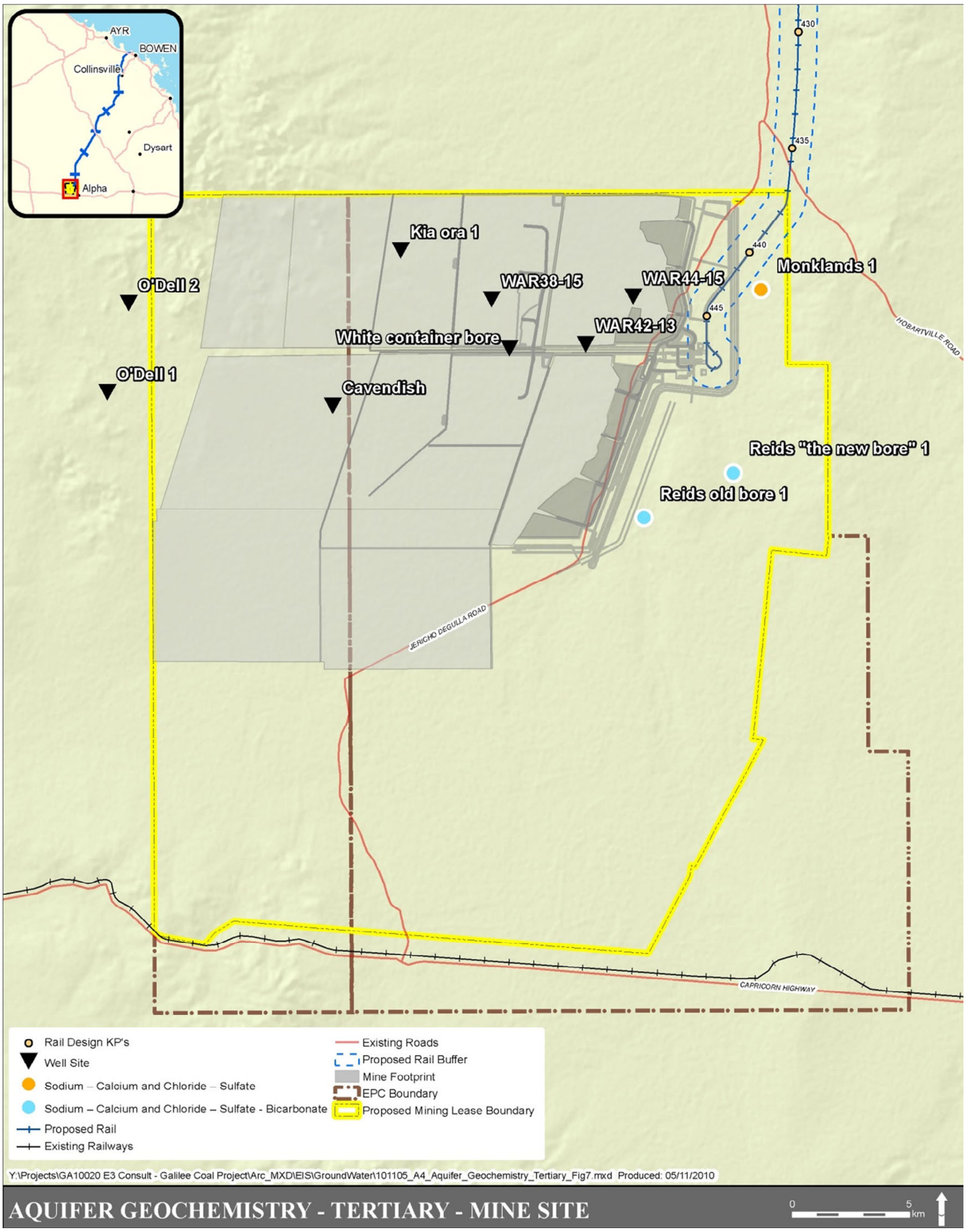

Figure 3-7: Tertiary Aquifer Geochemistry – Mine

The tertiary aquifers within the study area are generally slightly brackish, pH neutral, contain low concentrations of trace metals, and have elevated nutrient concentrations. Comparisons between water quality data and the ANZECC 2000 guidelines are presented in Table 3-4 to Table 3-7.

The likely cause of the increased nutrient loading may be a combination of livestock effluent, other farming practices or general nitrogen movement in shallow systems. The ratios of nutrients in the Tertiary aquifer samples are illustrated in Figure 3-8. This shows that tertiary aquifer waters are dominated by nitrate, nitrite, and total nitrogen.

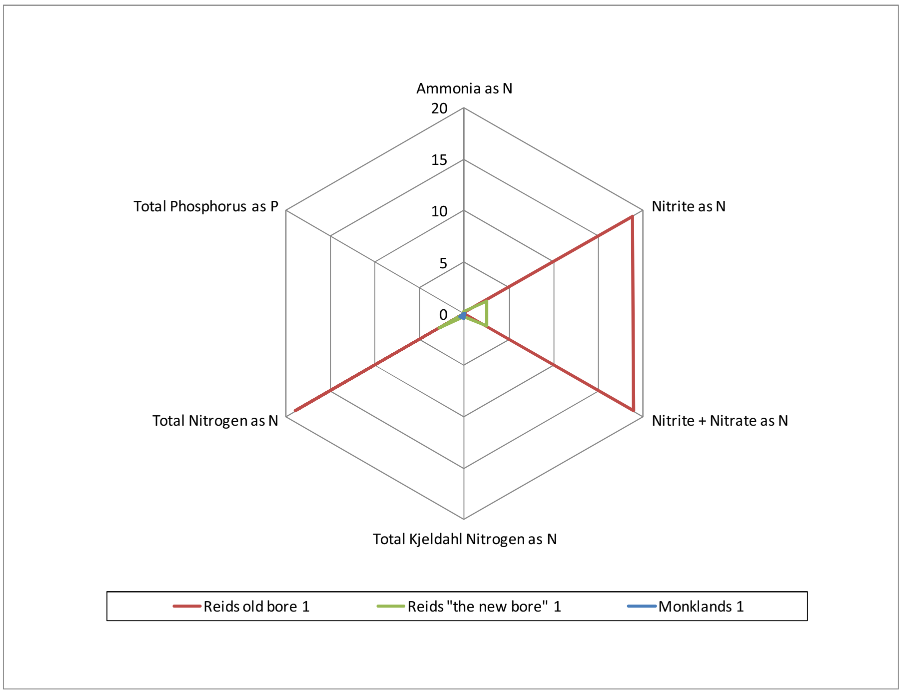

Figure 3-8: Radar Plot of Tertiary Aquifer Nutrient Data

Increased levels of both N and P in various forms may be the result of nutrients from stock effluent leaching through the vadose zone and entering the shallow tertiary groundwater. Increased nutrient leaching may have been accentuated as a result of the significant late summer rainfall events of the 2009 – 2010 seasons.

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Table 3-4: Tertiary Aquifer Physical Parameter Results

Well ID	Sampling Date	Level (AHD)	Depth to Water (mbgl)	Well Invert (RL)	Depth (RL)	Temperature (°C)	Turbidity (NTU)	Dissolved oxygen (%)	Electrical conductivity (mS/cm)	pH - Field	Electrical Conductivity - Field
ANZECC 2000 Freshwater 99%		NC	NC	NC	NC	NC	NC	NC	NC	6 - 7.5	NC
ANZECC 2000 Primary industry		NC	NC	NC	NC	NC	NC	NC	NC	NC	NC
ANZECC 2000 Stock water		NC	NC	NC	NC	NC	NC	NC	NC	NC	NC
LOR		-	-	-	-	-	-	-	-	-	-
Units		m				°C	NTU	%	ms	pH	mS/cm
Monklands 1	-	-	15	-	-	21.2	3.1	36.9	-	6.88	-0.4
Reids old bore 1	-	-	23	-	-	26.3	-	64.7	-	7.11	2.51
Reids "the new bore" 1	-	-	12.6	-	-	26.8	2.9	57.4	-	6.93	1.298
12030076	11/08/1977	399.38	9.19	390.19	390.19	-	-	-	20.8	8	-
12030076	7/11/1978	399.38	9.43	389.95	389.95	-	-	-	22.7	7.8	-
12030076	13/12/1983	399.38	9.45	389.93	389.93	-	-	-	20.5	8.1	-
12030076	16/12/2009	399.38	9.6	389.78	389.78	-	-	-	0	-	22800
12030077	11/08/1977	400	2.61	397.39	397.39	-	-	-	0.21	7.5	-
12030077	13/12/1983	400	2.75	397.25	397.25	-	-	-	0.19	7.4	-

Note: - = No data NC = No criteria Highlighted values exceed criteria

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Table 3-5: Tertiary Aquifer Metals Results

Well ID	Sampling Date	Cadmium	Chromium	Copper	Nickel	Lead	Zinc	Manganese	Iron	Mercury
ANZECC 2000 Freshwater 99%		0.00004	NC	0.001	0.008	0.001	0.0024	1.2	NC	0.00006
ANZECC 2000 Primary industry		0.01	0.1	0.2	0.2	2.0	2.0	0.2	0.2	0.002
ANZECC 2000 Stock water		0.01	1.0	1.0	1.0	0.1	20.0	NC	NC	0.0020
LOR		0.0001	0.001	0.001	0.001	0.001	0.005	0.001	0.05	0.0001
Units		mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Monklands 1	-	<0.0001	<0.001	0.001	<0.001	<0.001	4.18	0.287	10.2	<0.0001
Reids old bore 1	-	<0.0001	<0.001	0.009	0.001	<0.001	0.098	0.034	0.07	<0.0001
Reids "the new bore" 1	-	<0.0001	<0.001	0.006	<0.001	<0.001	0.091	0.022	0.12	<0.0001
12030076	11/08/1977	-	-	-	-	-	-	-	-	-
12030076	7/11/1978	-	-	-	-	-	-	-	-	-
12030076	13/12/1983	-	-	-	-	-	-	0.01	0.01	-
12030076	16/12/2009	-	-	-	-	-	-	-	-	-
12030077	11/08/1977	-	-	-	-	-	-	-	-	-
12030077	13/12/1983	-	-	-	-	-	-	0.01	6.1	-

Note: - = No data   NC = No criteria   Highlighted values exceed criteria

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Table 3-6: Tertiary Aquifer Nutrient Results

Well ID	Sampling Date	Ammonia as N	Nitrite + Nitrate as N	Total Kjeldahl Nitrogen as N	Total Nitrogen as N	Total Phosphorus as P	Total Dissolved Solids
ANZECC 2000 Freshwater 99%		0.32	0.15	NC	0.15	0.01	NC
ANZECC 2000 Primary industry		NC	NC	NC	5	0.05	NC
ANZECC 2000 Stock water		NC	30	NC	NC	NC	2000
LOR		0.01	0.01	0.1	0.1	0.01	1
Units		mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Monklands 1	-	0.05	0.04	0.5	0.5	<0.01	2250
Reids old bore 1	-	0.09	18.9	<0.1	18.9	<0.01	2170
Reids "the new bore" 1	-	0.19	2.47	0.3	2.8	0.02	815
12030076	11/08/1977	-	-	-	-	-	13618
12030076	7/11/1978	-	-	-	-	-	14211
12030076	13/12/1983	-	-	-	-	-	13315
12030076	16/12/2009	-	-	-	-	-	-
12030077	11/08/1977	-	-	-	-	-	117.3
12030077	13/12/1983	-	-	-	-	-	168.3

Note: - = No data NC = No criteria Highlighted values exceed criteria

Table 3-7: Tertiary Aquifer Cations/Anions

Well ID	Sampling Date	Carbonate Alkalinity as CaCO3	Bicarbonate Alkalinity as CaCO3	Total Alkalinity as CaCO3	Acidity as CaCO3	Sulfate as SO4 2-	Chloride	Calcium	Magnesium	Sodium	Potassium	Nitrite as N	Total Anions	Total Cations	Ionic Balance
ANZECC 2000 Freshwater 99%		NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	0.017	NC	NC	NC
ANZECC 2000 Primary industry		NC	NC	NC	NC	NC	350	NC	NC	NC	NC	NC	NC	NC	NC
ANZECC 2000 Stock water		NC	NC	NC	NC	1000-	NC	1000	NC	NC	NC	1.5	NC	NC	NC
LOR		1	1	1	1	1	1	1	1	1	1	0.01	0.01	0.01	0.01
Units		mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	meq/L	meq/L	%
Monklands 1	-	<1	151	151	37	67	1170	41	54	661	10	0.04	37.4	35.1	2.62
Reids old bore 1	-	<1	318	318	22	156	946	72	83	554	20	18.8	36.3	2.62	1.67
Reids "the new bore" 1	-	<1	147	147	20	20	313	10	10	219	6	2.47	12.2	11	4.86
12030076	11/08/1977	0	341	-	-	890	7200	190	280	4860	30	0	-	-	-
12030076	7/11/1978	0	408	-	-	980	7700	130	310	4830	30	10	-	-	-
12030076	13/12/1983	6.6	340	-	-	920	7300	130	295	4450	27	0.5	-	-	-
12030076	16/12/2009	-	-	-	-	-	-	-	-	-	-	-	-	-	-
12030077	11/08/1977	0.1	44	-	-	13	42	3.9	2.9	34	0.2	0	-	-	-
12030077	13/12/1983	0.1	36.5	-	-	5.1	32	4.5	2.9	30	4	1.5	-	-	-

Note: - = No data   NC = No criteria   Highlighted values exceed criteria

3.3.1.1 Stock Water

Groundwater from the Tertiary aquifers within and surrounding the mine site exceeded the ANZECC 2000 stock drinking water guidelines for four of the constituents analysed. Trace metals are generally present in concentrations below the ANZECC 2000 livestock drinking water criteria.

3.3.1.2 Irrigation

The Tertiary aquifer groundwater did not exceed the ANZECC 2000 irrigation water thresholds for the constituents analysed. Tertiary groundwater can therefore be considered generally suitable for irrigation purposes.

3.3.1.3 Potable

Tertiary aquifers in and surrounding the mine exceeded the Australian drinking water standards (NHMRC and NRMMC 2004) for a number of the constituents analysed.

3.3.1.4 Ecosystems

The ANZECC 2000 freshwater 99% criteria were exceeded on a number of occasions. Nitrogen, nitrate, nitrite and phosphorous exceed ANZECC 2000 freshwater 99% criteria within the shallow aquifers, however they were generally lower than the ANZECC 2000 95% criteria. Copper concentrations were also above the guidelines, however, the observed concentration range of 0.001 – 0.009 mg/L is significantly below both naturally occurring freshwater concentrations and the livestock drinking water guideline of 1 mg/L. Zinc concentrations exceeded the guidelines, with a maximum observed concentration of 4.18 mg/L.

3.3.2 Water Quality – Permian Aquifers

Water of the Permian aquifers is dominated by chloride anions, sodium and potassium cations and is classified by Hem (1992) as sodium-calcium, chloride-sulfate and chloride-sulfate-bicarbonate waters (Figure 3-9).

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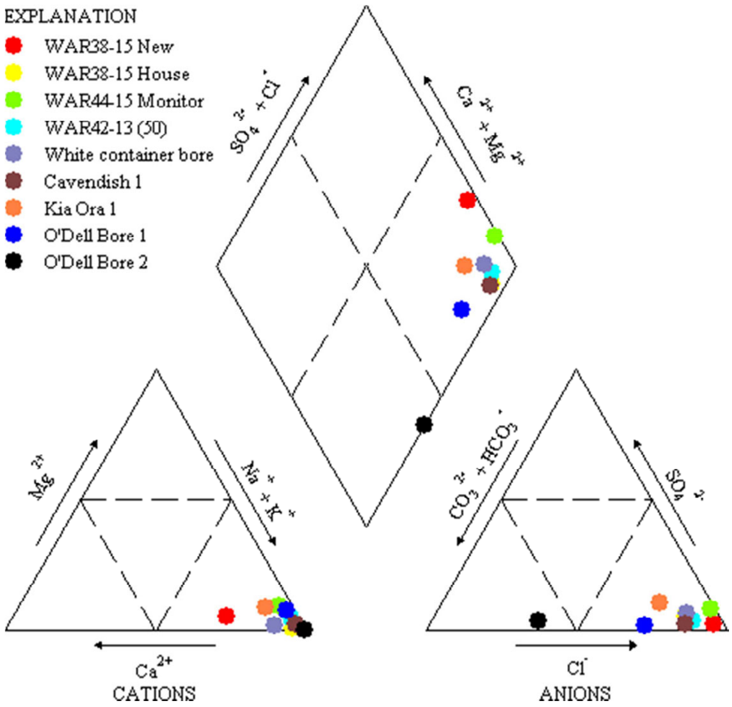

Figure 3-9: Piper Diagram of Permian Aquifer Geochemistry

The weathered Permian geochemistry of the mine is shown in Figure 3-10.

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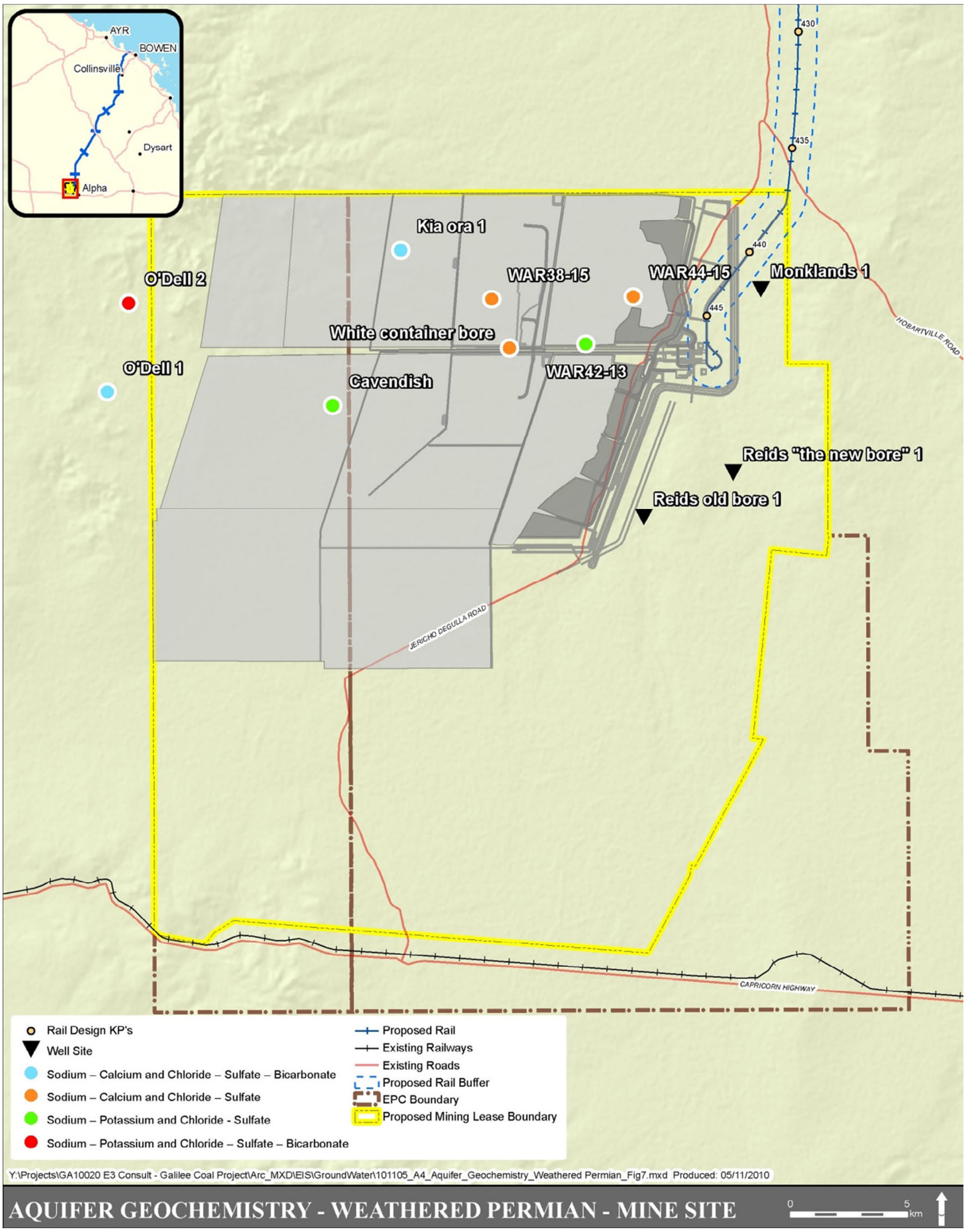

Figure 3-10: Weathered Permian Geochemistry - Mine

Water quality results from bores in the Permian zone are presented in Table 3-8 to Table 3-12.

The Permian aquifers are characterised by neutral to slightly alkaline pH, trace metals in low concentrations and elevated levels of nitrogen, total kjeldahl nitrogen and ammonia. Figure 3-11 and Figure 3-12 outline the respective ratios of nutrients in the Permian aquifer samples. Figure 3-11 shows that the bores have a similar pattern indicating similar nutrient ratios while Figure 3-12 shows the bores have different ratios suggesting different influences on the groundwater. Bores that terminate in the various coal seams and surrounding interburden and overburden layers have high nitrogen and ammonia compared to bores of the weathered Permian zone (Cavendish 1, O'Dell bore 1 and O'Dell bore 2).

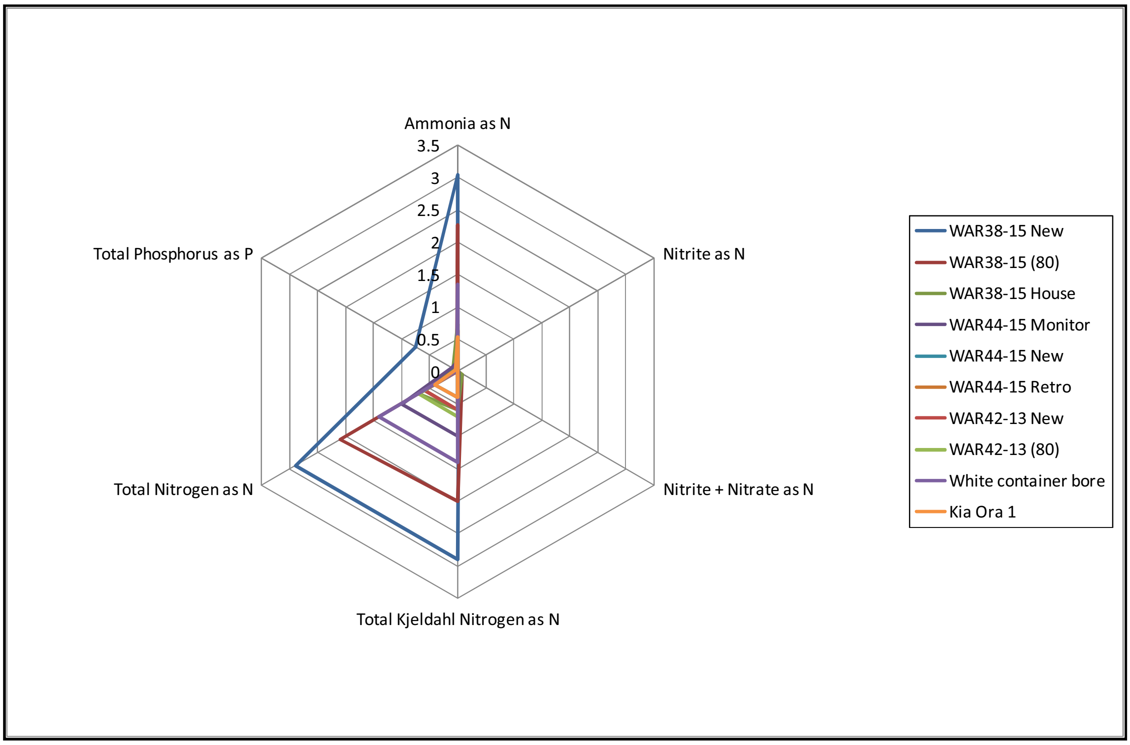

Figure 3-11: Radar Plot of Permian Aquifer Nutrient Data (A)

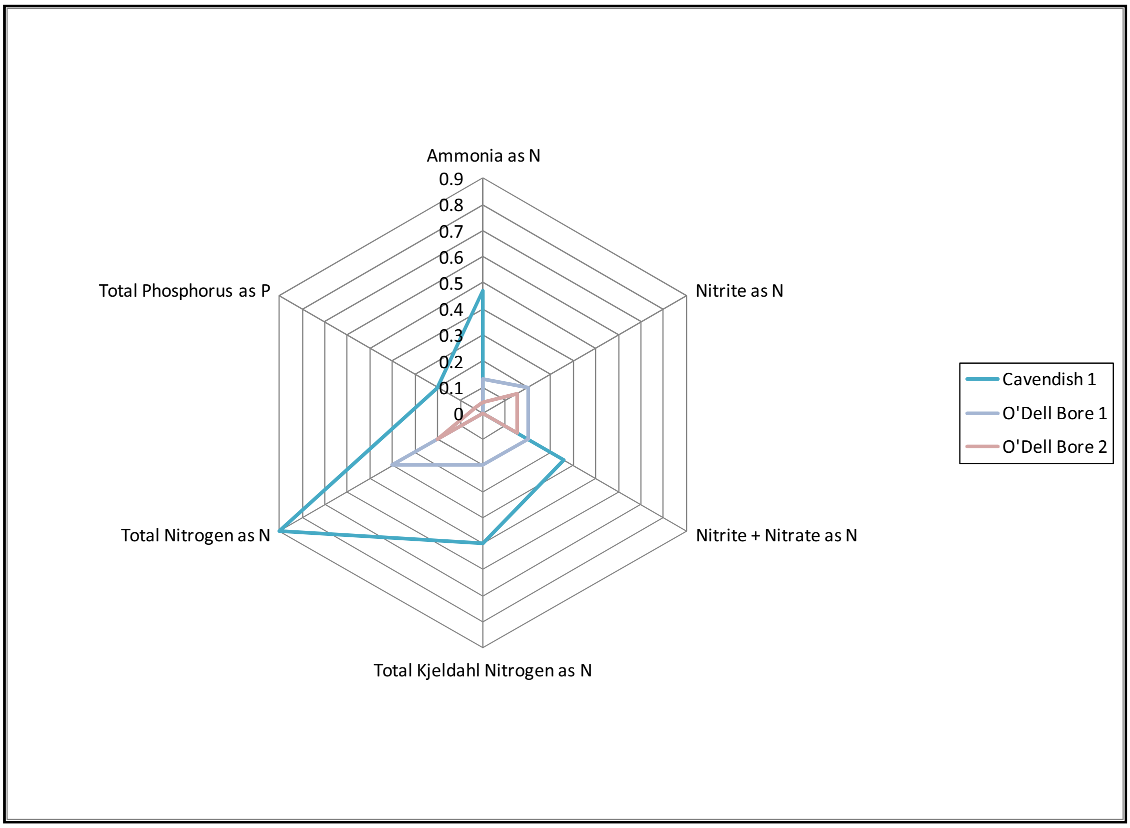

Figure 3-12: Radar Plot of Permian Aquifer Nutrient Data (B)

The water quality within the Permian aquifers is likely to reflect the age of the water and the characteristics of the aquifer material. The Permian aquifers often occur in and around the various coal seams as stated in SKM (October 2009). The presence of trace metals may be the result of leaching of these metals from the coal into the groundwater.

Table 3-8: Permian Aquifer Physical Parameter Results

Well ID	Sampling Date	Depth to Water (mbgl)	Temperature (°C)	Turbidity (NTU)	Dissolved oxygen (%)	Electrical conductivity (mS/cm)	pH - Field
ANZECC 2000 Freshwater 99%		-	NC	NC	NC	NC	6 - 7.5
ANZECC 2000 Primary industry		-	NC	NC	NC	NC	-
ANZECC 2000 Stock water		-	NC	NC	NC	NC	-
LOR		-	0.1	0.1	0.1	0.01	-
Units		m		NTU	%	ms/cm	pH
WAR38-15 New	14/05/2010	51.00	25.20	32.90	30.10	9.03	7.11
WAR38-15 (80)	14/05/2010	51.00	26.70	20.40	15.10	9.41	7.15
WAR38-15 House	15/05/2010	-	22.40	0.70	23.70	2.13	8.14
WAR44-15 Monitor	13/05/2010	11.00	29.30	147.70	69.30	14.05	6.35
WAR44-15 New	13/05/2010	12.00	27.30	1.30	13.00	6.25	6.92
WAR44-15 Retro	13/05/2010	11.00	27.60	13.30	13.30	6.45	6.94
WAR42-13 (50)	12/05/2010	16.00	-	-	-	-	-
WAR42-13 New	12/05/2010	16.00	29.80	132.90	11.10	3.21	7.55
WAR42-13 (80)	12/05/2010	17.00	-	-	-	-	-
White container bore	15/05/2010	-	22.40	1.50	13.60	3.48	7.73
Cavendish 1	15/05/2010	-	26.30	2.50	27.00	0.48	5.74
Kia Ora 1	15/05/2010	-	26.60	0.40	8.50	7.71	7.00
O'Dell Bore 1	16/06/2010	91.19	23.00	-0.30	14.40	-	5.34
O'Dell Bore 2	16/06/2010	71.51	25.60	4.10	20.10	-	6.36
Monklands 1	17/06/2010	15 - 20	21.20	3.10	36.9	-0.40	6.88
Reids old bore 1	17/06/2010	23.00	26.30	-	64.70	2.51	7.11
Reids "the new bore" 1	17/06/2010	12.60	26.80	2.90	57.40	1.30	6.93

Note: - = No data   NC = No criteria   Highlighted values exceed criteria

Table 3-9: Permian Aquifer Metal Results

Well ID	Sampling Date	Arsenic	Cadmium	Chromium	Copper	Nickel	Lead	Zinc	Manganese	Iron	Mercury
ANZECC 2000 Freshwater 99%		0.001	0.00004	NC	0.001	0.008	0.001	0.0024	1.2	NC	0.00006
ANZECC 2000 Primary industry		0.1	0.01	0.1	0.2	0.2	2.0	2.0	0.2	0.2	0.002
ANZECC 2000 Stock water		0.5	0.1	1.0	1.0	1.0	0.1	20.0	NC	NC	NC
LOR		0.001	0.0001	0.001	0.001	0.001	0.001	0.005	0.001	0.05	0.0001
Units		mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
WAR38-15 New	14/05/2010	0.002	<0.0001	0.002	0.002	0.004	<0.001	0.11	0.314	0.47	<0.0001
WAR38-15 (80)	14/05/2010	0.001	<0.0001	0.002	<0.001	0.001	<0.001	0.012	0.265	0.61	<0.0001
WAR38-15 House	15/05/2010	<0.001	<0.0001	0.002	0.007	<0.001	<0.001	0.076	0.036	0.05	<0.0001
WAR44-15 Monitor	13/05/2010	<0.001	<0.0001	<0.001	0.001	<0.001	<0.001	0.007	0.313	0.86	<0.0001
WAR44-15 New	13/05/2010	<0.001	<0.0001	<0.001	0.002	0.003	<0.001	0.008	0.232	0.63	<0.0001
WAR44-15 Retro	13/05/2010	0.005	0.0024	0.001	0.018	0.035	<0.001	0.202	1.36	0.4	<0.0001
WAR42-13 (50)	12/05/2010	0.004	<0.0001	0.003	0.002	0.012	0.001	0.013	0.916	0.16	<0.0001
WAR42-13 New	12/05/2010	<0.001	0.0006	<0.001	0.001	0.002	<0.001	0.006	0.084	0.06	<0.0001
WAR42-13 (80)	12/05/2010	<0.001	<0.0001	<0.001	<0.001	<0.001	<0.001	<0.005	0.095	0.26	<0.0001
White container bore	15/05/2010	<0.001	<0.0001	0.001	<0.001	<0.001	<0.001	<0.005	0.125	0.1	<0.0001
Cavendish 1	15/05/2010	0.001	<0.0001	0.001	<0.001	0.002	<0.001	0.018	0.034	0.14	<0.0001
Kia Ora 1	15/05/2010	0.002	<0.0001	0.006	<0.001	<0.001	<0.001	0.005	0.082	0.27	<0.0001
O'Dell Bore 1	16/06/2010	-	<0.0001	<0.001	<0.001	0.007	<0.001	0.014	0.022	0.16	<0.0001
O'Dell Bore 2	16/06/2010	-	<0.0001	<0.001	0.002	<0.001	<0.001	0.017	0.016	<0.05	<0.0001
Monklands 1	17/06/2010	-	<0.0001	<0.001	0.001	<0.001	<0.001	4.18	0.287	10.2	<0.0001
Reids old bore 1	17/06/2010	-	<0.0001	<0.001	0.009	0.001	<0.001	0.098	0.034	0.07	<0.0001
Reids "the new bore" 1	17/06/2010	-	<0.0001	<0.001	0.006	<0.001	<0.001	0.091	0.022	0.12	<0.0001

Note: - = No data NC = No criteria Highlighted values exceed criteria

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Table 3-10: Permian Aquifer Nutrient Results

Well ID	Sampling Date	Ammonia as N	Nitrite + Nitrate as N	Total Kjeldahl Nitrogen as N	Total Nitrogen as N	Total Phosphorus as P
ANZECC 2000 Freshwater 99%		0.32	0.15	NC	0.15	0.01
ANZECC 2000 Primary industry		NC	NC	NC	5	0.05
ANZECC 2000 Stock water		NC	30	NC	NC	NC
LOR		0.01	0.01	0.1	0.1	0.01
Units		mg/L	mg/L	mg/L	mg/L	mg/L
WAR38-15 New	14/05/2010	3.04	0.02	2.9	2.9	0.76
WAR38-15 (80)	14/05/2010	2.27	0.09	2	2.1	0.03
WAR38-15 House	15/05/2010	0.73	0.09	0.6	0.7	0.09
WAR44-15 Monitor	13/05/2010	0.17	0.02	1	1	0.11
WAR44-15 New	13/05/2010	0.44	<0.01	0.4	0.4	<0.01
WAR44-15 Retro	13/05/2010	0.63	<0.01	0.6	0.6	0.03
WAR42-13 (50)	12/05/2010	45.7	0.01	42.5	42.5	3.58
WAR42-13 New	12/05/2010	0.64	<0.01	0.6	0.6	<0.01
WAR42-13 (80)	12/05/2010	0.73	<0.01	0.7	0.7	0.02
White container bore	15/05/2010	1.34	<0.01	1.4	1.4	0.02
Cavendish 1	15/05/2010	0.47	0.36	0.5	0.9	0.2
Kia Ora 1	15/05/2010	0.54	<0.01	0.4	0.4	0.05
O'Dell Bore 1	16/06/2010	0.13	0.2	0.2	0.4	<0.01
O'Dell Bore 2	16/06/2010	0.04	0.15	<0.1	0.2	0.04
Monklands 1	17/06/2010	0.05	0.04	0.5	0.5	<0.01
Reids old bore 1	17/06/2010	0.09	18.9	<0.1	18.9	<0.01
Reids "the new bore" 1	17/06/2010	0.19	2.47	0.3	2.8	0.02

Note: - = No data   NC = No criteria   Highlighted values exceed criteria

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Table 3-11: Permian Aquifer Alkalinity and TDS Results

Well ID	Sampling Date	Total Dissolved Solids	Hydroxide Alkalinity as CaCO3	Carbonate Alkalinity as CaCO3	Bicarbonate Alkalinity as CaCO3	Total Alkalinity as CaCO3	Acidity as CaCO3
ANZECC 2000 Freshwater 99%		NC	NC	NC	NC	NC	NC
ANZECC 2000 Primary industry		NC	NC	NC	NC	NC	NC
ANZECC 2000 Stock water		2000	NC	NC	NC	NC	NC
LOR		1	1	1	1	1	1
Units		mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
WAR38-15 New	14/05/2010	10100	<1	<1	130	130	13
WAR38-15 (80)	14/05/2010	8300	<1	<1	135	135	13
WAR38-15 House	15/05/2010	1130	<1	<1	97	97	<1
WAR44-15 Monitor	13/05/2010	15800	<1	<1	139	139	26
WAR44-15 New	13/05/2010	5810	<1	<1	164	164	11
WAR44-15 Retro	13/05/2010	6320	<1	<1	173	173	9
WAR42-13 (50)	12/05/2010	7400	<1	<1	553	553	11
WAR42-13 New	12/05/2010	2540	<1	<1	165	165	4
WAR42-13 (80)	12/05/2010	2760	<1	<1	167	167	4
White container bore	15/05/2010	2020	<1	<1	93	93	2
Cavendish 1	15/05/2010	503	<1	<1	34	34	24
Kia Ora 1	15/05/2010	4840	<1	<1	406	406	22
O'Dell Bore 1	16/06/2010	138	<1	<1	17	17	68
O'Dell Bore 2	16/06/2010	229	<1	<1	93	93	18
Monklands 1	17/06/2010	2250	<1	<1	151	151	37
Reids old bore 1	17/06/2010	2170	<1	<1	318	318	22
Reids "the new bore" 1	17/06/2010	815	<1	<1	147	147	20

Note: - = No data NC = No criteria Highlighted values exceed criteria

Table 3-12: Permian Aquifer Cation/Anion Results

Well ID	Sampling Date	Sulfate as SO4 2-	Chloride	Calcium	Magnesium	Sodium	Potassium	Nitrite as N	Total Anions	Total Cations	Ionic Balance
ANZECC 2000 Freshwater 99%		NC	NC	NC	NC	NC	NC	0.017	NC	NC	NC
ANZECC 2000 Primary industry		NC	350	NC	NC	NC	NC	NC	NC	NC	NC
ANZECC 2000 Stock water		1000-2000	NC	1000	NC	NC	NC	1.5	NC	NC	NC
LOR		1	1	1	1	1	1	0.01	0.01	0.01	0.01
Units		mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	meq/L	meq/L	%
WAR38-15 New	14/05/2010	89	3740	555	126	1640	36	<0.01	110	110	0.07
WAR38-15 (80)	14/05/2010	50	2700	393	92	1160	25	<0.01	79.9	78.3	0.97
WAR38-15 House	15/05/2010	43	694	22	3	489	4	<0.01	22.4	22.8	0.75
WAR44-15 Monitor	13/05/2010	612	6810	190	434	3970	64	<0.01	208	219	2.74
WAR44-15 New	13/05/2010	214	3790	97	122	2180	24	<0.01	115	110	1.91
WAR44-15 Retro	13/05/2010	184	3500	100	111	2020	20	<0.01	106	102	1.77
WAR42-13 (50)	12/05/2010	183	4870	86	142	2840	40	<0.01	152	140	4.03
WAR42-13 New	12/05/2010	161	1890	66	33	1280	16	<0.01	60	62.1	1.76
WAR42-13 (80)	12/05/2010	124	1520	54	27	1040	12	<0.01	48.8	50.7	1.88
White container bore	15/05/2010	56	738	52	8	473	5	<0.01	23.8	23.9	0.2
Cavendish 1	15/05/2010	6	225	4	4	149	4	<0.01	7.14	7.13	0.13
Kia Ora 1	15/05/2010	246	1690	126	118	1140	21	<0.01	60.9	66.2	4.11
O'Dell Bore 1	16/06/2010	1	46	1	3	34	2	0.2	1.66	1.84	-
O'Dell Bore 2	16/06/2010	5	54	<1	<1	77	3	0.15	3.47	35.5	0.61
Monklands 1	17/06/2010	67	1170	41	54	661	10	0.04	37.4	35.1	2.62
Reids old bore 1	17/06/2010	156	946	72	83	554	20	18.8	36.3	2.62	1.67
Reids "the new bore" 1	17/06/2010	20	313	10	10	219	6	2.47	12.2	35.5	4.86

Note: - = No data   NC = No criteria   Highlighted values exceed criteria

3.3.2.1 Stock Water

Total dissolved solids was the only analyte to exceed ANZECC 2000 stock drinking water guidelines.

3.3.2.2 Irrigation

Water within the mine is currently not used for irrigation purposes; however, chloride, iron, manganese, total P and zinc exceeded ANZECC 2000 primary industry guidelines and a number of constituents exceeded the ANZECC 2000 freshwater 99% guidelines. Negative down flow effects from irrigating land with water from Permian aquifers may occur, particularly in areas where surface runoff is directed towards streams. These effects may include soil anion build up, raised concentrations of potentially harmful nutrients and metals in both shallow groundwater and surface water bodies.

3.3.2.3 Potable

Groundwater from the Permian aquifers exceeded the Australian human health guidelines (NHMRC and NRMMC 2004) for a number of the analytes assessed, of particular concern are arsenic, cadmium, nickel, lead, and nitrate.

3.3.2.4 Ecosystems

The ANZECC 2000 freshwater 99% criteria were exceeded on a number of occasions. Ammonia, arsenic, cadmium, chloride, copper, iron, manganese, nitrate, nitrate + nitrite, total N, total P, pH total dissolved solids and zinc were present in the Permian aquifers at concentrations greater than those specified in the ANZECC 2000 freshwater 99% guidelines.

3.3.3 Water Quality – Great Artesian Basin and Associated Aquifers

Landowners bores located in the GAB and associated aquifers and sampled in this study reported water quality dominated by sodium and potassium cations and chloride anions and are classified by Hem (1992) as Sodium – Calcium and Chloride – Sulfate – Bicarbonate waters (Figure 3-13) and are characterised by neutral to slightly acidic pH, slightly elevated levels of trace metals and raised background levels of nutrients. Water quality data for the GAB and associated aquifers are presented in Appendix C.

Waratah Coal

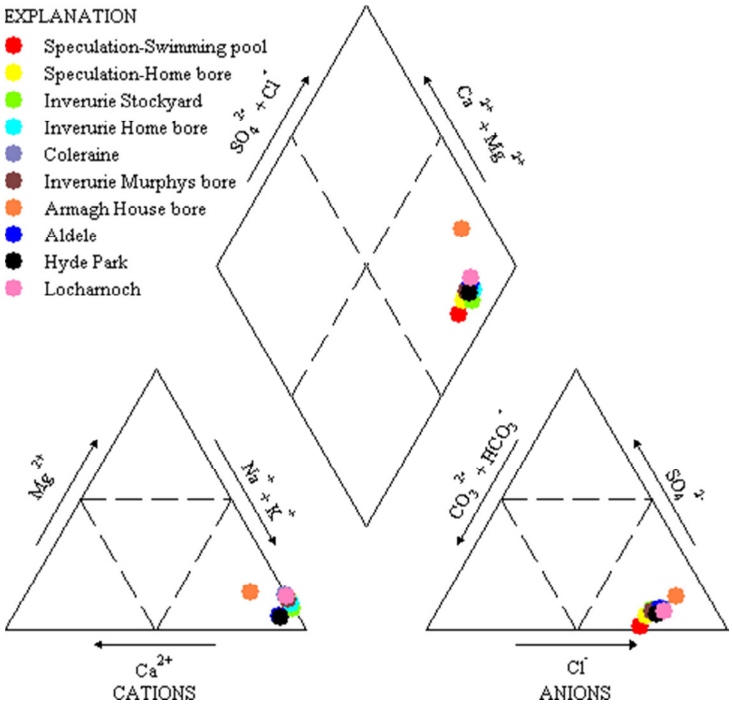

Figure 3-13: Piper Diagram of the GAB and Associated Aquifers Geochemistry

The cation-anion results reflect reports by GABCC (2009), which state that the GAB aquifers are generally sodium bicarbonates with chloride and minor carbonate.

Complete water quality results from bores in the GAB aquifers are presented in Appendix C.

3.3.3.1 Stock Water

Groundwater from the GAB and associated aquifers west of the mine site did not exceed the ANZECC stock drinking water guidelines. Ground water from these aquifers can therefore be considered suitable for livestock drinking water.

3.3.3.2 Irrigation

The GAB aquifer groundwater samples did not exceed the ANZECC 2000 irrigation water thresholds for the constituents analysed (Appendix C). Groundwater can therefore be considered suitable for irrigation purposes.

3.3.3.3 Potable

Groundwater from the GAB and associated aquifers did not exceed Australian drinking water human health guidelines (NHMRC and NRMMC 2004) for the analytes assessed.

3.3.3.4 Ecosystems

The ANZECC 2000 freshwater 99% species protection criteria were exceeded on a number of occasions. Water quality within the GAB and associated aquifers sampled during this study exceeded the ANZECC 2000 freshwater 99% guideline values for copper, nickel, zinc, nitrate, total nitrogen, and phosphorous. Chloride exceeded the primary industry guideline value on three occasions, total phosphorous, and total nitrogen on one occasion each. Nitrate exceeded the livestock drinking water guideline on one occasion.

3.4 Constant Discharge Aquifer Test Calculations

3.4.1 WAR42-13

Over the duration of pumping, groundwater levels in environmental monitoring bore WAR42-13(50) were not altered. Due to the short duration of the test, antecedent trends and barometric fluctuations were not observed and had no impact on observed water levels. It was therefore not considered necessary to make corrections for these fluctuations prior to analysis.

The groundwater level in bore WAR42-13(65) drew down by a maximum of 0.77m. A significant water level fluctuation occurred in the data as a result of a short reduction in flow rate (Figure 3-14); however, the level of noise created by changes in flow rate is not great enough to significantly distort the resulting drawdown curve and hence the predicted parameters.

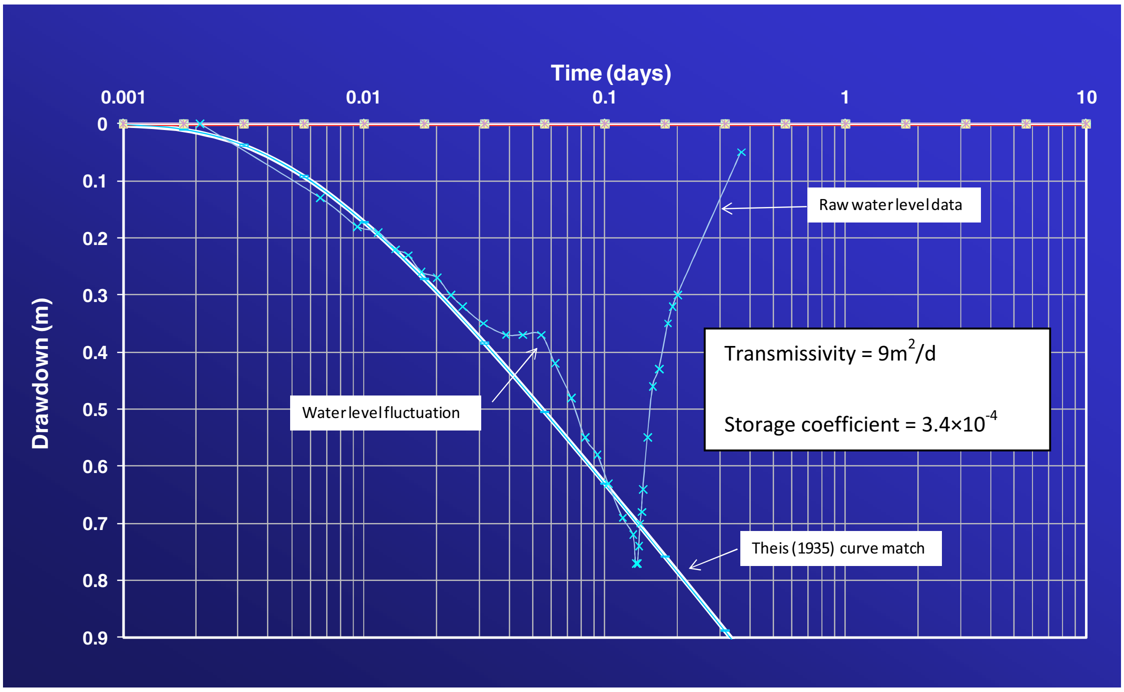

Figure 3-14: Drawdown Data and Curve Match for Bore WAR42-13(65)

Water level throughout this test was measured using a manual dipper which may have contributed to the apparent level of noise in the data. It should be noted that water levels in environmental monitoring bore WAR42-13(65) were measured both throughout the period of bore development and bore purging prior to water sampling. The results suggest that there were water level fluctuations resulting from the bore development process. This occurred prior to grouting and bore completion. Water levels in bore WAR42-13(65) were logged throughout water sampling; however, interference and recovery of water levels were not observed. A large volume (2,000 L) of grout was required to fill the annulus surrounding the bore casing. It is likely that large interconnected void spaces/dissolution channels existed at depth which resulted in the grout migrating beyond the bentonite slug and this may have interfered with the seal and/or the bore screen.

Throughout the period of bore purging for water sampling purposes , the water level in bore WAR42-13(80) drew down by a maximum of approximately 0.2m (Appendix D). There was no evidence of either barometric fluctuations or antecedent trends distorting bore water levels. Therefore, these were not corrected for prior to analysis.

Throughout the development process of monitoring bore WAR42-13(New), the observed drawdown in adjacent monitoring bores WAR42-13(65) and WAR42-13(80) were similar (Figure 3-15). It is therefore apparent that these bores are screened within the same aquifer, or aquifers with direct connection.

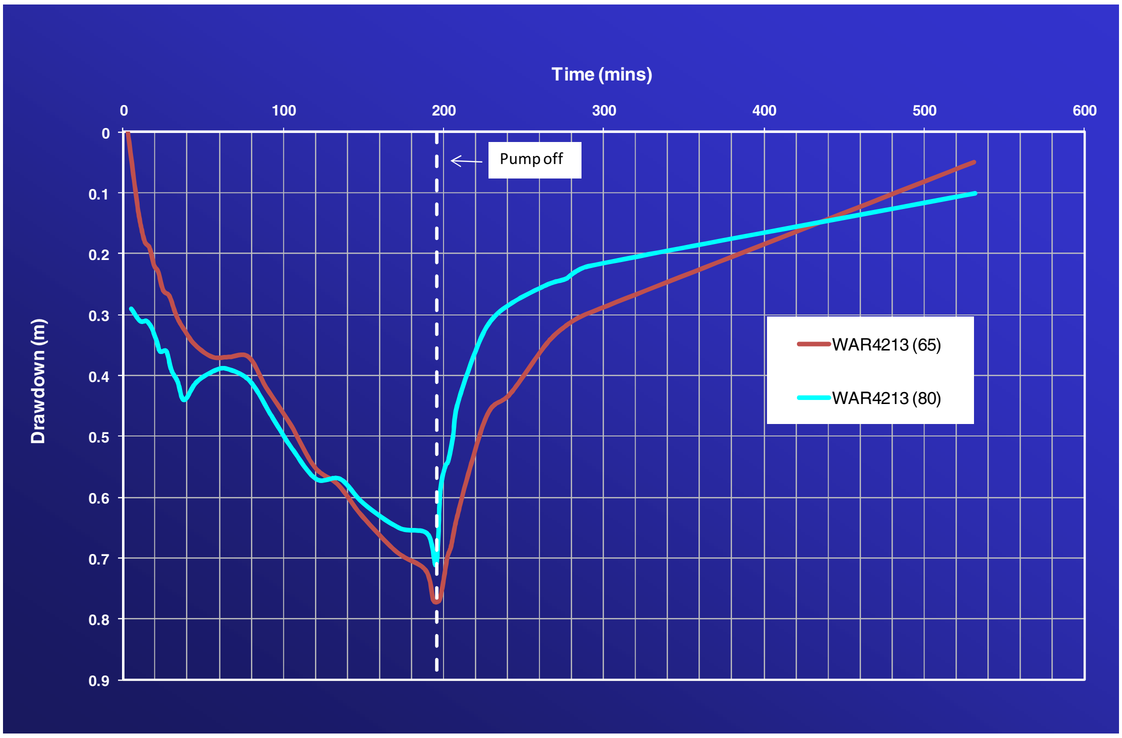

Figure 3-15: Plot of Water Level Drawdown in WAR42-13(65) and WAR42-13(80) during airlifting.

Plots of water level data are provided in Appendix C.

The interference data recorded for bores WAR42-13(65) and WAR42-13(80) were analysed using the Theis (1935) method to assess aquifer transmissivity (T) and storativity (S). The Hantush and Jacob (1955) method for leaky aquifers was also attempted however the length of the aquifer trials were not sufficient to determine the likely influence of leakage and as a result the predicted aquifer parameters were identical to those obtained using the Theis (1935) method.

Aquifer parameters resulting from the curve matches are summarised in Table 3-13. Plots showing the matched curves are provided in Appendix C.

Table 3-13: WAR42-13(65) and WAR42-13(80) Results – Theis (1935)

Bore	Hydrogeologic Unit	Radius (r) from pumped bore (m)	Transmissivity (m^2/d)	Storage	Aquifer type
WAR42-13(65)	Coal Seam C	20	9	3.4×10^{-4}	Slightly Leaky – Confined
WAR42-13(80)	Coal Seam DL	20	34	5.5×10^{-5}	Slightly Leaky – Confined
Average		-	21.5	1.98×10^{-4}	Slightly Leaky – Confined

The aquifers in which the WAR42-13 bores terminate are likely to be slightly leaky to confined. This assumption is based on the fact that reasonable matches with the measured data were possible using the Theis (1935) method for confined aquifers, the Hantush and Jacob method for leaky aquifers, the lack of drawdown in shallow bores when pumping from greater depths, and the presence of potential confining layers (clay bearing sands and ironstone) from depths of 17m.

The predicted transmissivity values are relatively low. However, these values are within the likely range for the stratigraphy intersected based on the average hydraulic conductivity for sandstone profiles of between 0.01 – 1 m/d (Kruseman and de Ridder, 1994) and a range in aquifer thickness of 5 – 15 m.

There is an order of magnitude difference between the storativity values for WAR42-13(65) and WAR42-13(80). This difference between values may be the result of the relatively short test period.

Leakage factor was not assessed from the drawdown data as the available test period was insufficient to obtain a robust estimate of this parameter.

Aquifer test setup and well details are outlined in Table 2-5

3.4.2 WAR44-15

Interference and recovery were not observed in WAR44-15(monitor) throughout bore development or bore purging/water sampling. It is therefore likely that the aquifer in which WAR44-15(monitor) terminates is not hydrologically connected to the deeper aquifers at the site. Fluctuations in barometric pressure were not considered prior to analysis as there was no evidence to suggest that these altered observed water levels. While a linear antecedent trend is evident in the data (Figure 3-16) it is likely to be the result of water level recovery after drilling and bore development.

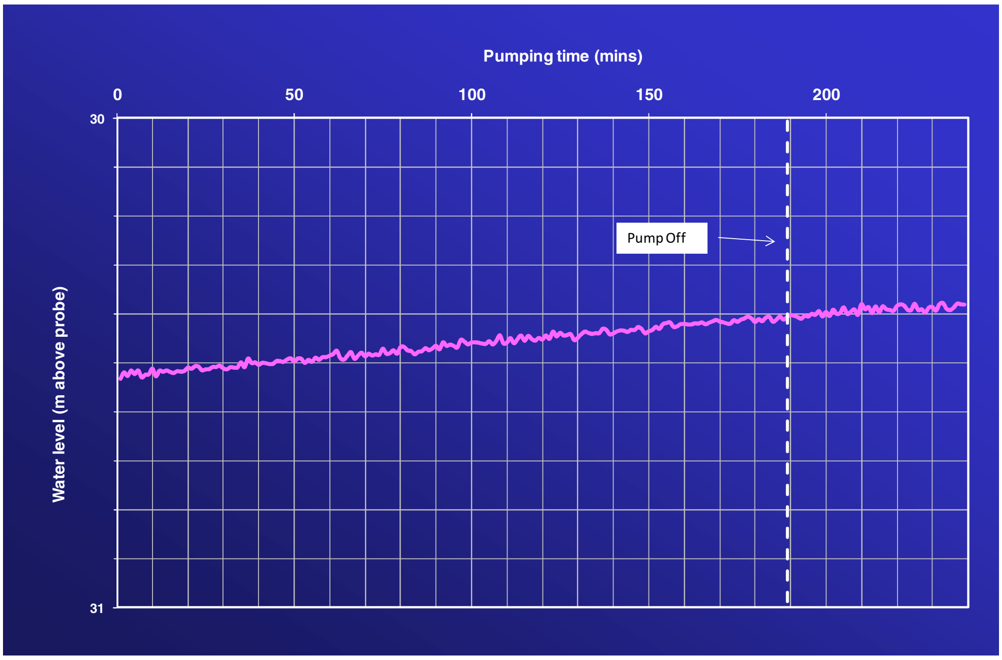

Figure 3-16: Raw Water Level Data for Bore WAR44-15(monitor)

Throughout both bore development and bore purging/sampling of WAR44-15(New), interference effects were observed in WAR44-15(retro). The maximum observed drawdown resulting from bore purging and water sampling was approximately 0.5 m. As with WAR44-15(monitor), antecedent trends and fluctuations in barometric pressure had no visible effect on observed water level, therefore corrections were not required. The interference data recorded in bore WAR44-15(retro) were analysed using the Theis (1935) method to estimate aquifer transmissivity (T) and storativity (S). A plot showing the matched curve is provided in Figure 3-17. Aquifer parameters resulting from the curve matches are summarised in Table 3-14. Plots of water level data are contained in Appendix C.

Table 3-14: WAR44-15(Retro) Results Theis (1935) Analysis Results

Bore	Radius (r) from pumped bore (m)	Transmissivity (m^2/d)	Storage	Aquifer type
WAR44-15(Retro)	20	9	9.1×10^{-5}	Slightly Leaky – Confined

The predicted transmissivity value is within the likely range for sandstone profiles based on the Kruseman and de Ridder (1994) estimated range in sandstone hydraulic conductivity of 0.01 – 1m/d and an aquifer thickness of between 5 – 15m. The predicted storativity value of 9.1×10^{-5} indicates that the aquifer has very little storage capacity.

It is inappropriate to predict leakage (B) from short duration drawdown tests. The lack of observed drawdown in WAR44-15(Monitor) which is screened at a shallower depth to the pumped bore may indicate a low rate of leakage. However, the short duration of the trial may not have allowed suitable time for effects to be observed in WAR44-15(Monitor).

Based on the lack of observed drawdown in WAR44-15(Monitor) which is screened at a shallower depth, it is assumed that leakage does not contribute a significant amount of water to deeper aquifers at this site.

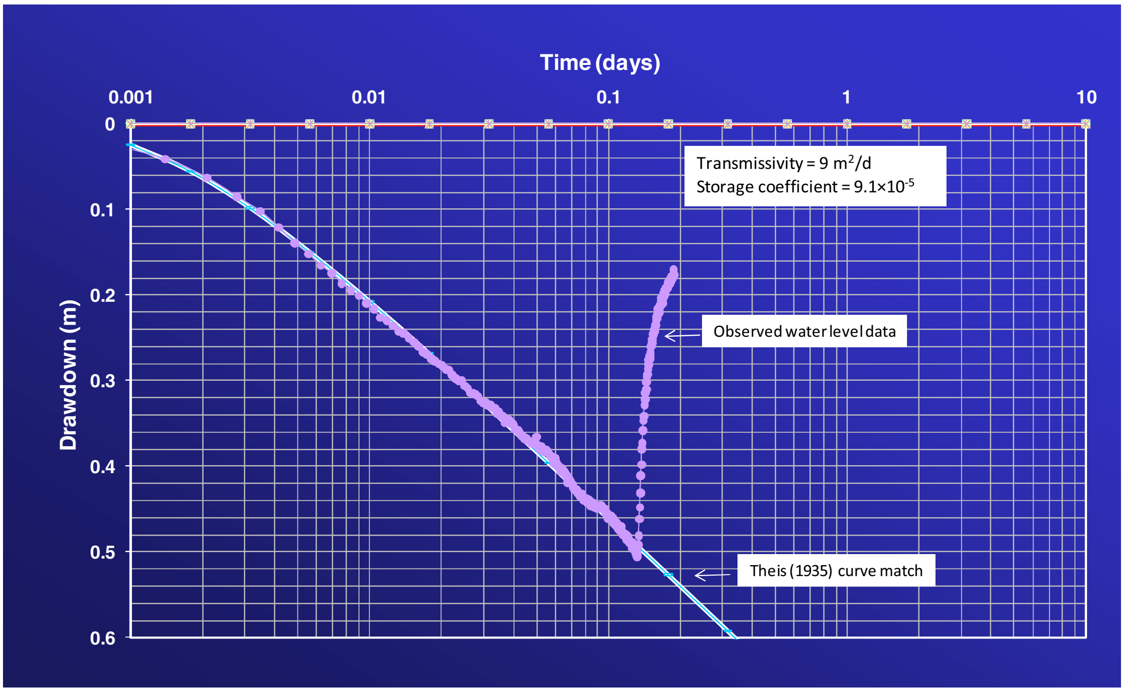

Figure 3-17: Drawdown Data and Curve Match for WAR44-15(Retro)

Aquifer test setup and well details are outlined in Table 2-4.

3.4.3 Slug Tests

Bores in proximity to the mine area reported results of 1.25 m/d to 0.001 m/d (Table 3-15).

Table 3-15: Summary table of slug test results

Bore Name	Bore location	Hydraulic Conductivity (m/d)
WAR38-15 (New)	Mine Lease Area	1.25
WAR38-15 (60)	Mine Lease Area	0.25
WAR44-15 (Monitor)	Mine Lease Area	0.0029
WAR42-13 (50)	Mine Lease Area	0.001
Reids “the new bore”	Mine Lease Area	0.73
Reids the old bore	Mine Lease Area	0.1
Monklands 1	Mine Lease Area	0.016
Hyde Park	GAB	2.9
Aldele	GAB	9
Locharnoch	GAB	>10
Coleraine	GAB	12

Results from a single bore slug test of WAR38-15(New) indicate a hydraulic conductivity of 1.25m/d. This value of hydraulic conductivity is within the expected range for the sandy stratigraphy of between 0.28 and 274 m/d (Freeze and Cherry, 1976). A hydraulic conductivity value of 0.25 m/d was predicted from the test data for WAR38-15(60) which is within the range for sandy material (Freeze and Cherry, 1976).

Slug testing of bore WAR44-15(monitor) indicated an aquifer hydraulic conductivity of 0.0029 m/d. The observed rate of water level recharge in the bore is indicative of semi-permeable aquifer material (Figure 3-18). The predicted hydraulic conductivity is also consistent with the likely range in values for siltstone and sandstone which is the dominant strata at this depth and location. It is possible that bore WAR44-15(monitor) has been screened in the upper confining layer between the tertiary and Permian sediments.

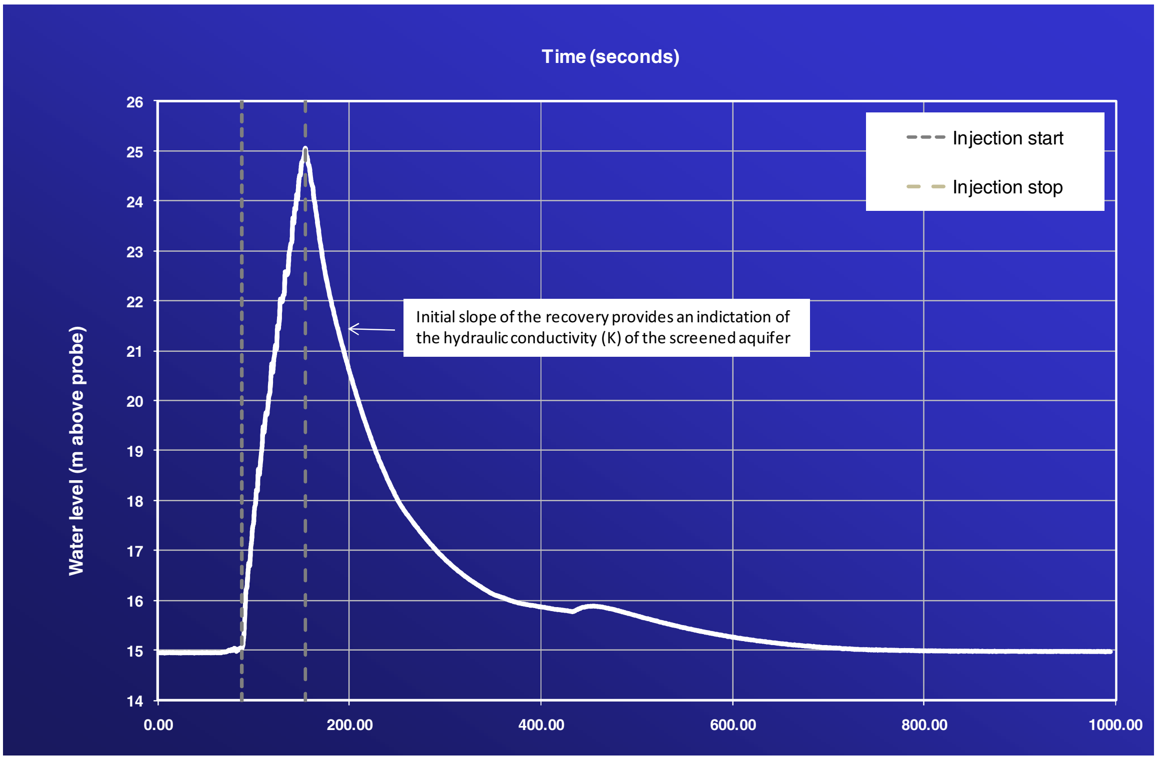

Figure 3-18: Plot of WAR38-15(60) Slug Test Data

Results from bore WAR42-13(50) indicate a hydraulic conductivity of approximately 0.001 m/d. WAR42-13(50) terminates in clayey material at the base of the tertiary strata. If the low permeability clays are extensive and form a barrier to significant downward movement of groundwater to deeper aquifers then they may form the upper confining layers for the multilayered Permian aquifers.

Results from a single bore slug test of “Reid’s the new bore” indicate a hydraulic conductivity of 0.73 m/d which is similar to values of hydraulic conductivity from other bores within the mine lease area. This value of hydraulic conductivity is within the expected range for the stratigraphy of between 0.28 and 274 m/d (Freeze and Cherry, 1976).

A hydraulic conductivity value of 0.1 m/d was predicted from the test data for “Reid’s the old bore” which is within the range for sandy material (Freeze and Cherry, 1976). As with “Reid’s the new bore”, the observed hydraulic conductivity in “Reid’s the old bore” is similar to other values observed within the mine lease area.

Results from the hydraulic test carried out on “Monkland’s 1” indicate a relatively low hydraulic conductivity of 0.016m/d.

Bores in the GAB and associated aquifers reported markedly higher results of 12 to 2.9 m/d.
Slug testing of the “Hyde Park” bore (DERM RN 103171) indicated an aquifer hydraulic conductivity of 2.9 m/d. The observed rate of water level recharge in the bore is indicative of the permeable aquifer material.

The predicted hydraulic conductivity is also consistent with the likely range in values for sandstone which is the dominant strata at this depth and location.

Results from the Aldele bore (DERM RN 3070) indicate a hydraulic conductivity of approximately 9 m/d which is within the upper range of likely hydraulic conductivity values for the GAB aquifers (GABCC 2009).

Water levels in the "Locharnoch" bore were not altered after the injection of 40L of water. The rapid infiltration of water into the aquifer indicates a relatively high hydraulic conductivity ($K \geq 10$ m/d).

A single bore slug test carried out on the Coleraine bore (DERM RN 3075) indicated an aquifer hydraulic conductivity of 12 m/d. This value is greater than the likely range for conductivities within the great artesian basin aquifers of 0.1 to 10 m/d (GABCC 2009), and also for the medium grained sandstone material of the Clematis group.

Hydraulic conductivities and therefore productivity of the GAB and associated aquifers are significantly greater than those of the Permian aquifers in and surrounding the mine lease area. It is likely that waters of the GAB aquifers are flowing in a westerly direction as opposed to those of the mine lease area that are flowing predominantly in an easterly direction. Concentrations of sodium, bicarbonate, and chloride are significantly greater within aquifers of the mine lease area than those within the GAB.

Differences between groundwater of the GAB and associated aquifers and those within the mine lease area are evident when aquifer hydraulic conductivity is plotted against the sum of sodium, bicarbonate and chloride (Figure 3-19). This is likely to be the result of the greater depth of the non-GAB aquifers which will result in longer residence times and therefore a higher degree of mineralisation.

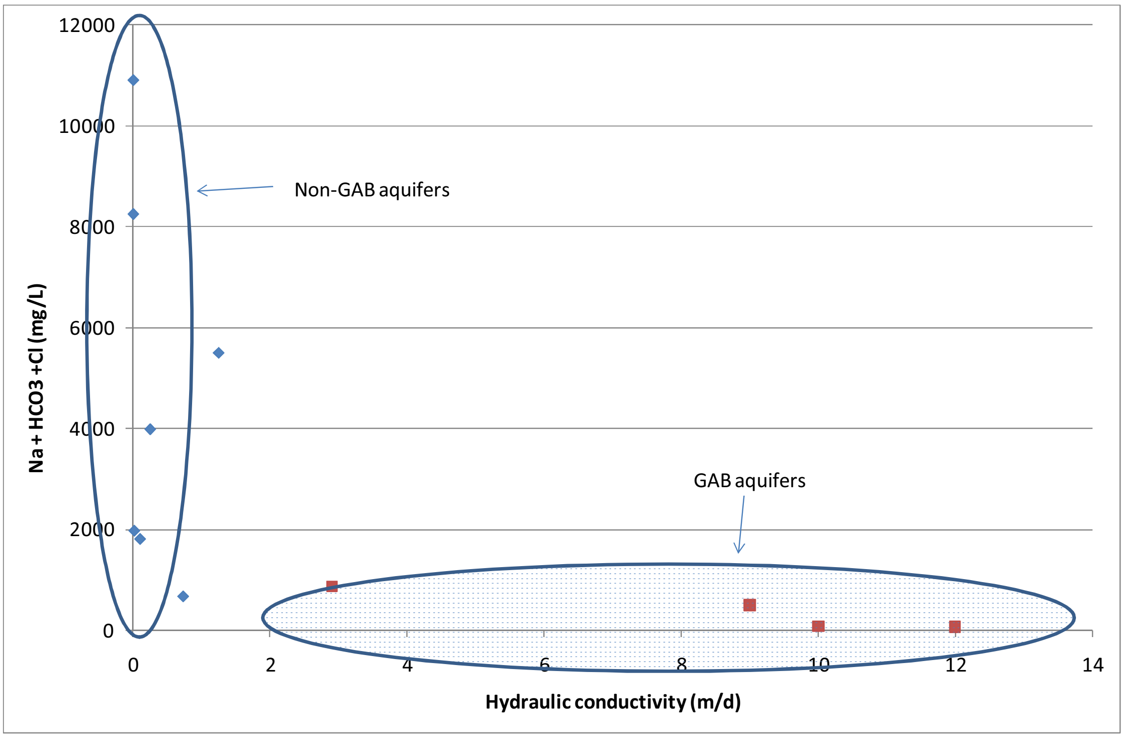

Figure 3-19: Comparison of GAB versus non-GAB aquifer characteristics and geochemistry

Slug test calculations and plots are presented in Appendix D.

3.4.4 Stygofauna Results

Analyses of samples collected from the bores indicated that there were no Stygofauna. Results from the stygofauna sampling regime are outlined in the Aquatic Ecology Technical Report.

3.4.5 Rewan Formation Infiltration Results

Results from a controlled infiltration experiment on shale layers in the Rewan Formation are presented in Figure 3-20. The slope of the linear trend provides an indication of the infiltration rate into the shale sample. The test resulted in a predicted infiltration rate of 0.14 m/d. This result is within the likely hydraulic conductivities of the confining beds of the GAB of between 1 – 0.001 m/d (Habermehl, 1980).

Waratah Coal

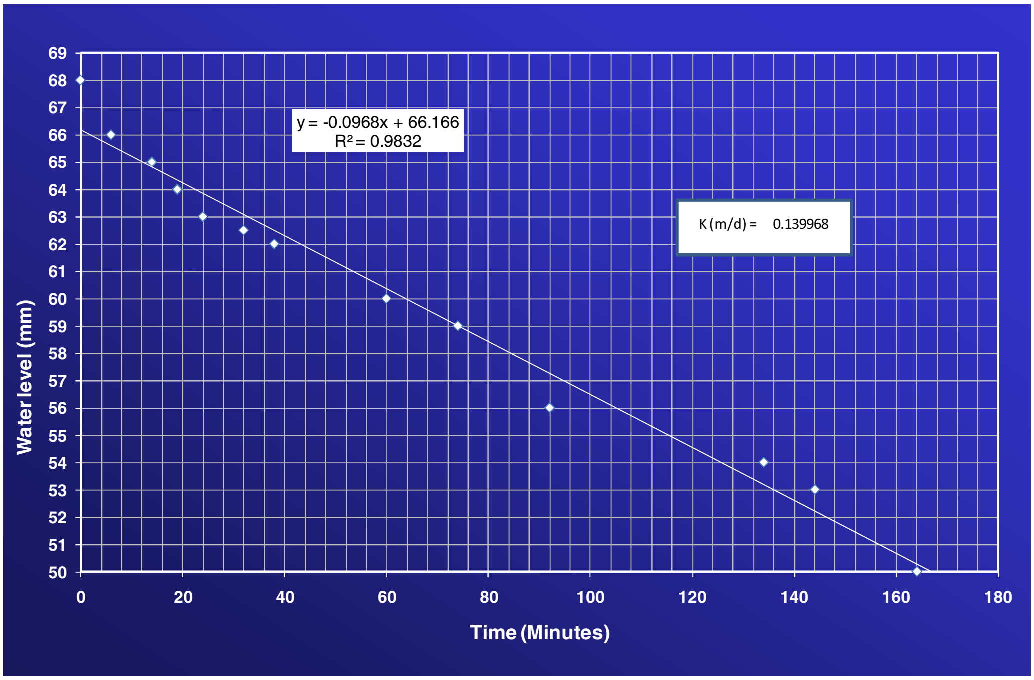

Figure 3-20: Double Ring Infiltrometer Test Results

3.5 Tertiary Aquifer Hydrogeological Regime

3.5.1 Distribution

Data for the characteristics of the shallow tertiary aquifers within and surrounding the mine lease area is sparse. DERM supplied data for bores within a radius of 50 km from the approximate centre of the mine. This data was limited with respect to aquifer depths and parameters. The available data indicate that tertiary aquifers occur predominantly alongside and below surface water bodies such as wetlands and streambeds. The depth of the aquifers ranged from 4 - 77.2 mbgl, with an average depth of 37.62 m and an average aquifer thickness of 2.02 m.

3.5.2 Groundwater Occurrence, Recharge and Flow

Bore 12030076 has a static water level of 9.3 m and a total depth of 28.3 m. Bore "Monkland's 1" is an equivalent depth; however is 3.8 km east north east of bore 12030076 and the static water level of 15 m is significantly deeper resulting in an estimated groundwater gradient of 0.0015 m/m in an easterly direction.

Tellerenha Creek lies to the west of bore 12030076. The Tellerenha Creek may recharge the shallow Tertiary aquifer during the wet season resulting in a gradient away from the creek.

3.5.3 Hydraulic Parameters and Yield

Due to the limited amount of historic tertiary aquifer data, it is difficult to accurately estimate aquifer hydraulic parameters. Limited yield data were available from the DERM database specifically for the tertiary aquifers. The available data indicate a range in aquifer yields of between 0.01 – 0.27 L/s.

3.6 Permian Aquifer Hydrogeological Regime

3.6.1 Distribution

Water bearing layers exist within the Permian strata at various depths. Aquifers within the Permian strata are usually associated with coal seams and the overburden and interburden above and between the various coal seams. A number of bores exist within a 50 km radius of the mine (Figure 3-2) that are screened in Permian aquifers. There is no apparent pattern to the spatial distribution of bores that terminate in Permian aquifers.

3.6.2 Groundwater Occurrence, Recharge and Flow

Recharge around the bores installed occurs locally by horizontal flow rather than vertical recharge as no disturbance of overlying water levels in bores was reported. Long term pump tests may provide further data to assess this hypothesis. Regional recharge may be occurring at leaky areas further west.

Based on groundwater contouring, the likely groundwater flow direction within the Permian aquifers including the various coal seams and interburden layers is in a north easterly direction (Figure 3-21 to Figure 3-23).

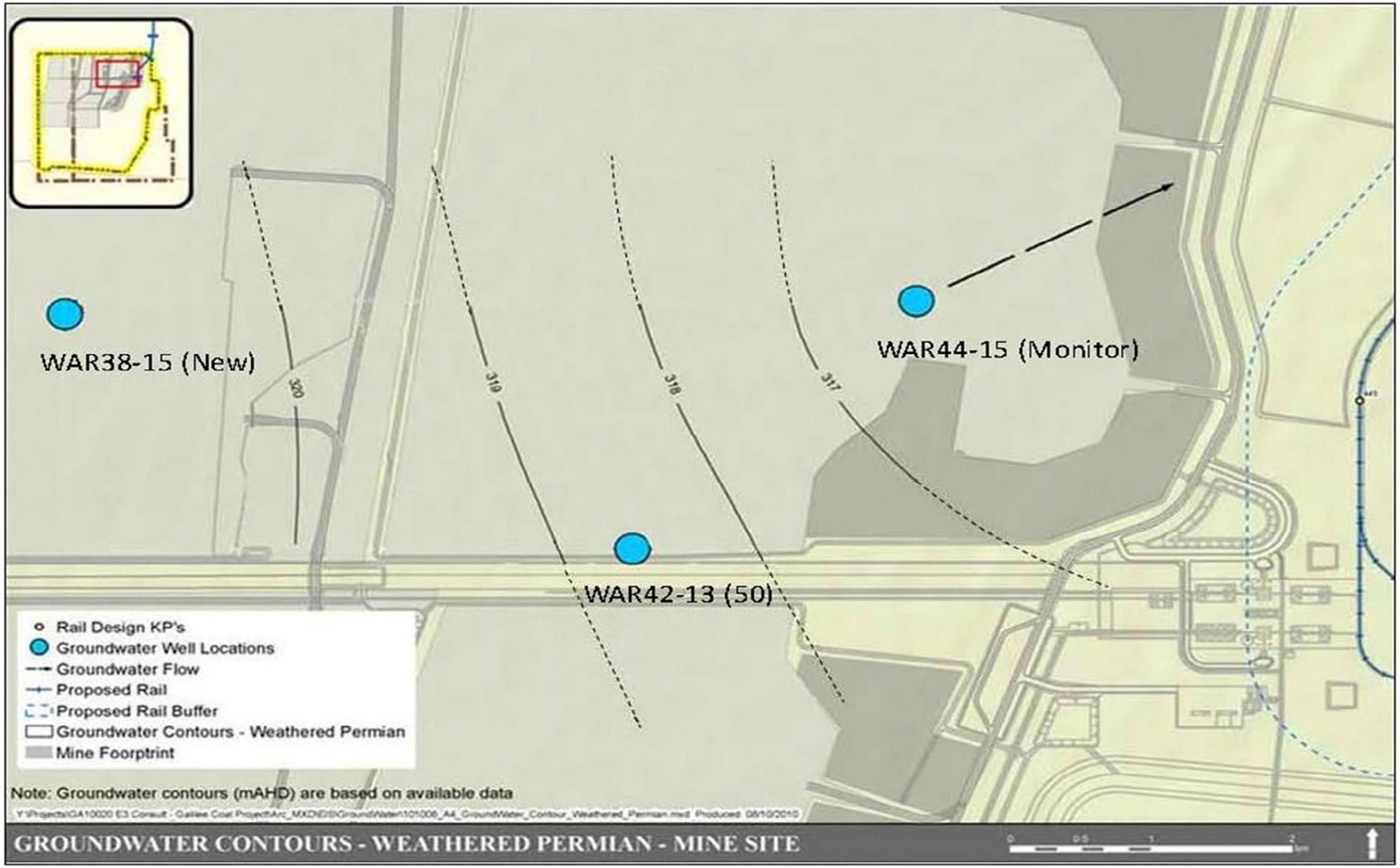

Figure 3-21: Weathered Permian Groundwater Contouring

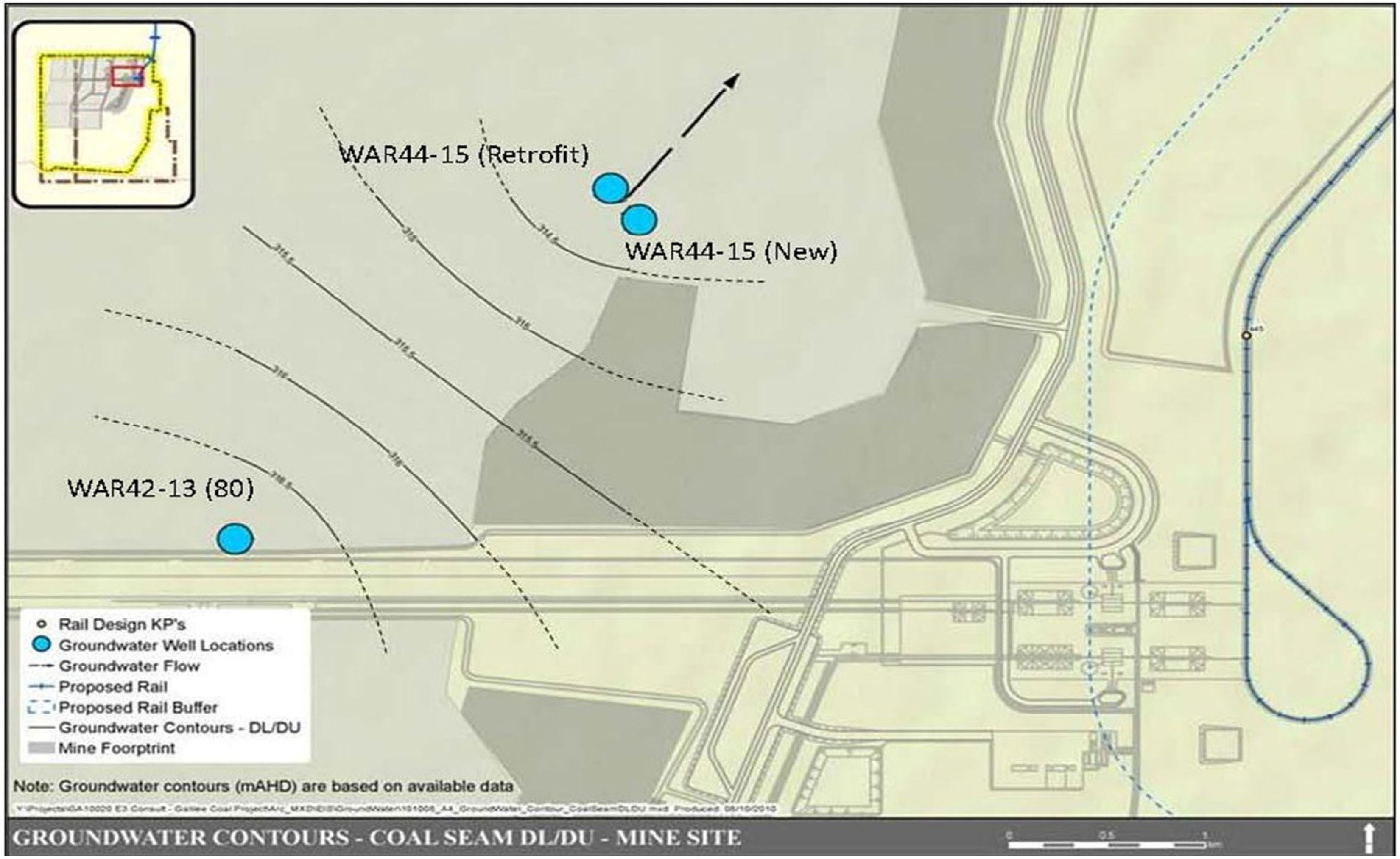

Figure 3-22: Interburden DU/DL Groundwater Contouring

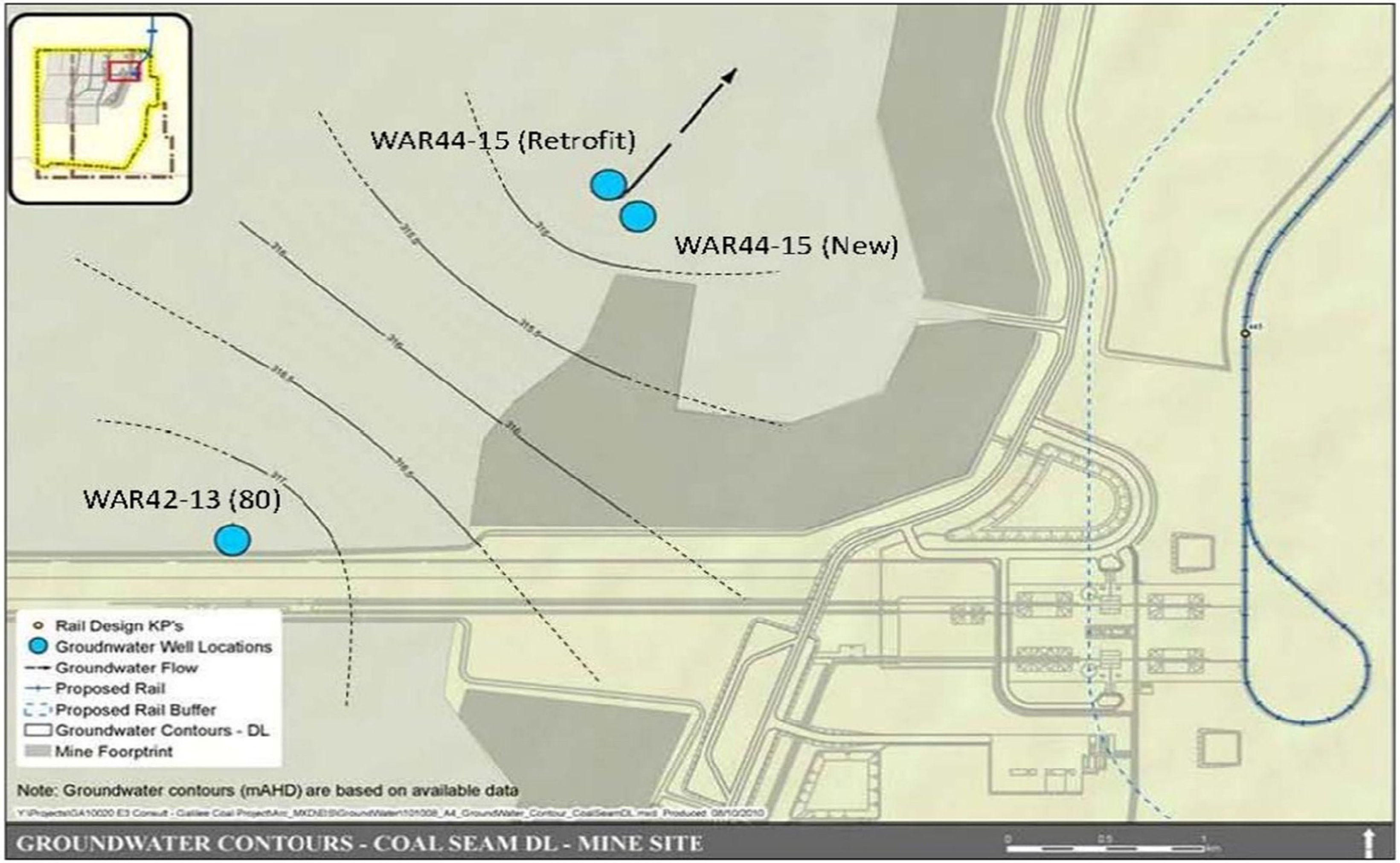

Figure 3-23: Coal Seam DL Groundwater Contouring

3.6.3 Hydraulic Parameters and Yield

Hydraulic parameters vary within the Permian aquifers at the mine. The weathered Permian sediments above the position of the coal seams display a range in hydraulic conductivity between 0.001 – 0.0029 m/d.

Transmissivities within the coal seams ranged from 9 – 34m^2/d based on the constant rate drawdown tests. Calculated values of hydraulic conductivity taking into account values of transmissivity and the relative thickness of each aquifer range from 1.8 to 6.8 m/d. Storage values within the coal seams ranged from 3.4×10^{-4} – 9.1×10^{-5}.

Hydraulic parameters in the interburden between the various coal seams displayed similar parameters to those of the coal seams. Pumping tests and bore production carried out on bores WAR38-15(New), WAR42-13(New) and WAR44-15(New) indicate yields within the Permian strata of between 0.15 – 0.3 L/s.

3.7 Predictive Modelling Results

3.7.1 Drawdown

A series of predictive steady state simulations of the open cut and underground mining sequence from year one to year 25 was undertaken to assess the potential area of influence of drawdown around the mine at 5 year intervals.

In year 1 draw downs of more than 5 m extend to a maximum of 1.1 km (Figure 3-24) from the open cuts and 5.9 km in year 5, while between year 10 to year 25 the resulting drawdown was estimated to extend to approximately 11 km in an east-west direction and 5 km north south and 15 km by year 25. To provide an indication of uncertainties in the model, simulations with variations of hydraulic model parameters and steady state simulations yielded estimates to extend up to approximately 30 km from the mine during the mine life. The assumptions outlined in section 2.4.11 are conservative and are anticipated to provide an indication of impacts at the larger end of the scale of potential impacts.

Waratah Coal

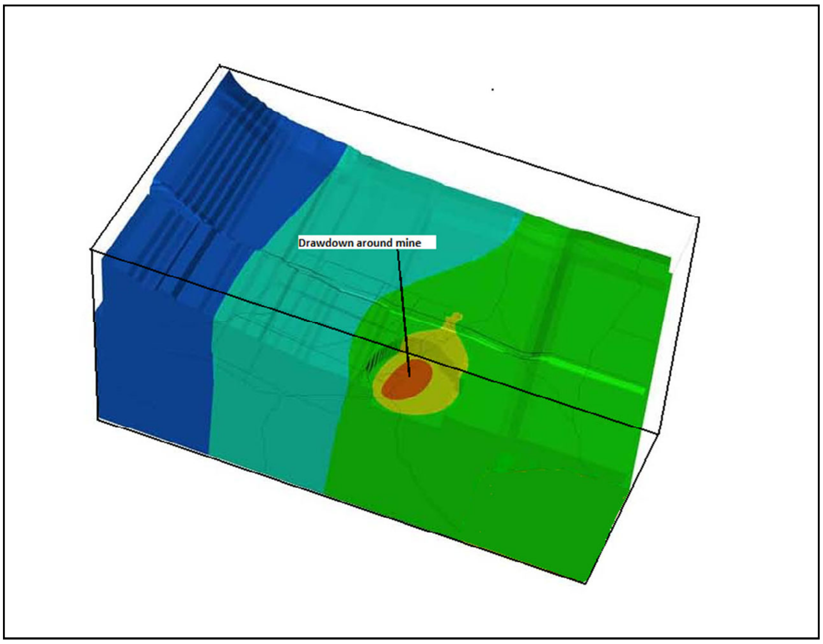

Figure 3-24: Example Model Output of Drawdown Around Mine

3.7.2 Inflows

The predicted mine inflows from the above modelling are summarised in Table 3-16.

Table 3-16: Estimated Mine Inflows

Year	Inflow Estimates (ML/year)
1	980-1,400
5	1,020-4,700
10	1,850-2,550
15	1,650-4,850
20	2,200-9,500
25	3,800-12,300

These estimates are based upon simulations with mass balance errors for the model of between 0.07% (Year 10) to 8.7% (Year 1). It is noted that initial inflows will likely be at the higher end of the estimates and that in reality inflows will reduce as mining progresses. This is because not all the modelled inflow estimates will report to the mine sumps and pumps as the modelled results assume no pre-drainage of the mine, include pore water in the mined material, excludes evaporation in the mine and assumes average conditions. For these reasons, it is considered that on average the actual recovered inflow water will be less than the modelled inflows.

Simulations with increased vertical hydraulic conductivity to simulate cracking reported inflows up to an order of magnitude higher than the above estimates. However, further detailed data is required before reliable estimates can be made.

3.7.3 Groundwater Recovery

Groundwater recovery was not complete in simulations of 50 years following mining. Given the absence of transient calibration data, the uncertainties in long term simulations beyond this are considered too large to provide meaningful results.

Current information from monitoring of mines indicates that full recovery of groundwater levels requires many decades (typically in the order of 50-100 years) and in some instances will not fully recover to pre-mining levels. This may be due in part to changes to aquifer permeability and reduced infiltration by fine spoil material reducing permeability in infiltration areas and from the mining processes. It is also possible that evaporation from water filled open cut mine voids may maintain water levels at lower depths than pre-mining levels. More detailed data including transient data during mining would be required to refine this assessment.

3.7.4 Comparison with Hancock EIS

Hancock Prospecting Pty Ltd recently released an Environmental Impact Statement for the Alpha Coal project in the Galilee Basin. The location of the proposed coal mine is approximately 30 km north of the Waratah Galilee Coal Mine therefore investigations for the Hancock mine will be relevant to Waratah Coals mine. Results outlined in the Groundwater technical chapter of the Hancock EIS have been reviewed and generally support the findings and conclusions of the investigations carried out for the Waratah Coal Project.

Table 3-17 provides comparisons between the assessment methods employed and findings of the respective groundwater technical investigations.

Table 3-17: Comparison with Hancock EIS data/results

Section/Parameter	Waratah Coal	Hancock	Consistency	Explanation
Existing Groundwater Environment				
Pump tests	3 hour constant discharge aquifer tests with pump rates of <1l/s.	24 – 100 hour pump tests with flow rates ranging from 1 – 10 l/s.	Low	Permitting issues (section 2.3.6) limited the length of the Waratah pumping trials to short duration 3 hour trials increasing the level of uncertainty. The hydraulic parameters outlined in the Hancock EIS groundwater technical report are similar to those of Waratah providing a greater level of certainty to the obtained results.
Aquifer test analysis methods	Theis (1935) and Hantush and Jacob (1955) methods.	Jacob method (Cooper and Jacob 1946).	Moderate	Similar aquifer test analysis methodologies were used to predict aquifer parameters. Hancock used the Jacob method (Cooper and Jacob 1946) for confined aquifers. Aquifer hydraulic parameters in the waratah project were predicted using both the Theis (1935) equation for confined aquifers and the Hantush and Jacob (1955) method for semi confined to leaky aquifers. The Jacob method is a variation on the Theis (1935) equation which incorporates unsteady state flow, and the Hantush and Jacob method is also a variation of the Theis (1935) method allowing for the prediction of leakage of water to layers above and below the aquifer in question. All three methods are frequently used in groundwater investigations of this type and are considered relevant.
Aquifer hydraulic conductivity	0.001 – 1.25 m/d within the Galilee Basin, and up to 12 m/d in the GAB and associated aquifers.	0.12 – 2m/d within the Galilee Basin.	High	The aquifer hydraulic conductivity values presented by Waratah and Hancock are consistent with published levels in sand/sandstone strata.

Section/Parameter	Waratah Coal	Hancock	Consistency	Explanation
Transmissivity	9 – 34m^2/d	4.3 – 65m^2/d	High	Hancock specify a slightly greater range in aquifer transmissivities than Waratah Coal, however the results are of similar orders of magnitude, and differences are likely to be due to the greater number of constant discharge aquifer test trials carried out by Hancock and potentially greater aquifer heterogeneity and anisotropy within the Hancock MLA.
Storage coefficient	1×10^{-4} - 1×10^{-5} Within the Galilee Basin.	1×10^{-3} - 1×10^{-5}	High	Hancock present a wider range in storage coefficients than Waratah Coal. This may be due to more heterogeneous and anisotropic aquifer material within the Hancock MLA or the larger number of constant discharge aquifer trials carried out by Hancock resulting in a more representative indication of storage coefficients.
Groundwater flow direction	Easterly groundwater flow direction based on contoured static water levels (mAHD).	Easterly flow direction based on contouring of coal exploration core hole water level data.	High	An easterly groundwater flow direction originating from recharge zones along the Great Dividing Range was observed in both the Hancock and Waratah groundwater technical reports. These predictions give justification to the hypothesis that the Galilee basin is separate from the GAB and associated aquifers.

Section/Parameter	Waratah Coal	Hancock	Consistency	Explanation
Recharge/Discharge	Implied recharge zones west of the mine lease area and discharge zones east of the mine lease area.	Specific recharge zones mentioned in areas of aquifer outcrop and diffuse recharge along the great dividing range. Specific discharge zones mentioned, in particular lagoon creek and the associated wetland, and groundwater springs.	Moderate	These points are estimates based on groundwater flow directions and aquifer geochemistry alluding to relatively old groundwater which may have travelled a significant distance.
		Water Quality		
Water Quality	Water quality has been compared with ANZECC 2000 and Australian drinking water guidelines.	Comparisons made with ANZECC and Australian Drinking water guidelines.	High	Both investigations compared results to the same water quality guidelines. Waters in both mine lease areas can broadly be considered suitable for livestock drinking water based on the analytes assessed, however not generally for human consumption as a number of the Australian drinking water criteria were exceeded.
Water classification	Predominantly sodium chloride waters.	Predominantly sodium chloride waters.	High	Similar aquifer geochemistry exists between mine sites. Groundwater within both mine lease areas are dominated by sodium cations and chloride anions, and are classified according to HEM (1992) as Chloride-Sulfate, and Chloride Sulfate Bicarbonate waters.

Section/Parameter	Waratah Coal	Hancock	Consistency	Explanation
Groundwater modelling				
Model types	3D numerical model based on obtained aquifer parameters and a conceptual hydrological model.	Conceptual hydrological models, a seepage model, and a 2D numerical model.	Moderate	Significant differences in groundwater modelling techniques have been reported in the respective EIS chapters. Waratah Coal have carried out 3D numerical modelling of the groundwater systems to predict the radius of drawdown surrounding the mine, and likely inflows of groundwater to the open pits and longwall sections, while Hancock have undertaken a more simplistic approach involving seepage modelling of mine inflows based on aquifer parameters, and the radius of significant drawdown was predicted using a 2D analytical modelling package.
Predicted radius of drawdown greater than 5m	10 – 30 km	14 – 30 km	High	Very similar predictions of the radius of influence were estimated based on the adopted modelling techniques of Waratah and Hancock.
Predicted mining inflows	Approximately 980 – 12,300 ML/Year	Approximately 2,800 – 8,200 ML/Year	Moderate	Inflows to mined voids are based on differing time frames and pit sizes accounting for the differences in range of inflows between the Waratah and Hancock Projects. The Waratah predictions are based on pit designs and mining periods of 1, 5, 10, 15, 20, and 25 years, and groundwater recovery after mining. The Hancock predictions are based on 1 year time intervals as the modelling methods will result in unacceptable levels of uncertainty if time periods are greater than 1 year.

The respective coal mines are within close proximity to each other therefore the geology, topography, hydrogeological characteristics, climatic regimes, dominant soils, and land use types are very similar. It is therefore not surprising that the predicted mining inflows and range in likely radius of drawdown were similar. While there is a level of uncertainty inherent in all modelling and analytical predictions, the consistency shown between the two investigations provides a higher level of certainty that the results of the modelling are accurate.

4 Rail Alignment

The rail alignment traverses 447 km from the mine to the APSD. The majority of the works involved in the construction of the rail alignment will be cut and fill and levelling as required. It is not anticipated that deep impact works will be involved except for the construction of pylons for bridge structures. A full description of the rail alignment is contained in the project description section of the EIS.

4.1 Previous Investigations

Previous studies in the area include a desktop study undertaken in 2009 (SKM, October 2009) for the project area and studies (i.e. GHD, 2010, Proposed Abbot Point Multi Cargo Facility Draft Environmental Impact Statement, North Queensland Bulk Ports Corporation) from the EIS's undertaken for the APSDA expansion programs. The following discussion is compiled from information from these sources.

Groundwater is managed through Groundwater Management Units (GMUs) or "Declared Areas" where groundwater is regulated. Areas where groundwater is not regulated are termed "non-Declared Areas." The GMU indicates that the mine lies within an area where the Queensland Government regulates the construction of bores and taking of water (The GMU extent is shown in Figure 4-1). Within this area, a water licence is generally required prior to taking water and a development permit is required prior to the construction of a bore. The exact requirements can vary from area to area and are prescribed by the *Water Act 2000*.

The rail corridor crosses the Bowen GMU from KP00 to KP04, a large undeclared groundwater area from KP04 to KP230 (as shown in Figure 4-2 between KP04 and KP230), and the Highlands GMU from KP230 to KP447. The position of the declared groundwater areas are shown in Figure 4-1 while the DERM registered groundwater bores along the rail alignment are shown in Figure 4-2 and Figure 4-3.

Waratah Coal

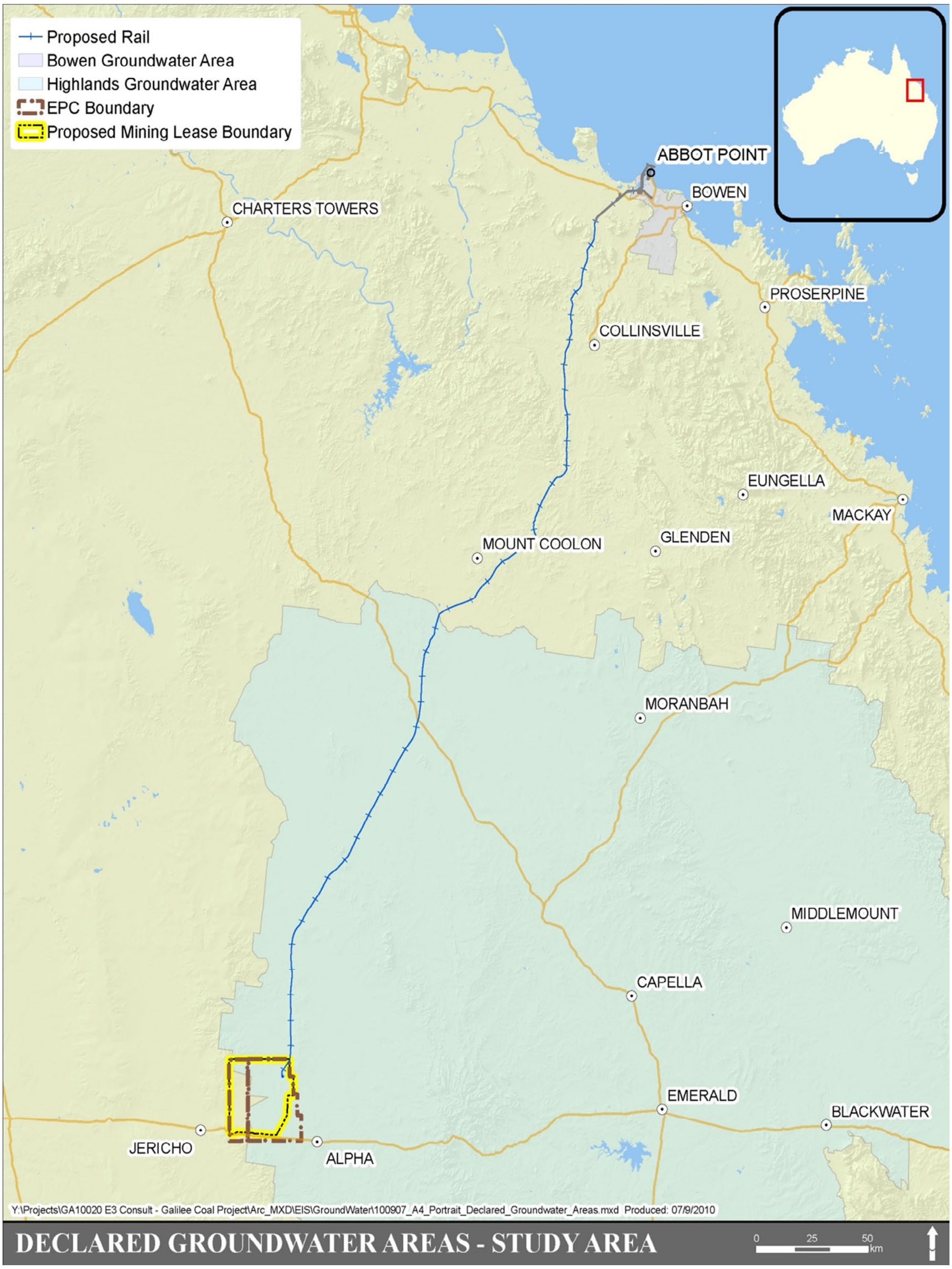

Figure 4-1: Map of Declared Groundwater Areas

Waratah Coal

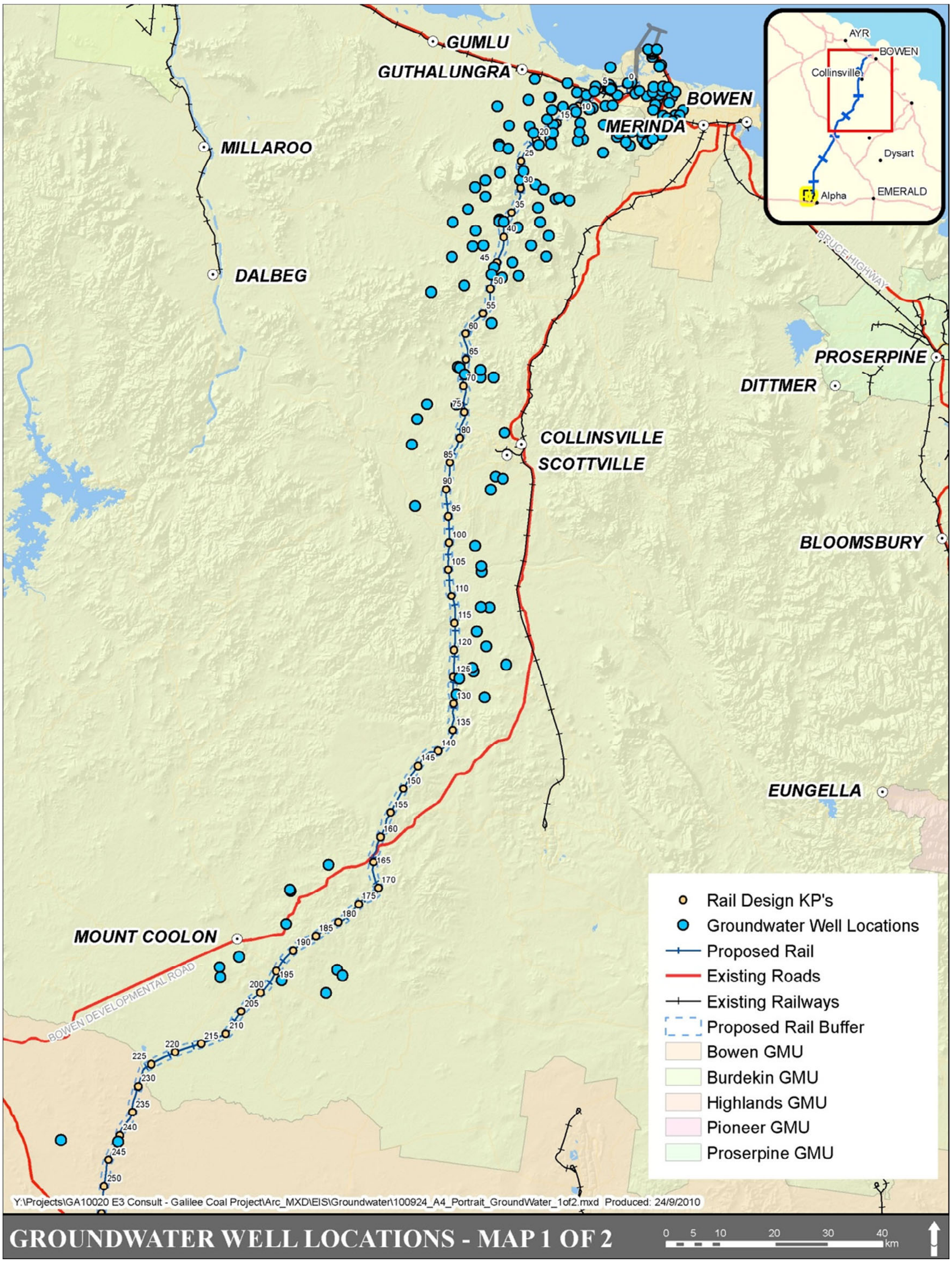

Figure 4-2: DERM Registered Groundwater Bores from KP00 to KP250

Waratah Coal

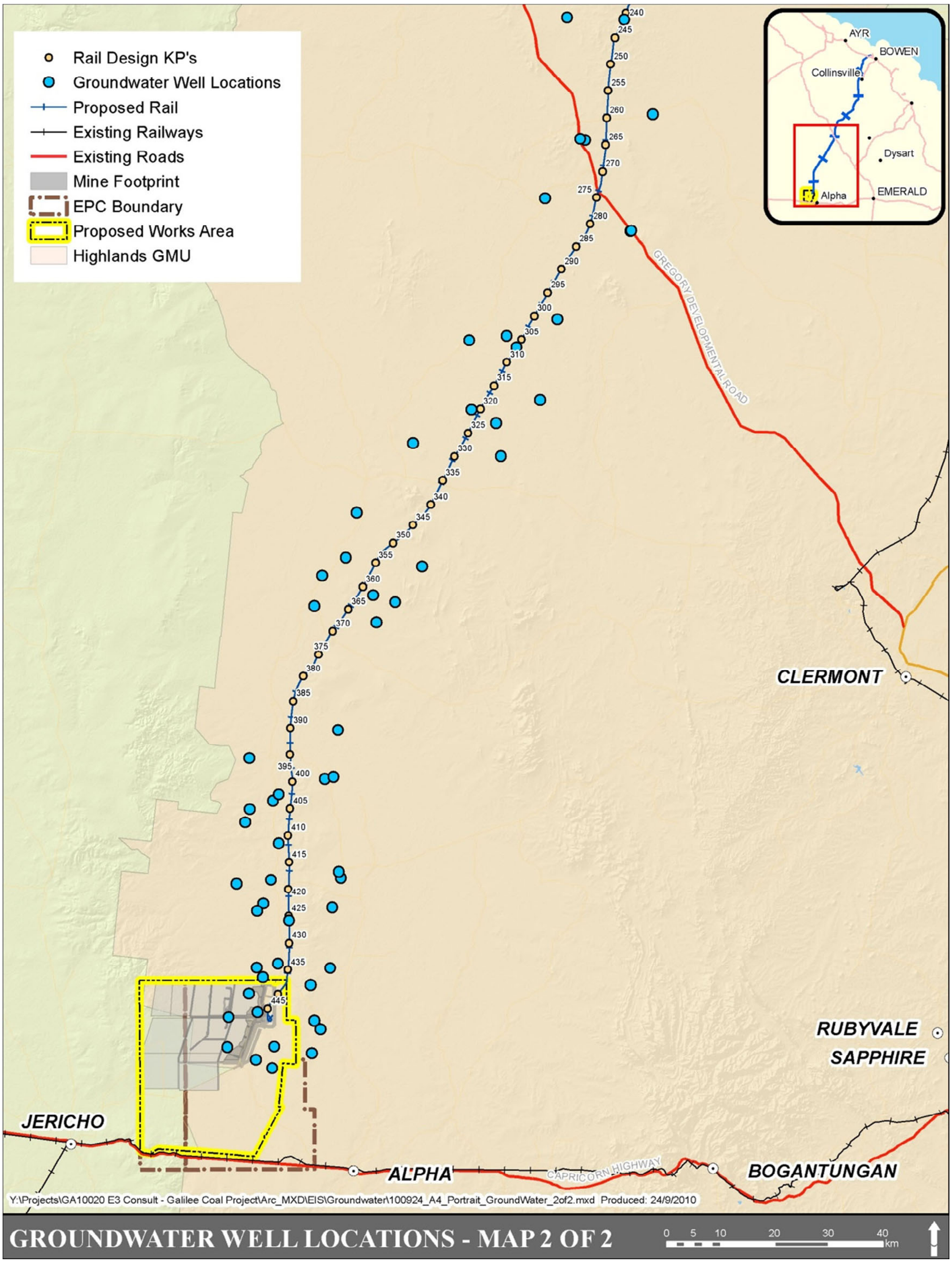

Figure 4-3: DERM Registered Groundwater Bores from KP240 to KP445

Both the Bowen and Highlands GMUs do not specify water quality objectives that need to be met for environmental and other public benefit outcomes. The Bowen GMU is discussed in Section 5. Within the Highlands GMU, an entitlement is required for all abstraction purposes other than stock and domestic water use.

Water quality should therefore meet the *EPP (Water)* requirements. The requirements are based on DERMs QWQG, as these are given precedence over other recognised guidelines. The rail alignment falls within the Central Coast Queensland region of the guidelines. Existing water quality data should be compared with Central Queensland values for upland and lowland streams. The available groundwater quality data from DERM records was limited to pH and total dissolved solids (mg/L). Total dissolved solids is not a parameter within the QWQGs for Central Queensland, so accordingly a comparison with the ANZECC 2000 guidelines is required.

4.2 KP04-KP230 Undeclared Groundwater Area

4.2.1 Aquifers

A large undeclared groundwater area is intersected by the rail alignment between KP04 and KP230. A discussion of the geology of the area is provided in the Geology, Soils and Landform Technical Reports to the EIS. The aquifer systems in this area can be categorised into three main groups discussed below.

- Aquifer systems predominantly in unconfined and confined weathered and fractured granite/igneous systems occur across much of the undeclared groundwater area between KP04 and KP230.
- Shallow unconfined and confined tertiary aquifers in shale, sandstone and clay strata are also likely to exist in the southern portion of the undeclared groundwater area between KP200 and KP230.
- DERM records indicate that groundwater in the Suttor Formation appears as an unconfined aquifer in the coarse sandstones with water levels between 10m to 80m depth.

Shallow alluvial unconfined aquifers in alluvial leads may occur in river valleys; however specific data does not exist for these aquifers.

4.2.2 Yields and Water Quality

Yields of between 1 and 5.6 L/s and a range in salinity between 400 and 1,300 mg/L total dissolved solids occurs in the granite aquifers (SKM, October 2009). No yield or salinity data was available for the tertiary aquifers within the area. Limited static water level data exist for bores within the area. This indicates water levels from 5 m to 30 mbgl within the undeclared groundwater area.

Yields and water quality in the alluvial leads was not present in the available DERM records.

4.2.3 Conceptual Hydrogeological Model

The conceptual hydrogeological model for the granitic aquifers comprises rainfall recharge onto areas of outcrop in the south and west of the undeclared groundwater area between KP130 and KP170 likely to be associated with the Mount Coolon range. Groundwater recharge from these zones would be expected to flow down a topographic gradient in a westerly direction via natural groundwater flow paths to the alluvial leads and to deeper weathered or fractured granite aquifers.

The hydrogeological model for the shallow unconfined tertiary aquifers comprises rainfall recharge across the entire area of the aquifers and also via infiltration from alluvial leads in river valleys. Direction of flow of these aquifers is likely to follow surface gradients. The alluvial leads are recharged via infiltration of rainfall and stream water in times of flow/flood. Flow direction in these leads will be towards the structural base of the alluvial lead and then in the downstream direction in river valleys. Where the rivers are effluent to the leads, some flows away from rivers may occur, whilst in areas where the alluvials are influential to the river flows, the flows will be towards the river.

4.3 KP230-KP447 Highlands Groundwater Management Unit

4.3.1 Aquifers

The rail alignment crosses the Highlands GMU between KP230 and KP447. The aquifer systems in this area are comprised predominantly of tertiary shale, sandstone (including the Suttor Formation) and clay strata. The depth to the top of these aquifers ranges from 10 – 150 mbgl and static water levels range from 10 m to 80 mbgl. Semi-confined Permian aquifers are likely to exist at greater depth within the area.

4.3.2 Yields and Water Quality

Data from the tertiary aquifers indicate a range in yield of between 0.3 to 13 L/s and a range in salinity of 200 to >10,000 mg/L total dissolved solids. Some of these values exceed the ANZECC 2000 guidelines for live stock drinking water of 2,000 mg/L; however guidelines for total dissolved solids are not specified for ecosystem protection.

4.3.3 Conceptual Hydrogeological Model

The conceptual hydrogeological model for the area comprise rainfall recharge to tertiary aquifers in areas east of the boundary of the GAB and percolation from surface water bodies during periods of flow. The semi confined Permian aquifers are recharged via both surface rainfall in recharge zones and leakage from the shallow unconfined tertiary aquifers.

5 Coal Terminal

The coal terminal is located within the Bowen GMU. A discussion of the groundwater contained within that GMU is provided below.

5.1 Previous Investigations

Previous studies in the Bowen GMU include desktop study undertaken in 2009 (SKM, October 2009) for the project area and studies (GHD, 2010, *Proposed Abbot Point Multi Cargo Facility Draft Environmental Impact Statement*, North Queensland Bulk Ports Corporation) from the EIS's undertaken for the APSDA expansion programs. The following discussion is compiled from information from these sources. The bores in the vicinity of the APSDA are shown in Figure 5-1.

The coal terminal will be located in areas with generally flat or gently sloping topography adjacent to coastal wetlands. The land has in the past been generally used for grazing on native pastureland.

The Bowen GMU plan does not specify water quality objectives that need to be met for environmental and other public benefit outcomes. Water quality should therefore meet the *EPP (Water)* requirements. The requirements are based on DERMs QWQG, as these are given precedence over other recognised guidelines. The coal terminal falls within the Central Coast Queensland region of the guidelines. Existing water quality data should to be compared with Central Queensland values for upland and lowland streams. The available groundwater quality data from DERM records was limited to pH and total dissolved solids (mg/L). Total dissolved solids is not a parameter within the QWQGs for Central Queensland, so accordingly a comparison with the ANZECC 2000 guidelines is required.

The GMU indicates that this is an area where the Queensland Government regulates the construction of bores and taking of water. Within this area, a water licence is generally required prior to taking water and a development permit is required prior to the construction of a bore. The exact requirements can vary from area to area and are prescribed by the *Water Act 2000*.

Groundwater in the region has previously been used to supply water to the port facility. The source of the water was the Splitters Creek bore field which is located 14 kilometres west of the port (Figure 5-1). An annual volume of 250 L was licensed for the remaining bores within the field and this volume was not considered likely to increase (GHD, 2009).

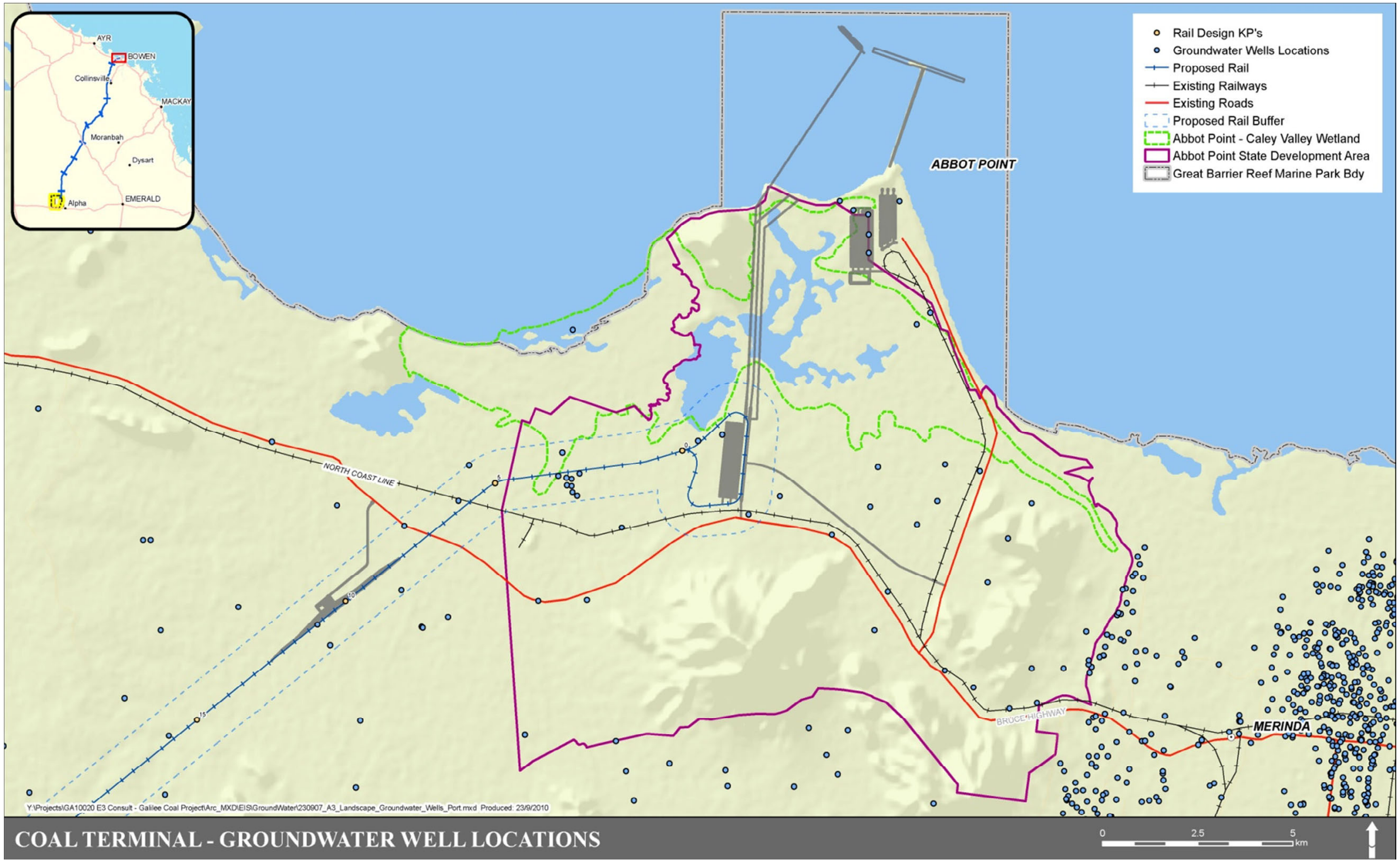

Figure 5-1: DERM Registered Groundwater Bores in the vicinity of APSDA

5.2 Aquifers

Searches of the DERM groundwater database indicate about 3,800 bores are recorded in the Bowen GMU. These mainly comprise bores in alluvial unconfined aquifers with groundwater at 2 m to 20 mbgl around the Don River (SKM, October 2009). There are six bores within 5 km of the coal terminal. The data from these bores indicates a two aquifer system comprising a shallow alluvial aquifer system and the presence of a deeper saline granite aquifer.

The aquifers within the immediate vicinity of the coal terminal are comprised of Quaternary deposits and mud flats interspersed with alluvial deposits (SKM, October 2009). Groundwater exists in a band of approximately 250 m width associated with the main dune ridge that intersects the site. A layer of silty sand at the base of the dunes is likely to form the primary water bearing strata within which the groundwater resources exist. This aquifer is likely to be bound above by sandy clay and below by saline clay sediments. It is also likely that within this aquifer system deeper saline groundwater exists below a lens of freshwater. The groundwater flow direction is likely to be both westerly and northerly from the granitoid intrusive and erosional outwash to the respective sinks of the Caley Valley Wetlands and Dingo Beach. bores installed in the fractured granitic intrusive are interpreted as flowing into surrounding granitic outwash and coastal sediments.

Water at the coal terminal is likely to be at a depth of <10 m hosted in both the granite aquifer and shallow alluvial aquifers.

5.3 Yield and Water Quality

Groundwater within the area is characterised by neutral to slightly acidic pH (pH 6.03 – 7.31) and is brackish to saline (GHD, 2009). The yields within the alluvial aquifers range from <1 to 20 L/s with salinities ranging from 500 to 1,000 mg/L total dissolved solids.

Yields of up to 40 L/s have been observed in the granitic aquifers. Groundwater within these aquifers ranges in salinity from 300 to 20,000 mg/L total dissolved solids.

5.4 Conceptual Hydrogeological Model

The conceptual hydrogeological model for the area as interpreted for this study comprises rainfall recharge onto coastal flats and from the granitic intrusive behind the coast to flow towards the coast through the granitic talus outwash and in coastal clay and mud sediments. Local recharge of dunal sand areas may generate discrete aquifers of freshwater overlying more saline waters with flow directions in the direction of local topography. Tidal inundation will contribute to the saline groundwater reported in previous studies. No data on a freshwater/saline water interface is noted in this study, however, it is considered that there will be a freshwater/saline water interface at the coast.

6 Potential Impacts

The following sections discuss the potential impacts to groundwater within the project area.

6.1 Mine site

6.1.1 Great Artesian Basin

The coal reserves of the mine area are outside the GAB (Figure 3-5). The presence of shale aquitards in units between the coal seams and the GAB aquifers and the predominantly easterly groundwater flow interpreted as being due to drape folds further to the west suggests a low potential for negative impacts on the GAB groundwater resources resulting from open cut, longwall and underground coal mining.

6.1.2 Mine Inflows

The numerical modelling indicates inflows to the mine will be around 980 to 12,300 ML/year during mining. This is anticipated to reduce over the mine life as drawdown dewaters the surrounding aquifers.

6.1.3 Drawdown and Water Levels

The extraction of groundwater by mine dewatering will lower the elevation of the piezometric surface of the aquifers and create a cone of depression around the mine. The cone of depression is anticipated to extend between 11 km to 30 km from the mine.

The model simulations indicate that drawdown may impact bores in the shallow Tertiary and Permian aquifers within 11 km to 30 km of the mine. There is potential for drawdown to impact surrounding landowners bores of the Tertiary and Permian aquifers where a connection is present between the aquifers. Where no connection is present, then the depressurisation of underlying aquifers is unlikely to impact on farm bores. The impact is anticipated to be greater to the east as the mine will intercept some of the recharge to the east and dewater aquifers sloping from the east.

No groundwater dependent ecosystems were identified in proximity to the mine. Vegetation that extracts groundwater is likely to be in alluvial areas where shallow groundwater is within the root zone (2 m to 5 m depth). Where these alluvials are not connected to the underlying aquifers and resultant depressurisation of the aquifers does not affect the alluvials, no significant impact is anticipated. The water is considered to be generally suitable for irrigation or livestock watering although some saline aquifers will not be suitable for these uses. Dewatering of the aquifers will result in the loss of this groundwater and these environmental values within the impacted area around the mine.

6.1.4 Impact of Subsidence

The likely maximum level of subsidence as stated in the Subsidence report section of the EIS is 3.27 m. Cracking of the overlying geology as a result of mining related subsidence is also likely to occur. This cracking could allow rapid infiltration of rainfall to the mined areas, and potentially lead to increased rates of flow into the mined voids resulting via leakage between aquifer layers.

6.1.5 Groundwater Contamination

The potential for groundwater contamination may occur as a result of impacts from coal rejects disposal; mining; goafing of the coal seam aquifers; leaking disposal facilities; spills and leaks from chemical, fuel and oil storage and handling at workshops and mine operations infrastructure. As no prior mining has occurred in the area of the mine no prior impacts from coal reject disposal could have occurred.

The potential for impacts from surface storages of rejects, waste, fuel, oil and chemical storages are considered to be low because:

- Groundwater levels around the mine are generally not shallow and will become deeper due to drawdown around the mine;
- Appropriately constructed storage and handling will result in low potential for leakages or spills; and
- The assessment of potential for acid generation and heavy metals impacts from the mine overburden and coal reject indicate a low potential for these impacts. This assessment is presented in Acid Sulfate Soils technical report to the EIS.

The groundwater is generally brackish to saline and useable for livestock drinking water and therefore, the potential for further deleterious impacts to potential uses is lower.

6.2 Rail Alignment

As the rail alignment will carry coal the main potential impacts with respect to groundwater are related to shallow near surface groundwater that could be impacted by railway construction activities.

Construction activities include:

- Establishment of works depots and laydown areas;
- Establishment of borrow pits, quarries and sand extraction pits;
- Establishment of water source points;
- Bulk earthworks; and
- Culvert construction, blasting, rail and bridge construction.

The potential impacts include:

- Contamination from fuel/chemical/raw material storage;

- Impacts to groundwater levels from quarries/sand extraction;
- Impacts to neighbouring groundwater users from groundwater sourced water supplies;
- Impacts to aquifers from blasting; and
- Impacts to shallow aquifers from bridge construction.

Storage and handling of fuels/chemicals/raw materials has the potential to impact groundwater where leaks or spills from storage and handling areas occur.

Where the groundwater that is impacted by contaminants is upgradient of an environmental receptor (ie: a water body), a groundwater bore, or within the radius of influence of an active groundwater bore there is potential for impacts to a receptor.

Impacts to local groundwater regimes may also occur where groundwater is within the construction zone in the upper 1 m of the surface or where bridge construction entails deeper construction in areas of shallow groundwater that requires dewatering of construction areas.

Where blasting for construction fractures aquifers causing increased permeability and changes to local groundwater regimes there is potential for alteration of the existing groundwater regime and/or disturbance of adjacent groundwater users infrastructure.

Where construction groundwater supplies are required there is potential for interference with adjacent groundwater users.

Where drilled piling is required, there is potential for drill muds to be introduced into the underlying aquifer.

6.3 Coal Terminal

At the Coal Terminal the following infrastructure is proposed:

- Equipment and fuel storage;
- Water and wastewater handling and treatment.

Potential impacts from the activities include:

- Impacts to groundwater from fuels and chemicals may occur from leaks and spills from fuel storage, refuelling activities and/or wastewater treatment and handling;
- Potential for leaching of contaminants from coal stockpiles;
- Sealing and settlement of areas due to the mass of infrastructure or coal stockpiles at the coal terminal may result in increased runoff and compaction of the shallow aquifer that may locally affect flow paths and groundwater levels around infrastructure;
- Where saline or acid waters are present, there is potential for corrosive effects on infrastructure; and

- Where groundwater levels are disturbed or large areas are sealed and either reduced rainfall infiltration and/or compaction of the underlying aquifer occurs there is potential for changes in shallow groundwater levels. In areas of acid sulphate soils this could result in exposure of ASS layers and generation of ASS Leachate.

The potential impacts resulting from acid sulphate soils due to fluctuating groundwater are discussed in the Acid Sulphate Soils Technical Report to the EIS.

7 Mitigation Measures

The potential impacts from the project highlighted above include several potential impacts common to the different components of the project. The management measures for the identified potential impacts are described below in Table 7-1.

Table 7-1: Mitigation Measures

Management requirement	Management measure	Component	Timing	Responsibility
Groundwater inflow	Groundwater inflow can be controlled by strategically placed sumps for pumping to surface storage, treatment and/or reuse. Consideration should be given to reuse of water in operations or for dust suppression.	Mine	Operation	Site management
Regional drawdown	The impact of drawdown on alluvial water levels and farm bores can be monitored by implementation of the monitoring plan proposed in Section 7.1.	Mine	Construction and operation	Site management
Alluvial aquifer drawdown	Where drawdown dewaters alluvial systems, artificial recharge maybe necessary to increasing recharge of wet season flows. This can occur through artificial recharge beds and/or injection of captured water into the underlying alluvials where the chemistry of recharge water is compatible with the aquifers and groundwater.	Mine	Construction and operation	Site management
Impacts on farm bores	Where drawdown impacts farm bores, replacement bores and pumps should be drilled to either intersect deeper areas of the aquifers currently being used or to access deeper aquifers below the level of mining. Waratah Coal may enter into agreements with landowners regarding these options prior to mining.	Mine	Construction and operation	Site management
Groundwater abstraction	Where groundwater is required for abstraction, a permit to take water and a development application to install a bore will be required. In addition, Waratah will enter into agreements with landholders to mitigate or make good, any impacts where groundwater abstraction affects groundwater in existing landowner bores.	Mine	Pre construction	Management
Spill control	Containment of all fuels, oils, chemicals and other materials should be undertaken to avoid the potential for impact to shallow groundwater.	Mine, rail and coal terminal	Construction and operation	Construction contractor and site operator/manager
Groundwater Contamination	Where groundwater contamination is identified the impact will be assessed and remediated in accordance with the requirements of the *Environmental Protection Act (1994)*.	Mine, rail and coal terminal	Construction and operation	Polluter
Erosion and sediment control	Surface flows should be channelled with appropriate erosion and sediment controls to minimise potential for erosional scouring of soils or increased sediment loading of recharge water leading to changes in recharge of shallow	Mine, rail and coal terminal	Construction and operation	Construction contractor and site operator/manager

Management requirement	Management measure	Component	Timing	Responsibility
	aquifers. Sediment control structures will be regularly checked, repaired, replaced and/or cleaned out. The control shall be maintained so that they will always have 70% of their capacity available. An Erosion and Sediment Control Plan should be prepared to alleviate this impact.			
Groundwater characterisation	Characterisation of groundwater levels and corrosivity should assess the potential for changes in groundwater levels and impacts to infrastructure.	Mine, rail and coal terminal	Pre construction	Site management
Shallow groundwater vulnerability assessment	In the identified areas of shallow unconfined groundwater, it is recommended that a site specific assessment of the depth and vulnerability of groundwater is undertaken prior to site works.	Mine, rail and coal terminal	Pre construction	Site management
Blasting	Where blasting is to be undertaken, conduct a census of bores within a 500m area and monitor bores to assess potential impacts and requirement for mitigation measures.	Mine, rail and coal terminal	Pre construction and operation	Site management

7.1 Monitoring Program

The plan for future monitoring of the impact of mining on the groundwater resources in the area likely to be affected by mining activities is based on installed monitoring bores and installation of future bores around tailings dam, mine waste spoil piles and near surrounding land users.

These bores will allow Waratah Coal to monitor the effects of mining on the groundwater resource and surrounding land users. This will allow for an assessment of the impacts of mining, provide a warning of potential impacts to land users, allow refinement and update the groundwater conceptual model and numerical model to refine the potential impacts so that remedial measures may be put in place.

A six monthly review of the monitoring program should be undertaken to assess actual and predicted impacts by revision of the groundwater modelling and refinement of the monitoring and remedial measures as required. The initial monitoring program is included in Table 7-2.

Table 7-2: Monitoring Program

Location	Parameters	Frequency	Comment
Radially around mine adjacent to final mine high wall design. Nested bores in Tertiary, Permian Overburden, Seam B, Seam C to E and underlying Permian Rock.	Water Level	Daily – down hole telemetry from electronic loggers	Monitor for drawdown.
	pH, EC, TDS, salinity, cations, anions, alkalinity and heavy metals.	3 monthly - down hole telemetry from electronic loggers	Assess changes in water quality.
Radially around mine 5 km from final high wall design. Monitor bores in aquifers intersected by farm bores.	Water Level	Weekly – down hole telemetry from electronic loggers	Monitor for drawdown.
	pH, EC, TDS, cations and anions, and alkalinity	3 monthly - down hole telemetry from electronic loggers	Baseline sample and sampling from first indication of drawdown to assess changes in water quality.
Radially around mine 10 km from final high wall design. Monitor bores in aquifers intersected by farm bores.	Water Level	Weekly – down hole telemetry from electronic loggers	Monitor for drawdown.
	pH, EC, TDS, cations and anions, and alkalinity	3 monthly - down hole telemetry from electronic loggers	Baseline sample and sampling from first indication of drawdown to assess changes in water quality.
Radially around tailings dam and waste spoil piles.	Water Level	Weekly – down hole telemetry from electronic loggers	Monitor for drawdown.
Nested bores in Tertiary and Permian Overburden.	pH, EC, TDS, salinity, cations, anions, heavy metals, and alkalinity.	Weekly telemetry from electronic loggers for ph, EC Monthly for cations, anions and heavy metals.	To assess changes in water quality.

8 Conclusion

The assessment found the mine site was the area with greatest potential for impacts to existing groundwater. The mine lies east of the boundary of the GAB and includes groundwater in the Galilee Basin. The presence of aquitards at the base of the GAB suggests low potential for impacts from the mine to the GAB. Preliminary modelling suggests the mine will have significant impacts to groundwater users within 12 km to 30 km of the mine from drawdown around the mine voids.

The potential for groundwater contamination may occur as a result of impacts from coal rejects disposal, mining, goafing of the coal seam aquifers, leaking tailings dams, spills and leaks from chemical, fuel and oil storage and handling at workshops and mine operations infrastructure.

A monitoring program with trigger levels has been suggested to assess the actual impacts from the mine during its development and Waratah Coal will enter into agreements with local land users for monitoring and “make good” arrangements where unacceptable impacts are reported. Further longer term hydraulic testing is required to fully predict the extent of potential impacts.

As the rail alignment will carry coal the main potential impacts with respect to groundwater are related to shallow near surface groundwater that could be impacted by railway construction activities. The potential impacts include contamination from fuel/chemical/raw material storage; impacts to groundwater levels from quarries/sand extraction; impacts to neighbouring groundwater users from groundwater sourced water supplies; impacts to aquifers from blasting; and Impacts to shallow aquifers from bridge construction.

At the Coal Terminal the proposed infrastructure has the potential to generate impacts to groundwater from fuels and chemicals, from leaks and spills from fuel storage, refuelling activities and/or wastewater treatment and handling, and the potential for leaching of contaminants from coal stockpiles. Sealing and settlement of areas due to the mass of infrastructure or coal stockpiles at the coal terminal may result in increased runoff and compaction of the shallow aquifer that may locally affect flow paths and groundwater levels around infrastructure. There is potential where saline or acid waters are present for corrosive effects on infrastructure. Where groundwater levels are disturbed or large areas are sealed and either reduced rainfall infiltration and/or compaction of the underlying aquifer occurs there is potential for change in shallow groundwater levels. In areas of acid sulphate soils this could result in exposure of ASS layers and generation of ASS leachate.

Mitigation measures to manage these have been provided and include site specific studies of vulnerable groundwater areas, management and containment measures for potential contaminants and a commitment to enter into agreements with landholders regarding groundwater usage (if required) and “make good” requirements if groundwater is impacted by project activities.

9 Recommendations

Based on the technical studies carried out, E3 consult recommend the following activities be implemented:

- The implementation of long term pumping tests and other hydraulic tests of bores in the mine area to assess impacts on local users;
- Updating the conceptual model with data obtained during the monitoring to assess any potential impacts on the mine on groundwater ecosystems;
- Further investigations regarding recharge areas and recharge rates to further aid in model enhancement;
- Refinement of the groundwater model based upon above data to assess transient scenarios;
- Undertaking geotechnical works to assess subsidence potential for cracking to affect the groundwater regime;
- Collection of mine inflows for reuse;
- Implementation of the groundwater monitoring program;
- Implementation of management plans and containment structures for potential contaminants;
- Remediation of groundwater contamination caused by the project;
- Geotechnical assessment of Coal Terminal and Rail alignment to assess areas where construction requirements (ie excavation or blasting) have potential for impacts to groundwater;
- Site specific investigation of the areas identified from geotechnical review; and
- Enter into agreements with surrounding landowners regarding monitoring of impacts and make good provisions where impacts occur.

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Waratah Coal

Abbreviations and Glossary of Terms

Abbreviations

Abbreviation	Meaning
°C	Degrees Celsius
µg	Microgram
µS/cm	Microsiemens per Centimetre
AHD	Australian Height Datum
ARMCANZ	Agriculture and Resource Management Council of Australia and New Zealand
ASS	Acid Sulfate Soil
BGL	Below Ground Level
cm	Centimetre
DERM	Department of Environment and Resource Management (Qld)
EC	Electrical Conductivity
EIS	Environmental Impact Statement
EPM	Exploration Permit Minerals
EPP	Environmental Protection Policy
EPP (Water)	Environmental Protection (Water) Policy 1997
g	Grams
GAB	Great Artesian Basin
GABCC	Great Artesian Basin Coordinating Committee
GDE	Groundwater Dependent Ecosystem
GMU	Groundwater Management Unit
Goaf	The area of underground working from which coal has been removed.
kg	Kilograms
km	Kilometre
km^2	Square Kilometre
KP	Kilometre Point
m	Metre
m/day	Metres per Day
m/s	Metres per Second
m^2	Square Metres
m^3	Cubic Metres
mAHD	Metres Above Australian Height Datum

Abbreviation	Meaning
Mbgl	Metres Below Ground Level
mg	Milligram
mg/L	Milligram per Litre
ML	Megalitres
ML	Mining Lease
mm	Millimetre
NATA	National Association of Testing Authorities
NTU	Nephelometric Turbidity Units
Qld	Queensland
QWQG	Queensland Water Quality Guidelines
SP/PR	Spontaneous Potential/Point Resistivity
TDS	Total Dissolved Solids
TKN	Total Kjeldahl Nitrogen
TN	Total Nitrogen
TOR	Terms of Reference
TP	Total Phosphorus
TSS	Total Suspended Solids
Water Act	Water Act 2000

Glossary of Terms

Abbreviation	Meaning
Abstraction	The removal of water from a resource e.g. the pumping of groundwater from an aquifer. Interchangeable with extraction.
Acid sulfate soils	Naturally occurring soils, sediments or organic substrates (e.g. peat) that are formed under waterlogged conditions. These soils contain iron sulfide minerals (predominantly as the mineral pyrite) or their oxidation products. In an undisturbed state below the water table, acid sulphate soils are benign. However if the soils are drained, excavated or exposed to air by a lowering of the water table, the sulfides will react with oxygen to form sulfuric acid.
Alluvial	Pertaining to, contained in, or composed of, alluvium; relating to the deposits made by flowing water; washed away from one place and deposited in another; as alluvial soil, mud, accumulations, or deposits.
Analyte	Substance or chemical constituent that is determined in an analytical procedure.
Annulus	Space between bore casing and the surrounding geology.
Aquifer	A water-saturated geologic unit that is capable of transmitting significant or usable quantities of groundwater under ordinary hydraulic gradients.
Aquitard	A water-saturated sediment or rock whose permeability is so low it cannot transmit any useful amount of water. An aquitard allows some measure of leakage between the aquifer interval it

Abbreviation	Meaning
	separates.
Artesian	A condition which applies to aquifers which are confined by layers of low permeability, and where the hydraulic head in the aquifer is higher than the overlying ground surface. Wells penetrating such aquifers may result in groundwater flowing at the surface without pumping.
Basin	A topographic depression containing, or capable of containing, sediment.
Bore / borehole	A hole drilled into the ground for exploratory purposes. See “wellbore”.
Boundary condition	Specific condition at the edge or surface of a system.
Channel	An eroded depression in the soil or bedrock surface within which alluvial deposits accumulate (i.e. gravel, sands, silt, clay).
Coal seam	A layer, vein, or deposit of coal.
Conductivity	A measure of waters' ability to conduct electricity.
Confined aquifer	Groundwater bound between layers of impermeable substances like clay or dense rock. When tapped by a well, water in confined aquifers is forced up, sometimes above the soil surface. This is how a flowing artesian well is formed.
Confining layer	Geologic material with little permeability or hydraulic conductivity. Water does not pass through this layer or the rate of movement is extremely slow.
Contaminant	A substance that is present in an environmental medium in excess of natural baseline concentration.
Corridor	A continuous link of suitable habitat between vegetation patches allowing movement by fauna.
Dam	A land-based structure or void that will contain, divert or control flowable substances. For the purposes of this study, a pond is also referred to as a dam.
Darcy’s Law	A groundwater movement equation formulated by Henry Darcy during the mid-1800s based on experiments on the flow of water through beds of sand. Darcy's Law forms the scientific basis of fluid permeability used in earth science.
Datalogger	An electronic device that records data over time or in relation to location either with a built in instrument or sensor or via external instruments and sensors.
Depletion	The loss of water from surface water reservoirs or groundwater aquifers at a rate greater than that of recharge.
Depressurisation	The lowering of the groundwater piezometric surface over the desired area.
Discharge	An outflow of water from a stream, pipe, groundwater aquifer, or watershed; the opposite of recharge.
Dissolved solids	Minerals and organic matter dissolved in water.
Dominant	One or more species, by means of their number, coverage, or size that exerts considerable influence upon or control of the conditions of existence of associated species.
Drawdown	A lowering of the groundwater level caused by pumping.
Electrical conductivity	Measure of a material to conduct electricity. Electrical conductivity of water is a measure of the impurity (dissolved ions) in water - usually measured in siemens per unit length (e.g. millisiemens per centimetre).
Ecology	The scientific study of the distribution and abundance of life and the interactions between organisms and their environment. The environment of an organism includes physical properties, which can be described as the sum of local abiotic factors such as insolation (sunlight), climate, and

Abbreviation	Meaning
	geology and biotic factors, which are other organisms that share its habitat.
Ecosystem	A natural unit consisting of all plants, animals and micro-organisms (biotic factors) in an area functioning together with all of the non-living physical (abiotic) factors of the environment.
Environmental impact statement (EIS)	The information document prepared by the proponent when undertaking an environmental impact assessment. It is prepared in accordance with terms of reference prepared or approved by government. EIS is the term used by the Environment Protection and Biodiversity Conservation Act 1999 and the Environmental Protection Act 1994, and it is defined in Part 4 of the State Development and Public Works Organisation Act 1971.
Erosion	The process by which material, such as rock or soil, is worn away or removed by wind or water.
Evapotranspiration	The process by which water is discharged to the atmosphere as a result of evaporation from the soil and surface-water bodies and transpiration by plants. Transpiration is the process by which water passes through living organisms, primarily plants, into the atmosphere.
Fauna	Animal life.
Flow rate	The time required for a volume of groundwater to move between points. Typically groundwater moves very slowly—sometimes as little as millimetres per year.
Fluvial	Material deposited by moving water (i.e. rivers and streams).
Formation	A geologic unit of distinct rock types that is large enough in scale to be mappable over a region.
Fresh water	Water that is not salty, especially when considered as a natural resource.
Gamma log	Gamma logs record the level of natural occurring gamma ray emissions from rocks around boreholes. The gamma ray signal is comprised of gamma ray emissions from at different energy levels from the radioactive isotopes of the elements potassium (40K), Thorium (232Th) and Uranium (238U) and the daughter products in the decay of each series. In sedimentary rock sequences, relatively high natural gamma counts are recorded in shales and other clay rich sediment (due to the affinity of clay minerals for potassium) and relatively low counts are recorded in clean quartz sandstones and limestones.
Granite	A granular igneous rock composed chiefly of felspar (orthoclase) and quartz, usually with one or more other minerals, as mica, hornblende, etc.
Groundwater	All the water contained in the pores/voids within unconsolidated sediments or consolidated rocks (i.e. bedrock).
Group	A grouping of geological or hydrogeological formations.
Hydraulic conductivity	The ease with which water moves through soil or rock. A coefficient (“K”) depends on the physical properties of formation and fluid. “K” is the rate of flow per unit crosssectional area under the influence of a unit gradient, and has the dimension of length3/length2 x time or length/time (e.g. m/s).
Hydraulic gradient	The change in hydraulic head or water level over a distance. Usually expressed in meters/meter. For example, a hydraulic gradient of 0.01 indicates a one-metre drop in water level over a distance of 100m. The hydraulic gradient is the driving force that causes groundwater to flow.
Hydrogeology	The science that relates geology, fluid movement (i.e. water) and geochemistry to understand water residing under the earth’s surface. Groundwater as used here includes all water in the zone of saturation beneath the earth’s surface, except water chemically combined in minerals.
Indicators	Anything that is used to measure the condition of something of interest. Indicators are often used as variables in the modelling of changes in complex environmental systems.

Abbreviation	Meaning
Infiltration	Flow of water from the land surface into the subsurface. Infiltration is the main factor in recharge of groundwater reserves.
Irrigation	The controlled application of water to cropland, hay fields, and/or pastures to supplement that supplied by nature.
Landform	A natural feature of a land surface such as a mountain, plain or valley.
Leachate	Liquids that have percolated through a soil and that carry substances in solution or suspension.
Likelihood	Used as a general description of probability or frequency. Can be expressed qualitatively or quantitatively (AS/NZS ISO 3100:2009 Risk management – Principles and guidelines).
Monitoring well	A constructed controlled point of access to an aquifer which allows groundwater observations. Small diameter observation wells are often called piezometers.
Nutrients	Any substance that promotes growth with living organisms. The term is generally applied to nitrogen and phosphorus in wastewater, but is also applied to other essential and trace elements.
Overburden	Any loose material which overlies bedrock (often used as a synonym for Quaternary sediments and/or surficial deposits) or any barren material, consolidated or loose, that overlies an ore body.
Percolation	The movement of water through the openings in rock or soil.
Permeability	A measure of the ability of a medium to transmit a fluid (any fluid). Similar to hydraulic conductivity that describes the ability of a porous medium to transmit water specifically.
Permian	Period of geological time, 290 – 248 million years before present.
pH	The logarithm of the reciprocal of hydrogen-ion concentration in gram atoms per litre; provides a measure on a scale from 0 to 14 of the acidity or alkalinity of a solution (where 7 is neutral and greater than 7 is more basic and less than 7 is more acidic).
Pollution	An alteration in the character or quality of the environment, or any of its components, that renders it less suited for certain uses. The alteration of the physical, chemical, or biological properties of water by the introduction of any substance that renders the water harmful to use.
Porosity	The ratio of the volume of void or air spaces in a rock or sediment to the total volume of the rock or sediment. The capacity of rock or soil to hold water varies with the material. For example, saturated small grain sand contains less water than coarse gravel.
Quaternary	Period of geological time covering the Holocene plus the Pleistocene. Up to 2.6 million years ago.
Radius of influence	Radial distance to points where hydraulic head is noticeably affected by a pumping well.
Recharge	The infiltration of water into the soil zone, unsaturated zone and ultimately the saturated zone. This term is commonly combined with other terms to indicate some specific mode of recharge such as recharge well, recharge area, or artificial recharge.
Recovery	The return of environmental conditions to the state before the project.
Remediation	Containment, treatment or removal of contaminated groundwater. May also include containment, treatment or removal of contaminated soil above the water table.
Runoff	The portion of precipitation (rain and snow) that ultimately reaches streams.
Salinity	An accumulation of soluble salts in the soil root zone, at levels where plant growth or land use is adversely affected. Also used to indicate the amounts of various types of salt present in soil or water (see total dissolved solids).
Sandstone	A sedimentary rock composed of individual grains of sand cemented together.

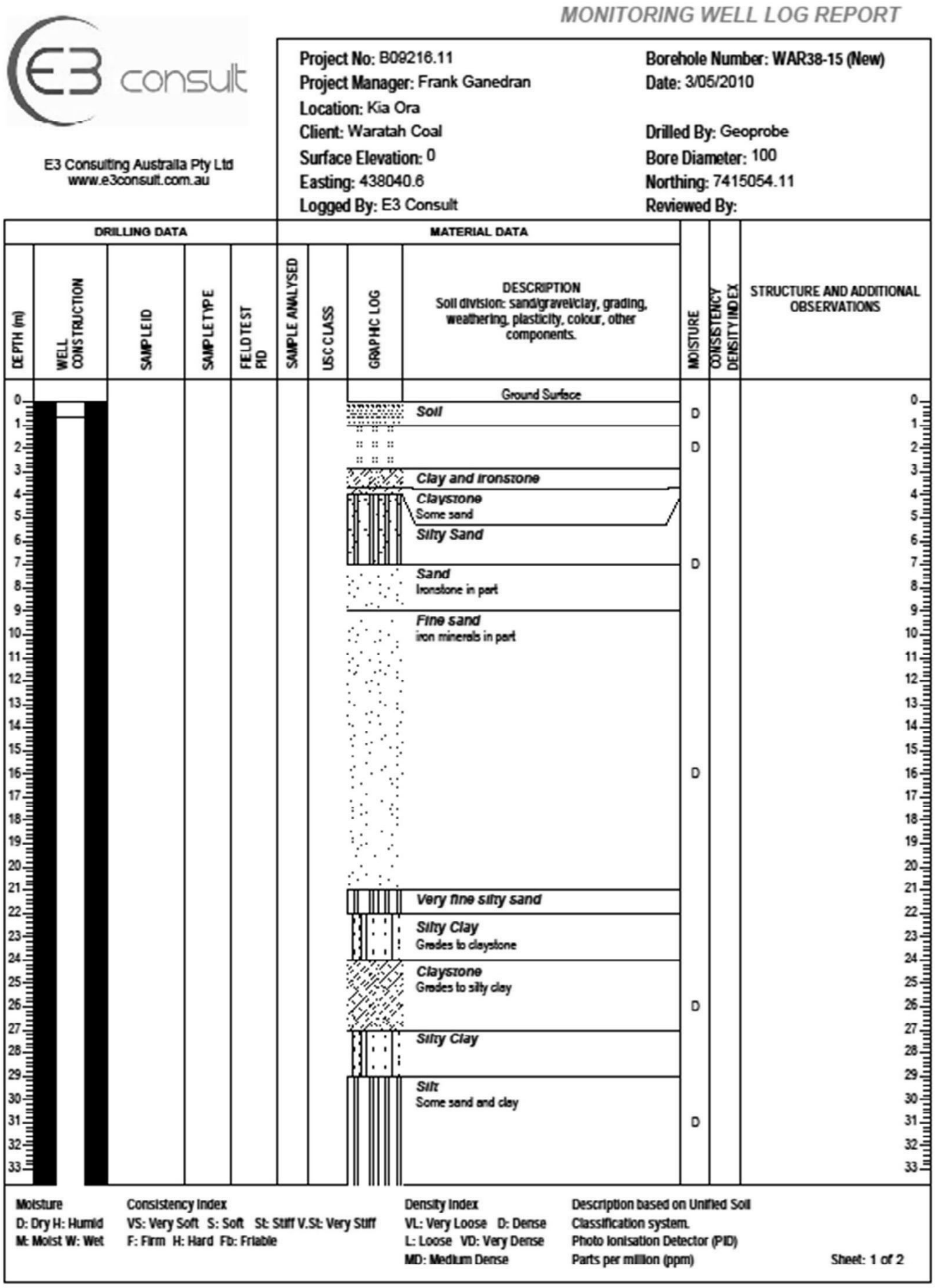
Abbreviation	Meaning
Seismic	Pertaining to shock waves, natural or artificial, within the Earth.
Shale	A sedimentary rock formed by the deposition of successive layers of clay.
Silt	Mud or clay or small rocks deposited by a river or lake. Fine particles in the size range 0.02 - 0.002 mm.
Siltstone	Fine-grained sandstone of consolidated silt.
Specific storage	The volume of water released from a unit volume of porous aquifer when there is a unit decline of hydraulic head. Compare with storativity, which is the specific storage multiplied by the aquifer thickness.
Static water level	1. Elevation or level of the water table in a well when the pump is not operating. 2. The level or elevation to which water would rise in a tube connected to an artesian aquifer or basin in a conduit under pressure.
Status	The listing of a species or community under various legislation or in government documents, for example, endangered, vulnerable, least concern Stepping stones Disconnected patches of habitat that more mobile species, or species with some tolerance of modified habitat, move through from one vegetation patch to another.
Storativity	The volume of water an aquifer releases from or takes into storage per unit surface area of the aquifer, per unit change in head. It is equal to the product of specific storage and aquifer thickness. In an unconfined aquifer, the storativity is equal to the specific yield.
Stratigraphy	The study of the sequence of layered geologic deposits based on their spatial positions, depositional sequence in time, and correlations across different localities.
Stygofauna	Any fauna that live within groundwater systems, such as caves and aquifers, or more specifically small, aquatic groundwater invertebrates, though terrestrial air-breathing subterranean animals are also sometimes included.
Subsidence	The gradual settling or sudden sinking of the land surface owing to natural or anthropogenic influences of materials in the subsurface.
Surface water	Water above the surface of the land, including lakes, rivers, streams, ponds, floodwater, and runoff.
Terms of Reference	As defined by Part 4 of the *State Development and Public Works Organisation Act 1971*.
Tertiary	A geological time unit from about 65 to 2 million years ago.
Topography	A description of the surface features of a place or region.
Total dissolved solids	Concentration of all substances dissolved in water (solids remaining after evaporation (TDS) of a water sample).
Transmissivity	A measure of the capability of the entire thickness of an aquifer to transmit water. Also known as coefficient of transmissivity.
Triassic	Period of geological time, approximately 180 – 250 million years before present.
Turbidity	The cloudiness or haziness of a fluid caused by individual particles (suspended solids) that are generally invisible to the naked eye, similar to smoke in air. The measurement of turbidity is a key test of water quality.
Unconfined Aquifer	A permeable bed only partly filled with water and overlying a layer of lower hydraulic conductivity. Its upper boundary is formed by a free water table where pore pressure is equal to atmospheric pressure. Water in a well penetrating an unconfined aquifer does not, in general, rise above the water surface.

Abbreviation	Meaning
Well	An excavation or structure created in the ground by digging, driving, boring or drilling to access water in the subsurface.
Yield	The quantity of water removed, or able to be removed from a well.

Waratah Coal

Appendix A – Well Construction and Borelog Details

Waratah Coal



MONITORING WELL LOG REPORT

E3 consult

E3 Consulting Australia Pty Ltd
www.e3consult.com.au

Project No: B09216.11	Borehole Number: WAR38-15 (New)
Project Manager: Frank Ganedran	Date: 3/05/2010
Location: Kia Ora	
Client: Waratah Coal	Drilled By: Geoprobe
Surface Elevation: 0	Bore Diameter: 100
Easting: 438040.6	Northing: 7415054.11
Logged By: E3 Consult	Reviewed By:

DRILLING DATA: DEPTH (m), WELL CONSTRUCTION, SAMPLE ID, SAMPLE TYPE, FIELD TEST PID

MATERIAL DATA: SAMPLE ANALYSED, USC CLASS, GRAPHIC LOG, DESCRIPTION (Soil division: sand/gravel/clay, grading, weathering, plasticity, colour, other components.), MOISTURE, CONSISTENCY DENSITY INDEX, STRUCTURE AND ADDITIONAL OBSERVATIONS

Description	Moisture
Ground Surface	
Soil	D
	D
Clay and ironstone	
Claystone Some sand	
Silty Sand	
Sand Ironstone in part	D
Fine sand iron minerals in part	D
Very fine silty sand	
Silty Clay Grades to claystone	
Claystone Grades to silty clay	D
Silty Clay	
Silt Some sand and clay	D

Moisture: D: Dry H: Humid M: Moist W: Wet

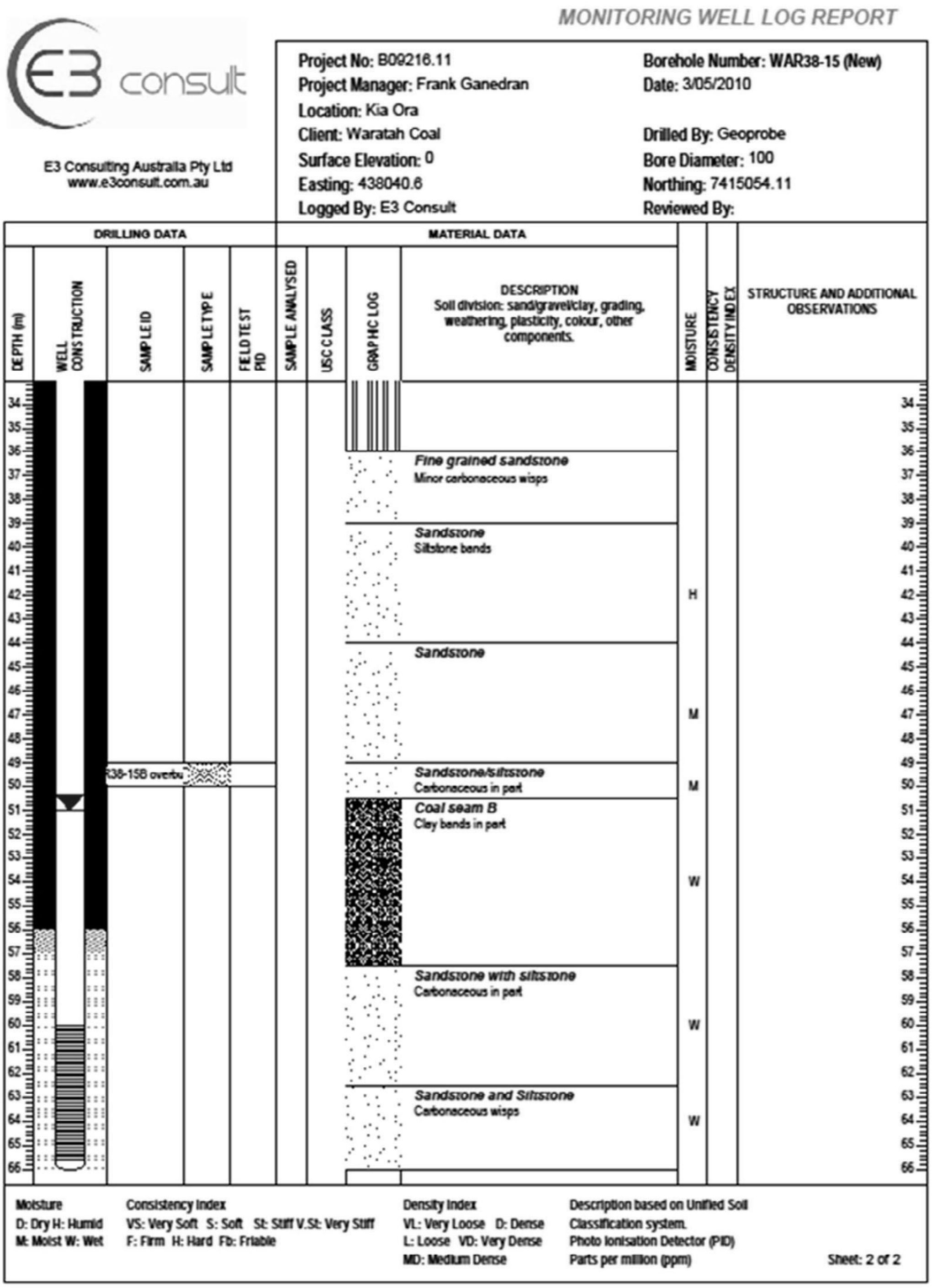
Consistency Index: VS: Very Soft S: Soft St: Stiff V.St: Very Stiff F: Firm H: Hard Fb: Friable

Density Index: VL: Very Loose D: Dense L: Loose VD: Very Dense MD: Medium Dense

Description based on Unified Soil Classification system. Photo Ionisation Detector (PID) Parts per million (ppm)

Sheet: 1 of 2

Waratah Coal



Waratah Coal

MONITORING WELL LOG REPORT

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QUEENSLAND 4102
Ph: +61 7 3303 8775 Fax: +61 7 3129 1895

Project No: B09216.11
Project Manager: Frank Ganedran
Location: Kia Ora
Client: Waratah Coal
Surface Elevation: 0
Easting: 442104.78

Borehole Number: WAR42-13 (New)
Date: 4/05/2010
Drilled By: Geoprobe
Bore Diameter: 100
Northing: 7413143.40

DEPTH (m)	WELL CONSTRUCTION	SAMPLE ID	SAMPLE TYPE	FIELD TEST PID	SAMPLE ANALYSED	USC CLASS	GRAPHIC LOG	DESCRIPTION Soil division: sand/gravel/clay, grading, weathering, plasticity, colour, other components.	MOISTURE	CONSISTENCY DENSITY INDEX	STRUCTURE AND ADDITIONAL OBSERVATIONS
0–1								***Soil***	D		
1–3								***Sandstone*** Iron bands			
3–15								***Sandstone*** Minor iron minerals	H		
15–17								***Sand*** Dark brown and becoming moist at 15m	M		
17–32								***Sand with some clay***	M		
32–43								***Sand with ironstone***	M		

Moisture
D: Dry H: Humid
M: Moist W: Wet

Consistency Index
VS: Very Soft S: Soft St: Stiff V.St: Very Stiff
F: Firm H: Hard Fb: Friable

Density Index
VL: Very Loose D: Dense
L: Loose VD: Very Dense
MD: Medium Dense

Description based on Unified Soil Classification system.
Photo Ionisation Detector (PID)
Parts per million (ppm)

Sheet 1 of 2

Waratah Coal

MONITORING WELL LOG REPORT

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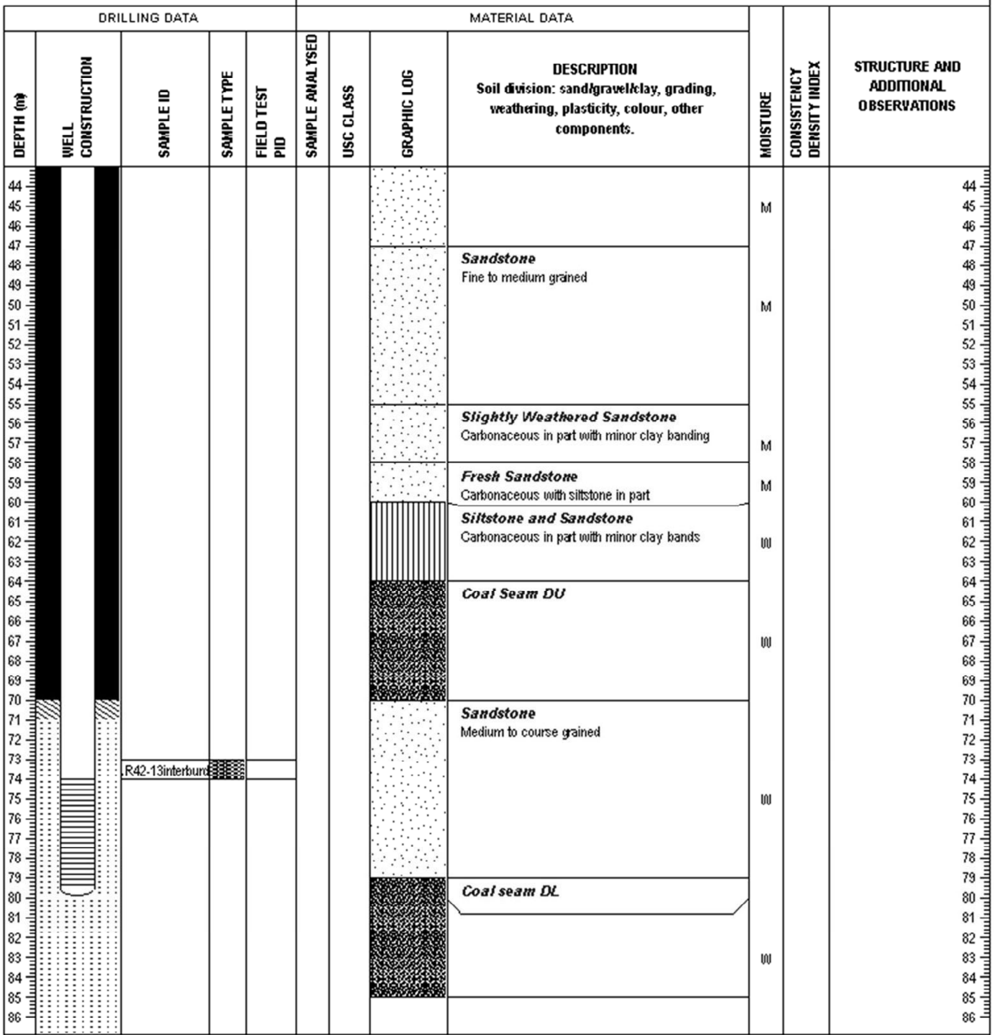

Moisture
D: Dry H: Humid
M: Moist W: Wet

Consistency Index
VS: Very Soft S: Soft St: Stiff V.St: Very Stiff
F: Firm H: Hard Fb: Friable

Density Index
VL: Very Loose D: Dense
L: Loose VD: Very Dense
MD: Medium Dense

Description based on Unified Soil Classification system.
Photo Ionisation Detector (PID)
Parts per million (ppm)

Sheet 2 of 2

Waratah Coal

MONITORING WELL LOG REPORT

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Ph: +61 7 3303 8775 Fax: +61 7 3129 1895

Project No: B09216.11
Project Manager: Frank Ganedran
Location: Kia Ora
Client: Waratah Coal
Surface Elevation: 0
Easting: 444099.79

Borehole Number: WAR44-15 (New)
Date: 6/05/2010
Drilled By: Geoprobe
Bore Diameter: 100
Northing: 7415170.44

DRILLING DATA: DEPTH (m) | WELL CONSTRUCTION | SAMPLE ID | SAMPLE TYPE | FIELD TEST PID

MATERIAL DATA: SAMPLE ANALYSED | USC CLASS | GRAPHIC LOG | DESCRIPTION Soil division: sand/gravel/clay, grading, weathering, plasticity, colour, other components. | MOISTURE | CONSISTENCY DENSITY INDEX | STRUCTURE AND ADDITIONAL OBSERVATIONS

Sample ID: WAR44-15TR

DESCRIPTION	MOISTURE
Soil Grades to silty sand	D
Claystone Medium grained grading to fine grained	D
Claystone Fine grained	D
Sand Clay in part	H
Fine grained sand Clay in part	
Iron stone Dark red with clay in part	H
Iron stone Pale red with sand in part	

Moisture	Consistency Index	Density Index	
D: Dry H: Humid	VS: Very Soft S: Soft St: Stiff V.St: Very Stiff	VL: Very Loose D: Dense	Description based on Unified Soil Classification system.
M: Moist W: Wet	F: Firm H: Hard Fb: Friable	L: Loose VD: Very Dense	Photo Ionisation Detector (PID)
		MD: Medium Dense	Parts per million (ppm)

Sheet 1 of 2

Waratah Coal

MONITORING WELL LOG REPORT

E3 Consulting Australia Pty Ltd
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Ph: +61 7 3303 8775 Fax: +61 7 3129 1895

Project No: B09216.11	**Borehole Number: WAR44-15 (New)**
Project Manager: Frank Ganedran	**Date:** 6/05/2010
Location: Kia Ora	
Client: Waratah Coal	**Drilled By:** Geoprobe
Surface Elevation: 0	**Bore Diameter:** 100
Easting: 444099.79	**Northing:** 7415170.44

DRILLING DATA: DEPTH (m) · WELL CONSTRUCTION · SAMPLE ID · SAMPLE TYPE · FIELD TEST PID

MATERIAL DATA: SAMPLE ANALYSED · USC CLASS · GRAPHIC LOG · DESCRIPTION (Soil division: sand/gravel/clay, grading, weathering, plasticity, colour, other components.) · MOISTURE · CONSISTENCY DENSITY INDEX · STRUCTURE AND ADDITIONAL OBSERVATIONS

Depth scale: 32 to 62

Sample ID: 44-15Du interbu

DESCRIPTION	MOISTURE
Iron stone becoming moist with some clay	M
Iron stone Very wet with silt and clay in part	W
Sand with clay Wet grading to finer sand and silt with depth	W
Clay Sand in part	W
Siltstone Clay in part and saturated	W
Siltstone Light grey	
Coal Mudstone banding	
Sandstone Medium grained	W

Moisture
D: Dry H: Humid
M: Moist W: Wet

Consistency Index
VS: Very Soft S: Soft St: Stiff V.St: Very Stiff
F: Firm H: Hard Fb: Friable

Density Index
VL: Very Loose D: Dense
L: Loose VD: Very Dense
MD: Medium Dense

Description based on Unified Soil Classification system.
Photo Ionisation Detector (PID)
Parts per million (ppm)

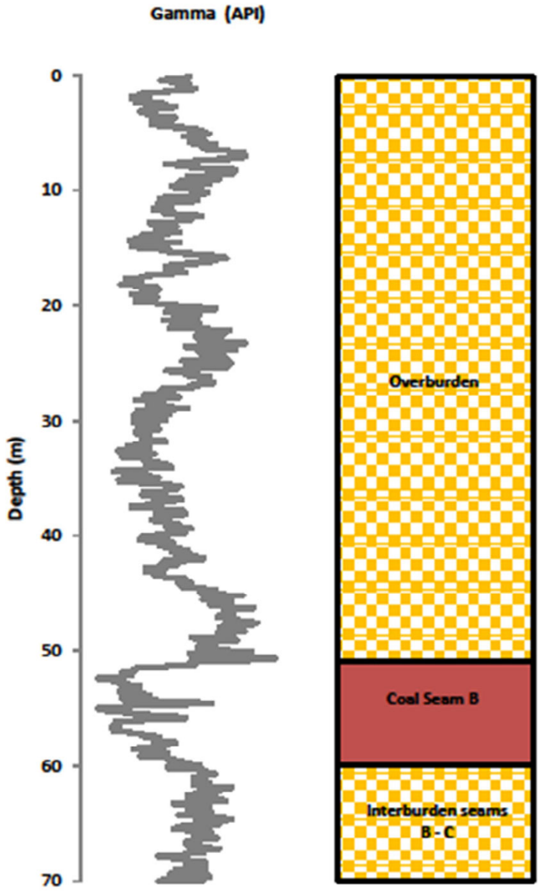
Sheet 2 of 2

Waratah Coal

Appendix B – Geophysical Survey Plots

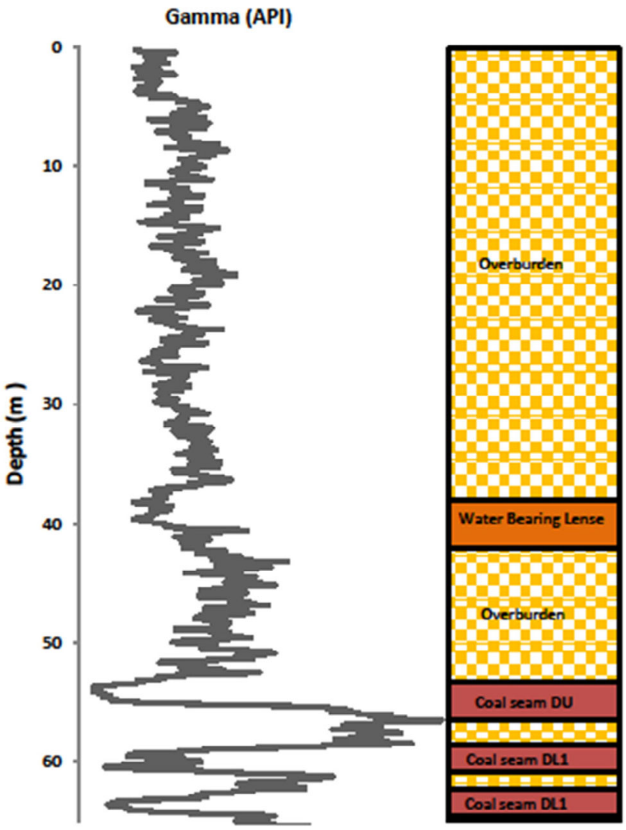
Waratah Coal

WAR38-15 Gamma



Waratah Coal

WAR44-15 Gamma



Appendix C – GAB and Associated Aquifers Water Quality Results

Well ID	Depth to Water (mbgl)	Temperature (°C)	Turbidity (NTU)	Dissolved oxygen (%)	Electrical conductivity (mS/cm)	pH - Field	Arsenic	Cadmium	Chromium	Copper	Nickel	Lead	Zinc	Mercury
ANZECC 2000 Freshwater 99%	-	NC	NC	NC	NC	6 - 7.5	0.001	0.00006	NC	0.001	0.008	0.001	0.0024	0.00006
ANZECC 2000 Primary industry	-	NC	NC	NC	NC	-	0.1	0.01	0.1	0.2	0.2	2.0	2.0	0.002
ANZECC 2000 Stock water	-	NC	NC	NC	NC	-	0.5	0.1	1.0	1.0	1.0	0.1	20.0	NC
LOR	-	0.1	0.1	0.1	0.01	-	0.001	0.0001	0.001	0.001	0.001	0.001	0.005	0.0001
Units	m		NTU	%	ms/cm	pH	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Speculation-swimming pool	-	29.2	27.5	2.27	0.1903	4.9	<0.001	<0.0001	<0.001	0.002	0.002	<0.001	0.009	<0.0001
Speculation-home bore	68.3	28.9	32.5	2.64	0.421	4.8	<0.001	<0.0001	0.002	<0.001	0.009	<0.001	0.009	<0.0001
Inverurie stockyard	42.82	26.6	0.3	1.52	0.18	4.1	<0.001	<0.0001	<0.001	0.046	0.004	0.001	0.14	<0.0001
Inverurie home bore	31.69	26.1	0	4.35	281	4.5	<0.001	<0.0001	<0.001	0.017	0.005	<0.001	0.037	<0.0001
Coleraine	63.15	28.9	0	3.14	0.006	4.8	<0.001	<0.0001	<0.001	0.001	0.004	<0.001	0.012	<0.0001
Inverurie murphys bore	94.6	27.3	1.9	3.63	0.1082	4.5	<0.001	<0.0001	<0.001	0.008	0.003	<0.001	0.018	<0.0001
Armagh house bore	46.91	27	4.5	1.85	5	6.6	<0.001	<0.0001	<0.001	<0.001	<0.001	<0.001	0.008	<0.0001
Aldele	27.8	29.5	2.9	1.91	0.807	5.2	<0.001	<0.0001	<0.001	<0.001	0.001	<0.001	0.107	<0.0001
Hyde park	33.17	30.1	4.9	1.45	1.845	5.5	<0.001	<0.0001	<0.001	0.003	<0.001	<0.001	0.007	<0.0001
Locharnoch	83	27.1	0	2.83	0.0013	4.2	<0.001	<0.0001	<0.001	0.008	0.006	<0.001	0.063	<0.0001

Note: - = No data   NC = No criteria   Highlighted values exceed criteria

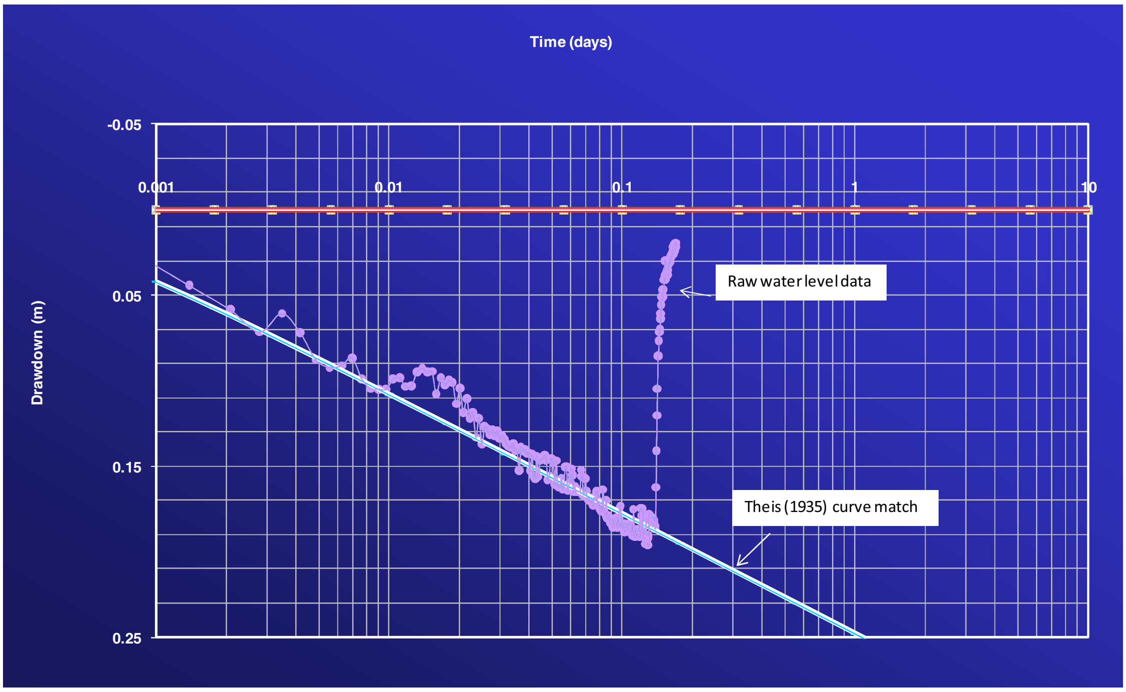
Well ID	Ammonia as N	Nitrite + Nitrate as N	Total Kjeldahl Nitrogen as N	Total Nitrogen as N	Total Phosphorus as P	Hydroxide Alkalinity as CaCO3	Carbonate Alkalinity as CaCO3	Bicarbonate Alkalinity as CaCO3	Total Alkalinity as CaCO3	Sulfate as SO4 2-	Chloride	Calcium	Magnesium	Sodium	Potassium	Nitrite as N	Total Anions	Total Cations	Ionic Balance
ANZECC 2000 Freshwater 99%	0.32	0.15	NC	0.15	0.01	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	0.017	NC	NC	NC
ANZECC 2000 Primary industry	NC	NC	NC	5	0.05	NC	NC	NC	NC	NC	350	NC	NC	NC	NC	NC	NC	NC	NC
ANZECC 2000 Stock water	NC	30	NC	NC	NC	NC	NC	NC	NC	1000-2	NC	1000	NC	NC	NC	1.5	NC	NC	NC
LOR	0.01	0.01	0.1	0.1	0.01	1	1	1	1	1	1	1	1	1	1	0.01	0.01	0.01	0.01
Units	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	meq/L	meq/L	%
Speculation-swimming pool	0.04	0.3	0.3	0.6	<0.01	<1	<1	24	24	1	59	<1	5	40	3	<0.01	2.17	2.22	-
Speculation-home bore	<0.01	0.7	<0.1	0.7	<0.01	<1	<1	29	29	6	84	1	7	53	5	<0.01	3.06	3.08	0.5
Inverurie stockyard	<0.01	0.4	<0.1	0.4	<0.01	<1	<1	17	17	6	57	<1	4	43	3	<0.01	2.08	2.26	-
Inverurie home bore	<0.01	0.4	0.1	0.5	<0.01	<1	<1	16	16	6	63	<1	5	44	3	<0.01	2.23	2.4	-
Coleraine	<0.01	1	0.1	1.1	0.02	<1	<1	9	9	4	38	<1	4	23	3	<0.01	1.34	1.41	-
Inverurie murphys bore	<0.01	1.8	<0.1	1.8	<0.01	<1	<1	9	9	3	30	<1	3	21	2	<0.01	1.08	1.21	-
Armagh house bore	0.15	0.2	0.3	0.5	0.02	<1	<1	212	211	253	1520	121	157	790	26	<0.01	52.4	54	1.6
Aldele	0.16	0.1	0.3	0.4	<0.01	<1	<1	66	66	29	260	13	11	170	11	<0.01	9.26	9.24	0.1
Hyde park	0.28	0.1	0.3	0.4	<0.01	<1	<1	125	125	35	449	21	15	291	16	<0.01	15.9	15.3	1.8
Locharnoch	<0.01	0.7	0.3	1	<0.01	<1	<1	10	10	4	43	<1	4	26	2	<0.01	1.49	1.51	-

Note: - = No data   NC = No criteria   Highlighted values exceed criteria

Appendix D – Aquifer Test Curve Matches

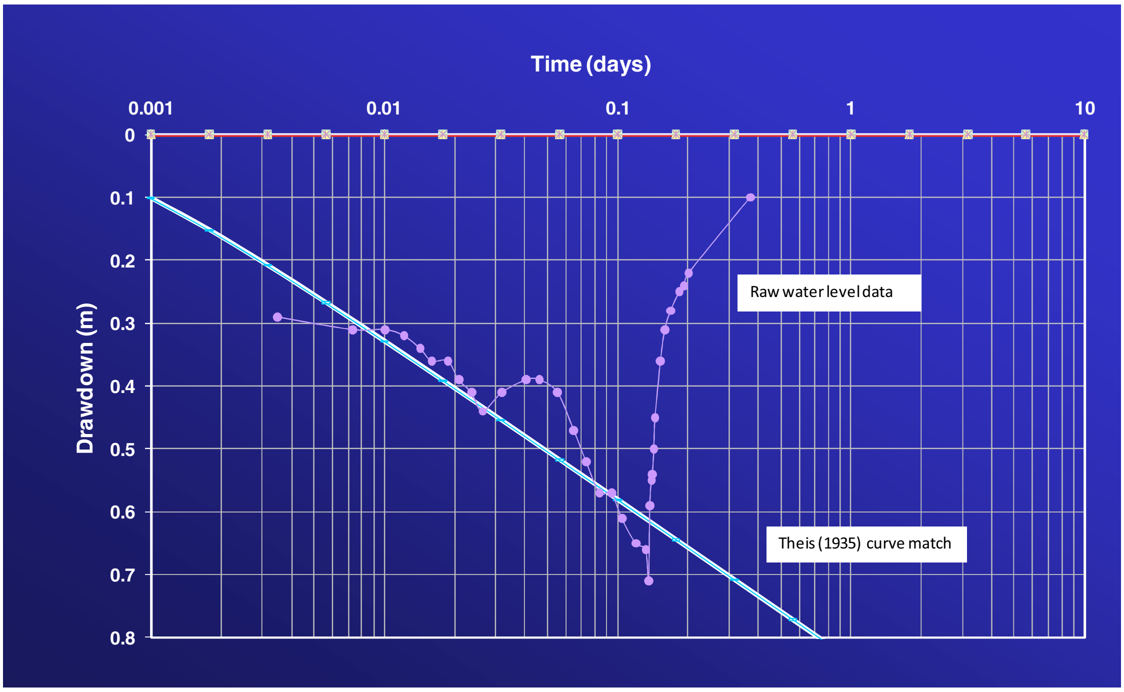
Waratah Coal

WAR42-13 (80)



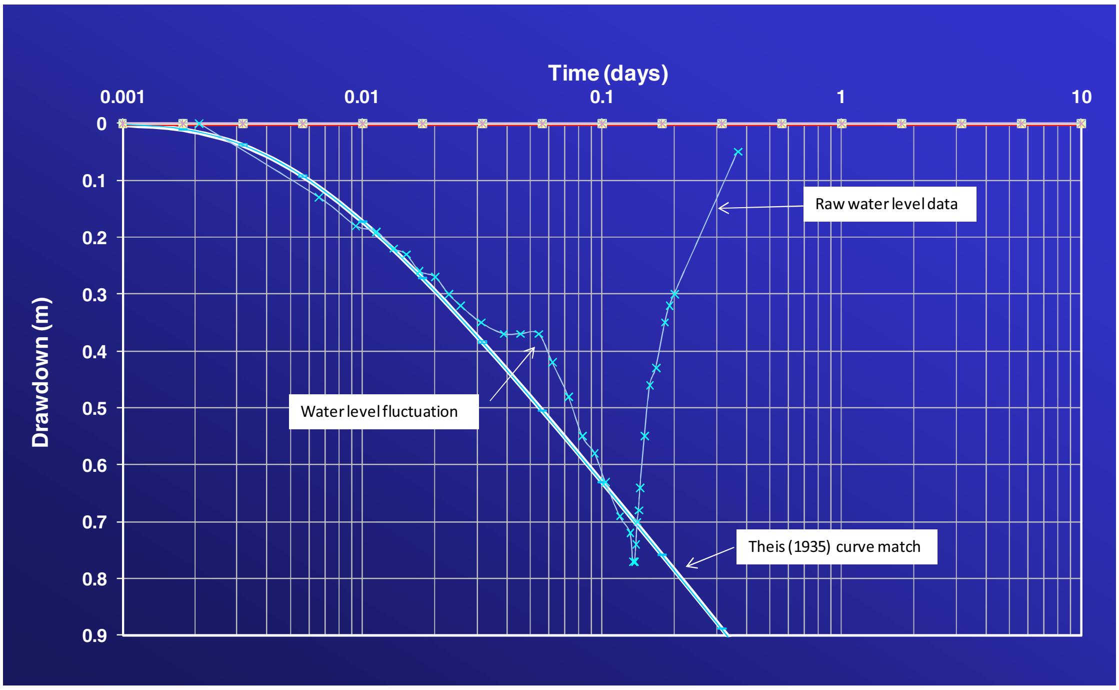
Waratah Coal

WAR42-13 (Airlift 80)



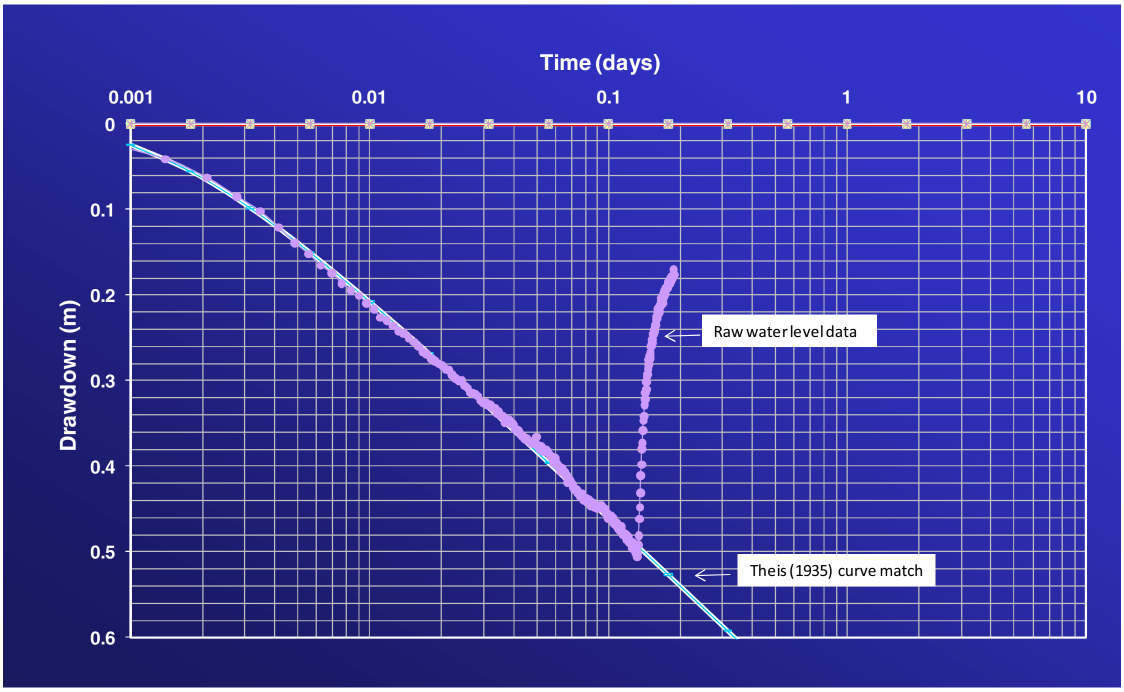
Waratah Coal

WAR42-13 (Airlift 65)



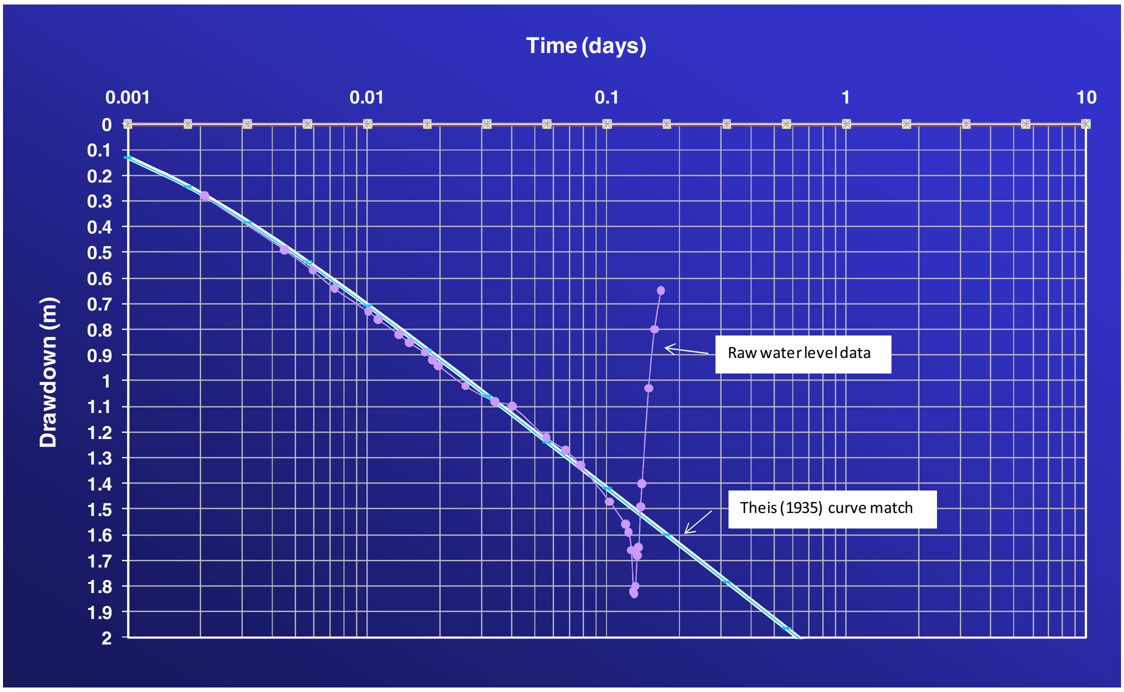
Waratah Coal

WAR44-15 (retrofit)



Waratah Coal

WAR44-15 (Airlift retrofit)



Waratah Coal

Appendix E – Slug Test Calculations

Waratah Coal

WELL ID: WAR38-15 (60)

INPUT

Construction:

Casing dia. (d_c)	0.05 Meter
Annulus dia. (d_w)	0.1 Meter
Screen Length (L)	6 Meter

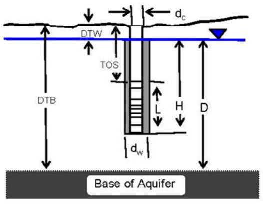
Depths to:

water level (DTW)	51 Meter
top of screen (TOS)	56.8 Meter
Base of Aquifer (DTB)	62.8 Meter

Annular Fill:

across screen -- Medium Sand
above screen -- Bentonite

Aquifer Material -- Medium-Grained Sandstone



COMPUTED

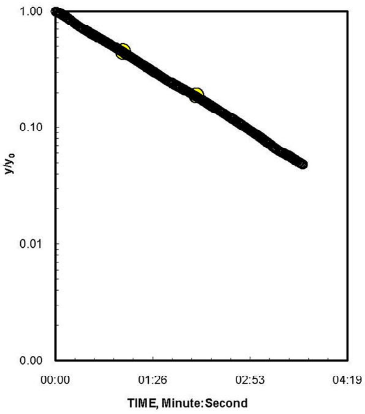
L_{wetted}	6 Meter
D =	11.8 Meter
H =	11.8 Meter
L/r_w =	120.00
$y_{0\text{-DISPLACEMENT}}$ =	9.53 Meter
$y_{0\text{-SLUG}}$ =	25.61 Meter

From look-up table using L/r_w

Fully penetrate C =	5.011
ln(Re/rw) =	4.114
Re =	10.04 Meter
Slope =	0.005761 $\log_{10}$/sec
$t_{90\%}$ recovery =	174 sec

K =	0.25 Meter/Day

Adjust slope of line to estimate K



REMARKS:

Bouwer and Rice analysis of slug test, WRR 1976

Reduced Data

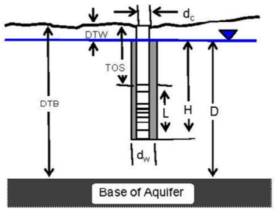
Entry	Time, Hr:Min:Sec	Water Level
1	0:00:01.0	25.04
2	0:00:05.0	24.69
3	0:00:09.0	24.25
4	0:00:13.0	23.67
5	0:00:17.0	23.11
6	0:00:21.0	22.63
7	0:00:25.0	22.24
8	0:00:29.0	21.89
9	0:00:33.0	21.58
10	0:00:37.0	21.29
11	0:00:41.0	21.00
12	0:00:45.0	20.73
13	0:00:49.0	20.46
14	0:00:53.0	20.21
15	0:00:57.0	19.95
16	0:01:01.0	19.72
17	0:01:05.0	19.49
18	0:01:09.0	19.28
19	0:01:13.0	19.07
20	0:01:17.0	18.87
21	0:01:21.0	18.67
22	0:01:25.0	18.51
23	0:01:29.0	18.34
24	0:01:33.0	18.18
25	0:01:37.0	18.03
26	0:01:41.0	17.90
27	0:01:45.0	17.78
28	0:01:49.0	17.68
29	0:01:53.0	17.57
30	0:01:57.0	17.48
31	0:02:01.0	17.38
32	0:02:05.0	17.28
33	0:02:09.0	17.19
34	0.02.13.0	17.10
35	0:02:17.0	17.02
36	0:02:21.0	16.93
37	0:02:25.0	16.86
38	0:02:29.0	16.79
39	0:02:33.0	16.72
40	0:02:37.0	16.65
41	0:02:41.0	16.58
42	0:02:45.0	16.52
43	0:02:49.0	16.47
44	0:02:53.0	16.41
45	0:02:57.0	16.36

Waratah Coal

WELL ID: WAR38-15 (New)

INPUT

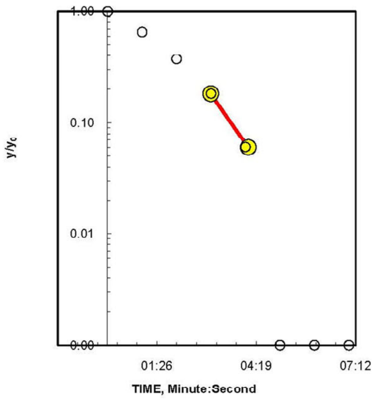
Construction:		
Casing dia. (d_c)	0.1	Meter
Annulus dia. (d_w)	0.125	Meter
Screen Length (L)	6	Meter
Depths to:		
water level (DTW)	51	Meter
top of screen (TOS)	60	Meter
Base of Aquifer (DTB)	66	Meter
Annular Fill:		
across screen --	Medium Sand	
above screen --	Bentonite	
Aquifer Material --	Medium-Grained Sandstone	



COMPUTED

L_{wetted}	6	Meter
D =	15	Meter
H =	15	Meter
L/r_w =	96.00	
$y_{0\text{-DISPLACEMENT}}$ =	5.91	Meter
$y_{0\text{-SLUG}}$ =	12.80	Meter
From look-up table using L/r_w		
Fully penetrate C =	4.156	
ln(Re/rw) =	4.098	
Re =	12.36	Meter
Slope =	0.007358	$\log_{10}$/sec
$t_{90\%}$ recovery =	136	sec
K =	**1.2**	**Meter/Day**

Adjust slope of line to estimate K



Reduced Data

Entry	Time, Hr:Min:Sec	Water Level
1	0:01:00.0	21.42
2	0:02:00.0	19.38
3	0:03:00.0	17.71
4	0:04:00.0	16.59
5	0:05:00.0	15.87
6	0:06:00.0	15.45
7	0:07:00.0	15.26
8	0:08:00.0	15.18
9	0:09:00.0	15.15
10	0:10:00.0	15.14
11	0:11:00.0	15.13
12	0:12:00.0	15.14
13	0:13:00.0	15.13
14	0:14:00.0	15.13
15	0:15:00.0	15.13
16	0:16:00.0	15.13
17	0:17:00.0	15.13
18	0:18:00.0	15.12
19	0:19:00.0	15.13
20	0:20:00.0	15.12
21	0:21:00.0	15.13
22	0:22:00.0	15.12

REMARKS:

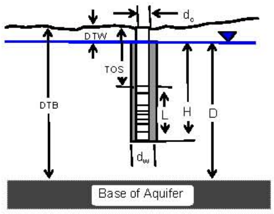
Bouwer and Rice analysis of slug test, WRR 1976

Waratah Coal

WELL ID: WAR42-13 (50)

INPUT

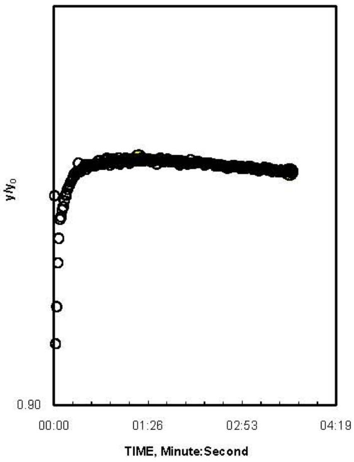
Construction:	
Casing dia. (d_c)	0.05 Meter
Annulus dia. (d_w)	0.1 Meter
Screen Length (L)	6 Meter
Depths to:	
water level (DTW)	17 Meter
top of screen (TOS)	44 Meter
Base of Aquifer (DTB)	50 Meter
Annular Fill:	
across screen --	Medium Sand
above screen --	Bentonite
Aquifer Material --	Medium-Grained Sandstone



COMPUTED

L_{wetted}	6 Meter
D =	33 Meter
H =	33 Meter
L/r_w =	120.00
$y_{0\text{-DISPLACEMENT}}$ =	4.67 Meter
$y_{0\text{-SLUG}}$ =	25.61 Meter
From look-up table using L/r_w	
Fully penetrate C =	5.011
ln(Re/rw) =	4.735
Re =	18.69 Meter
Slope =	2.15E-05 $\log_{10}$/sec
$t_{90\%}$ recovery =	46431 sec
K =	0.0011 Meter/Day

Adjust slope of line to estimate K



REMARKS:

Bouwer and Rice analysis of slug test, WRR 1976

Reduced Data

Entry	Time, Hr:Min:Sec	Water Level
1	0:00:01.0	32.67
2	0:00:05.0	32.57
3	0:00:09.0	32.64
4	0:00:13.0	32.69
5	0:00:17.0	32.71
6	0:00:21.0	32.72
7	0:00:25.0	32.73
8	0:00:29.0	32.74
9	0:00:33.0	32.74
10	0:00:37.0	32.74
11	0:00:41.0	32.75
12	0:00:45.0	32.74
13	0:00:49.0	32.76
14	0:00:53.0	32.75
15	0:00:57.0	32.76
16	0:01:01.0	32.75
17	0:01:05.0	32.76
18	0:01:09.0	32.76
19	0:01:13.0	32.76
20	0:01:17.0	32.75
21	0:01:21.0	32.76
22	0:01:25.0	32.75
23	0:01:29.0	32.75
24	0:01:33.0	32.75
25	0:01:37.0	32.76
26	0:01:41.0	32.75
27	0:01:45.0	32.76
28	0:01:49.0	32.75
29	0:01:53.0	32.75
30	0:01:57.0	32.75
31	0:02:01.0	32.75
32	0:02:05.0	32.75
33	0:02:09.0	32.75
34	0:02:13.0	32.75
35	0:02:17.0	32.75
36	0:02:21.0	32.75
37	0:02:25.0	32.75
38	0:02:29.0	32.74
39	0:02:33.0	32.74
40	0:02:37.0	32.74
41	0:02:41.0	32.74
42	0:02:45.0	32.74
43	0:02:49.0	32.74
44	0:02:53.0	32.74
45	0:02:57.0	32.74

Waratah Coal

WELL ID: WAR44-15 (Monitor)

INPUT

Construction:

Casing dia. (d_c)	0.05 Meter
Annulus dia. (d_w)	0.1 Meter
Screen Length (L)	6 Meter

Depths to:

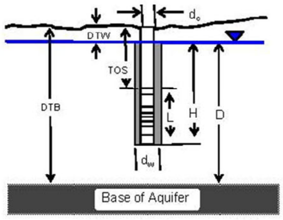
water level (DTW)	11 Meter
top of screen (TOS)	43 Meter
Base of Aquifer (DTB)	49 Meter

Annular Fill:

across screen -- Medium Sand

above screen -- Bentonite

Aquifer Material -- Fine-Grained Sandstone



COMPUTED

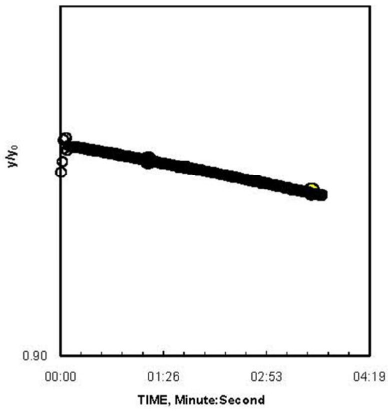
L_{wetted}	6 Meter
D =	38 Meter
H =	38 Meter
L/r_w =	120.00
$y_{0\text{-DISPLACEMENT}}$ =	10.42 Meter
$y_{0\text{-SLUG}}$ =	20.49 Meter

From look-up table using L/r_w

Fully penetrate C =	5.011
ln(Re/rw) =	4.817
Re =	20.30 Meter
Slope =	5.72E-05 log_{10}/sec
$t_{90\%}$ recovery =	17490 sec

K = 0.0029 Meter/Day

Adjust slope of line to estimate K



REMARKS:

Bouwer and Rice analysis of slug test, WRR 1976

Reduced Data

Entry	Time, Hr:Min:Sec	Water Level
1	0:00:01.0	29.62
2	0:00:05.0	29.83
3	0:00:09.0	29.78
4	0:00:13.0	29.78
5	0:00:17.0	29.77
6	0:00:21.0	29.76
7	0:00:25.0	29.76
8	0:00:29.0	29.75
9	0:00:33.0	29.75
10	0:00:37.0	29.74
11	0:00:41.0	29.74
12	0:00:45.0	29.73
13	0:00:49.0	29.73
14	0:00:53.0	29.72
15	0:00:57.0	29.71
16	0:01:01.0	29.71
17	0:01:05.0	29.70
18	0:01:09.0	29.70
19	0:01:13.0	29.69
20	0:01:17.0	29.69
21	0:01:21.0	29.68
22	0:01:25.0	29.68
23	0:01:29.0	29.67
24	0:01:33.0	29.67
25	0:01:37.0	29.66
26	0:01:41.0	29.66
27	0:01:45.0	29.65
28	0:01:49.0	29.64
29	0:01:53.0	29.64
30	0:01:57.0	29.63
31	0:02:01.0	29.63
32	0:02:05.0	29.62
33	0:02:09.0	29.62
34	0:02:13.0	29.61
35	0:02:17.0	29.61
36	0:02:21.0	29.60
37	0:02:25.0	29.59
38	0:02:29.0	29.59
39	0:02:33.0	29.58
40	0:02:37.0	29.58
41	0:02:41.0	29.57
42	0:02:45.0	29.56
43	0:02:49.0	29.55
44	0:02:53.0	29.55
45	0:02:57.0	29.54

Waratah Coal

WELL ID: Aldele

INPUT

Construction:

Casing dia. (d_c)	0.15 Meter
Annulus dia. (d_w)	0.25 Meter
Screen Length (L)	3 Meter

Depths to:

water level (DTW)	27.8 Meter
top of screen (TOS)	125 Meter
Base of Aquifer (DTB)	130 Meter

Annular Fill:

across screen -- Coarse Sand

above screen -- Bentonite

Aquifer Material -- Medium Sand

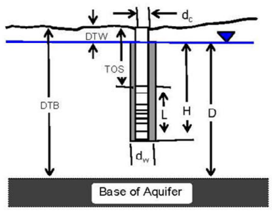
COMPUTED

L_{wetted}	3 Meter
D =	102.2 Meter
H =	100.2 Meter
L/r_w =	24.00
$y_{0\text{-DISPLACEMENT}}$ =	0.31 Meter
$y_{0\text{-SLUG}}$ =	1.14 Meter

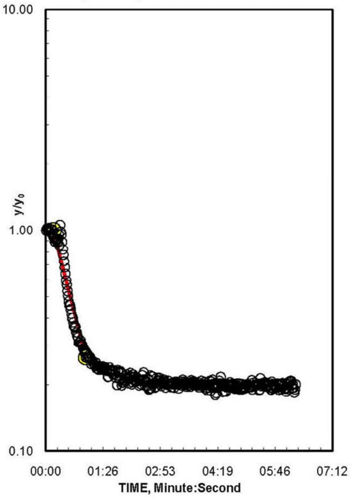
From look-up table using L/r_w

Fully penetrate C =	1.876
ln(Re/rw) =	4.121
Re =	25.28 Meter
Slope =	0.01177 $\log_{10}$/sec
$t_{90\%}$ recovery =	85 sec

K = 9 Meter/Day



Adjust slope of line to estimate K



REMARKS:

Bouwer and Rice analysis of slug test, WRR 1976

Reduced Data

Entry	Time, Hr:Min:Sec	Water Level
1	0:00:01.0	13.81
2	0:00:09.0	13.81
3	0:00:17.0	13.78
4	0:00:25.0	13.77
5	0:00:33.0	13.66
6	0:00:41.0	13.62
7	0:00:49.0	13.60
8	0:00:57.0	13.59
9	0:01:05.0	13.58
10	0:01:13.0	13.58
11	0:01:21.0	13.57
12	0:01:29.0	13.57
13	0:01:37.0	13.57
14	0:01:45.0	13.57
15	0:01:53.0	13.57
16	0:02:01.0	13.56
17	0:02:09.0	13.57
18	0:02:17.0	13.56
19	0:02:25.0	13.56
20	0:02:33.0	13.56
21	0:02:41.0	13.57
22	0:02:49.0	13.56
23	0:02:57.0	13.56
24	0:03:05.0	13.56
25	0:03:13.0	13.56
26	0:03:21.0	13.56
27	0:03:29.0	13.56
28	0:03:37.0	13.56
29	0:03:45.0	13.56
30	0:03:53.0	13.56
31	0:04:01.0	13.56
32	0:04:09.0	13.56
33	0:04:17.0	13.56
34	0:04:25.0	13.56
35	0:04:33.0	13.56
36	0:04:41.0	13.56
37	0:04:49.0	13.56
38	0:04:57.0	13.56
39	0:05:05.0	13.56
40	0:05:13.0	13.56
41	0:05:21.0	13.56
42	0:05:29.0	13.56
43	0:05:37.0	13.56
44	0:05:45.0	13.56
45	0:05:53.0	13.56

Waratah Coal

WELL ID: Coleraine

Local ID: S-1292
Date: 14/08/1997
Time: 0:00

INPUT

Construction:

Casing dia. (d_c)	0.15	Meter
Annulus dia. (d_w)	0.25	Meter
Screen Length (L)	3	Meter

Depths to:

water level (DTW)	63.15	Meter
top of screen (TOS)	97	Meter
Base of Aquifer (DTB)	101	Meter

Annular Fill:

across screen -- Coarse Sand
above screen -- Bentonite

Aquifer Material -- Medium Sand

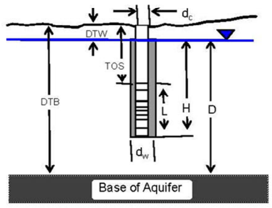
COMPUTED

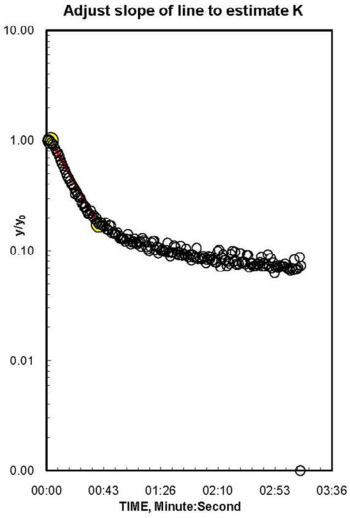
L_{wetted}	3	Meter
D =	37.85	Meter
H =	36.85	Meter
L/r_w =	24.00	
$y_{0\text{-DISPLACEMENT}}$ =	#N/A	Meter
$y_{0\text{-SLUG}}$ =	2.28	Meter

From look-up table using L/r_w

Partial penetrate A =	2.334	
B =	0.376	
ln(Re/rw) =	3.093	
Re =	9.05	Meter
Slope =	0.020864	log_{10}/sec
$t_{90\%}$ recovery =	48	sec

K = 12 Meter/Day





REMARKS:

Bouwer and Rice analysis of slug test, WRR 1976

Reduced Data

Entry	Time, Hr:Min:Sec	Water Level
1	0:00:01.0	32.59
2	0:00:05.0	32.56
3	0:00:09.0	32.48
4	0:00:13.0	32.39
5	0:00:17.0	32.33
6	0:00:21.0	32.28
7	0:00:25.0	32.25
8	0:00:29.0	32.22
9	0:00:33.0	32.21
10	0:00:37.0	32.19
11	0:00:41.0	32.19
12	0:00:45.0	32.19
13	0:00:49.0	32.18
14	0:00:53.0	32.17
15	0:00:57.0	32.16
16	0:01:01.0	32.16
17	0:01:05.0	32.16
18	0:01:09.0	32.16
19	0:01:13.0	32.16
20	0:01:17.0	32.15
21	0:01:21.0	32.16
22	0:01:25.0	32.15
23	0:01:29.0	32.15
24	0:01:33.0	32.15
25	0:01:37.0	32.15
26	0:01:41.0	32.14
27	0:01:45.0	32.15
28	0:01:49.0	32.15
29	0:01:53.0	32.14
30	0:01:57.0	32.14
31	0:02:01.0	32.14
32	0:02:05.0	32.14
33	0:02:09.0	32.14
34	0:02:13.0	32.14
35	0:02:17.0	32.14
36	0:02:21.0	32.15
37	0:02:25.0	32.14
38	0:02:29.0	32.14
39	0:02:33.0	32.14
40	0:02:37.0	32.14
41	0:02:41.0	32.14
42	0:02:45.0	32.14
43	0:02:49.0	32.14
44	0:02:53.0	32.13
45	0:02:57.0	32.14

Waratah Coal

WELL ID: Hyde Park

INPUT

Construction:

Casing dia. (d_c)	0.15 Meter
Annulus dia. (d_w)	0.25 Meter
Screen Length (L)	3 Meter

Depths to:

water level (DTW)	33.17 Meter
top of screen (TOS)	107 Meter
Base of Aquifer (DTB)	110 Meter

Annular Fill:

across screen -- Coarse Sand
above screen -- Bentonite

Aquifer Material -- Medium-Grained Sandstone

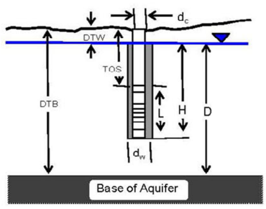
COMPUTED

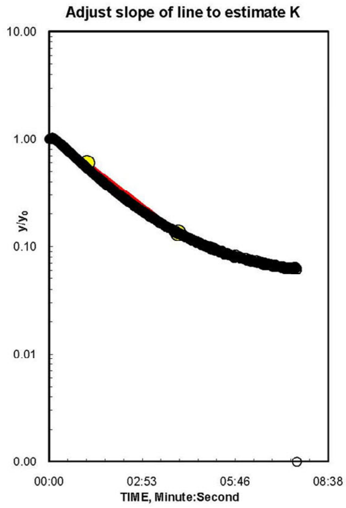
L_{wetted}	3 Meter
D =	76.83 Meter
H =	76.83 Meter
L/r_w =	24.00
$y_{0\ DISPLACEMENT}$ =	1.92 Meter
$y_{0\text{-}SLUG}$ =	2.28 Meter

From look-up table using L/r_w

Fully penetrate C =	1.876
ln(Re/rw) =	4.008
Re =	22.59 Meter
Slope =	0.003852 log_{10}/sec
$t_{90\%}$ recovery =	260 sec

K = 2.9 Meter/Day





REMARKS:

Bouwer and Rice analysis of slug test, WRR 1976

Reduced Data

Entry	Time, Hr:Min:Sec	Water Level
1	0:00:01.0	15.32
2	0:00:11.0	15.31
3	0:00:21.0	15.14
4	0:00:31.0	14.97
5	0:00:41.0	14.81
6	0:00:51.0	14.67
7	0:01:01.0	14.54
8	0:01:11.0	14.43
9	0:01:21.0	14.33
10	0:01:31.0	14.24
11	0:01:41.0	14.17
12	0:01:51.0	14.09
13	0:02:01.0	14.03
14	0:02:11.0	13.98
15	0:02:21.0	13.93
16	0:02:31.0	13.89
17	0:02:41.0	13.85
18	0:02:51.0	13.81
19	0:03:01.0	13.78
20	0:03:11.0	13.76
21	0:03:21.0	13.73
22	0:03:31.0	13.71
23	0:03:41.0	13.69
24	0:03:51.0	13.67
25	0:04:01.0	13.65
26	0:04:11.0	13.64
27	0:04:21.0	13.62
28	0:04:31.0	13.62
29	0:04:41.0	13.61
30	0:04:51.0	13.59
31	0:05:01.0	13.58
32	0:05:11.0	13.58
33	0:05:21.0	13.58
34	0:05:31.0	13.56
35	0:05:41.0	13.56
36	0:05:51.0	13.55
37	0:06:01.0	13.55
38	0:06:11.0	13.54
39	0:06:21.0	13.54
40	0:06:31.0	13.54
41	0:06:41.0	13.53
42	0:06:51.0	13.53
43	0:07:01.0	13.53
44	0:07:11.0	13.53
45	0:07:21.0	13.52

WELL ID: Monklands 1

INPUT

Construction:

- Casing dia. (d_c) 0.15 Meter
- Annulus dia. (d_w) 0.25 Meter
- Screen Length (L) 3 Meter

Depths to:

- water level (DTW) 19.4 Meter
- top of screen (TOS) 28 Meter
- Base of Aquifer (DTB) 35 Meter

Annular Fill:

- across screen -- Coarse Sand
- above screen -- Bentonite

Aquifer Material -- Fine-Grained Sandstone

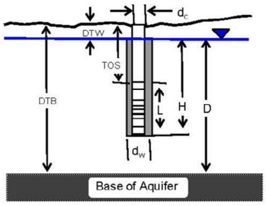
COMPUTED

- L_{wetted} 3 Meter
- D = 15.6 Meter
- H = 11.6 Meter
- L/r_w = 24.00
- $y_{0\text{-DISPLACEMENT}}$ = 1.69 Meter
- $y_{0\text{-SLUG}}$ = 2.28 Meter

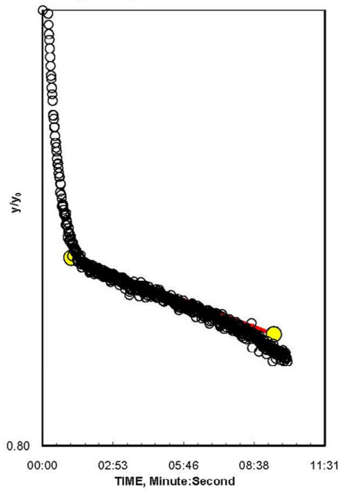
From look-up table using L/r_w

- Partial penetrate A = 2.334
- B = 0.376
- ln(Re/rw) = 2.535
- Re = 5.18 Meter
- Slope = 3.45E-05 $\log_{10}$/sec
- $t_{90\%}$ recovery = 29019 sec

K = 0.016 Meter/Day



Adjust slope of line to estimate K



REMARKS:

Bouwer and Rice analysis of slug test, WRR 1976

Reduced Data

Entry	Time, Hr:Min:Sec	Water Level
1	0:00:01.0	18.59
2	0:00:14.0	18.58
3	0:00:27.0	18.50
4	0:00:40.0	18.45
5	0:00:53.0	18.42
6	0:01:06.0	18.40
7	0:01:19.0	18.39
8	0:01:32.0	18.38
9	0:01:45.0	18.38
10	0:01:58.0	18.37
11	0:02:11.0	18.37
12	0:02:24.0	18.37
13	0:02:37.0	18.37
14	0:02:50.0	18.37
15	0:03:03.0	18.37
16	0:03:16.0	18.37
17	0:03:29.0	18.37
18	0:03:42.0	18.36
19	0:03:55.0	18.36
20	0:04:08.0	18.36
21	0:04:21.0	18.36
22	0:04:34.0	18.36
23	0:04:47.0	18.36
24	0:05:00.0	18.35
25	0:05:13.0	18.35
26	0:05:26.0	18.35
27	0:05:39.0	18.35
28	0:05:52.0	18.35
29	0:06:05.0	18.35
30	0:06:18.0	18.34
31	0:06:31.0	18.34
32	0:06:44.0	18.34
33	0:06:57.0	18.34
34	0:07:10.0	18.34
35	0:07:23.0	18.34
36	0:07:36.0	18.34
37	0:07:49.0	18.34
38	0:08:02.0	18.33
39	0:08:15.0	18.33
40	0:08:28.0	18.33
41	0:08:41.0	18.33
42	0:08:54.0	18.32
43	0:09:07.0	18.32
44	0:09:20.0	18.32
45	0:09:33.0	18.32

Waratah Coal

WELL ID: Reids the new bore

INPUT

Construction:

Casing dia. (d_c)	0.15 Meter
Annulus dia. (d_w)	0.25 Meter
Screen Length (L)	3 Meter

Depths to:

water level (DTW)	11.4 Meter
top of screen (TOS)	18 Meter
Base of Aquifer (DTB)	21 Meter

Annular Fill:

across screen -- Coarse Sand

above screen -- Bentonite

Aquifer Material -- Fine-Grained Sandstone

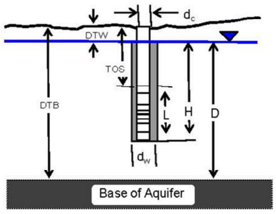
COMPUTED

L_{wetted}	3 Meter
D =	9.6 Meter
H =	9.6 Meter
L/r_w =	24.00
$y_{0\ DISPLACEMENT}$ =	0.16 Meter
$y_{0\text{-}SLUG}$ =	1.14 Meter

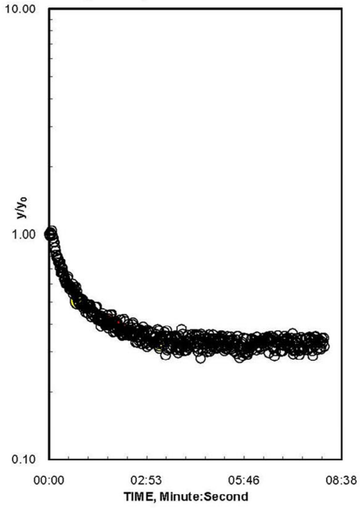
From look-up table using L/r_w

Fully penetrate C =	1.876
ln(Re/rw) =	3.016
Re =	8.38 Meter
Slope =	0.001293 log_{10}/sec
$t_{90\%}$ recovery =	774 sec

K = 0.73 Meter/Day



Adjust slope of line to estimate K



REMARKS:

Bouwer and Rice analysis of slug test, WRR 1976

Reduced Data

Entry	Time, Hr:Min:Sec	Water Level
1	0:00:01.0	17.66
2	0:00:11.0	17.64
3	0:00:21.0	17.61
4	0:00:31.0	17.60
5	0:00:41.0	17.59
6	0:00:51.0	17.59
7	0:01:01.0	17.58
8	0:01:11.0	17.58
9	0:01:21.0	17.57
10	0:01:31.0	17.57
11	0:01:41.0	17.57
12	0:01:51.0	17.57
13	0:02:01.0	17.56
14	0:02:11.0	17.56
15	0:02:21.0	17.56
16	0:02:31.0	17.56
17	0:02:41.0	17.56
18	0:02:51.0	17.56
19	0:03:01.0	17.56
20	0:03:11.0	17.55
21	0:03:21.0	17.55
22	0:03:31.0	17.55
23	0:03:41.0	17.55
24	0:03:51.0	17.56
25	0:04:01.0	17.55
26	0:04:11.0	17.56
27	0:04:21.0	17.56
28	0:04:31.0	17.56
29	0:04:41.0	17.55
30	0:04:51.0	17.56
31	0:05:01.0	17.55
32	0:05:11.0	17.55
33	0:05:21.0	17.55
34	0:05:31.0	17.55
35	0:05:41.0	17.55
36	0:05:51.0	17.55
37	0:06:01.0	17.55
38	0:06:11.0	17.55
39	0:06:21.0	17.55
40	0:06:31.0	17.55
41	0:06:41.0	17.55
42	0:06:51.0	17.55
43	0:07:01.0	17.56
44	0:07:11.0	17.55
45	0:07:21.0	17.56

Waratah Coal

WELL ID: Reids the old bore

INPUT

Construction:

Casing dia. (d_c)	0.15 Meter
Annulus dia. (d_w)	0.25 Meter
Screen Length (L)	3 Meter

Depths to:

water level (DTW)	13.3 Meter
top of screen (TOS)	19 Meter
Base of Aquifer (DTB)	22 Meter

Annular Fill:

across screen -- Coarse Sand

above screen -- Bentonite

Aquifer Material -- Fine-Grained Sandstone

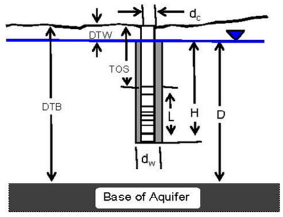
COMPUTED

L_{wetted}	3 Meter
D =	8.7 Meter
H =	8.7 Meter
L/r_w =	24.00
$y_{0\text{-DISPLACEMENT}}$ =	0.34 Meter
$y_{0\text{-SLUG}}$ =	1.14 Meter

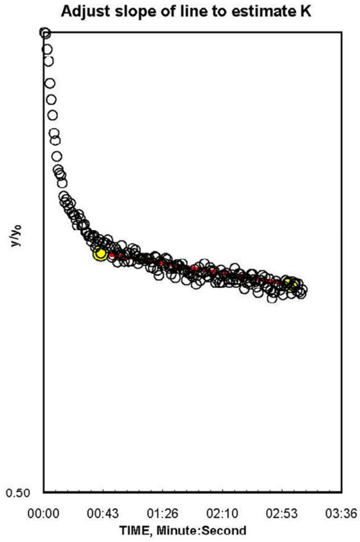
From look-up table using L/r_w

Fully penetrate C =	1.876
ln(Re/rw) =	2.963
Re =	7.95 Meter
Slope =	0.000148 $\log_{10}$/sec
$t_{90\%}$ recovery =	6744 sec

K = 0.082 Meter/Day



Adjust slope of line to estimate K



REMARKS:

Bouwer and Rice analysis of slug test, WRR 1976

Reduced Data

Entry	Time, Hr:Min:Sec	Water Level
1	0:00:01.0	19.29
2	0:00:05.0	19.27
3	0:00:09.0	19.24
4	0:00:13.0	19.23
5	0:00:17.0	19.22
6	0:00:21.0	19.21
7	0:00:25.0	19.21
8	0:00:29.0	19.21
9	0:00:33.0	19.20
10	0:00:37.0	19.20
11	0:00:41.0	19.20
12	0:00:45.0	19.20
13	0:00:49.0	19.20
14	0:00:53.0	19.20
15	0:00:57.0	19.20
16	0.01:01.0	19.20
17	0:01:05.0	19.20
18	0:01:09.0	19.19
19	0:01:13.0	19.19
20	0:01:17.0	19.19
21	0:01:21.0	19.19
22	0:01:25.0	19.19
23	0:01:29.0	19.19
24	0:01:33.0	19.19
25	0:01:37.0	19.19
26	0:01:41.0	19.19
27	0:01:45.0	19.19
28	0:01:49.0	19.19
29	0:01:53.0	19.19
30	0:01:57.0	19.19
31	0:02:01.0	19.19
32	0:02:05.0	19.19
33	0:02:09.0	19.19
34	0:02:13.0	19.19
35	0:02:17.0	19.19
36	0:02:21.0	19.19
37	0:02:25.0	19.19
38	0:02:29.0	19.19
39	0:02:33.0	19.19
40	0:02:37.0	19.19
41	0:02:41.0	19.19
42	0:02:45.0	19.18
43	0:02:49.0	19.19
44	0:02:53.0	19.18
45	0:02:57.0	19.19