7 Groundwater

7 Groundwater

7.1 Description of Environmental Values

The Environmental Protection (Water) Policy 1997 and the Environmental Protection (Water) Amendment Policy (No. 1) 2008 [herein referred to as the EPP (Water)] serves to protect Queensland's waters while allowing for ecologically sustainable development. The purpose of this policy is achieved by providing a framework for:

- Identifying environmental values for Queensland waters.
- Deciding and stating water quality guidelines and objectives to enhance or protect the environmental values.
- Making consistent and equitable decisions about Queensland waters that promote efficient use of resources and best practice environmental management.
- Involving the community through consultation and education, and promoting community responsibility.

The location of the project site is outside those areas described in Schedule 1 of the EPP (Water). The EPP (Water) states that for waters not listed in Schedule 1 the environmental values to be enhanced or protected are the following qualities:

- Biological integrity of a pristine or modified aquatic ecosystem.
- Suitability for recreational use (primary recreation, secondary recreation, visual appreciation).
- Suitability for minimal treatment before supply as drinking water.
- Suitability for use in primary industries (irrigating crops, farm use, stock water, aquaculture, aquatic food for human consumption).
- Suitability for industrial use.
- Cultural and spiritual values.

7.1.1 Geology and Groundwater Occurrence

7.1.1.1 Geology

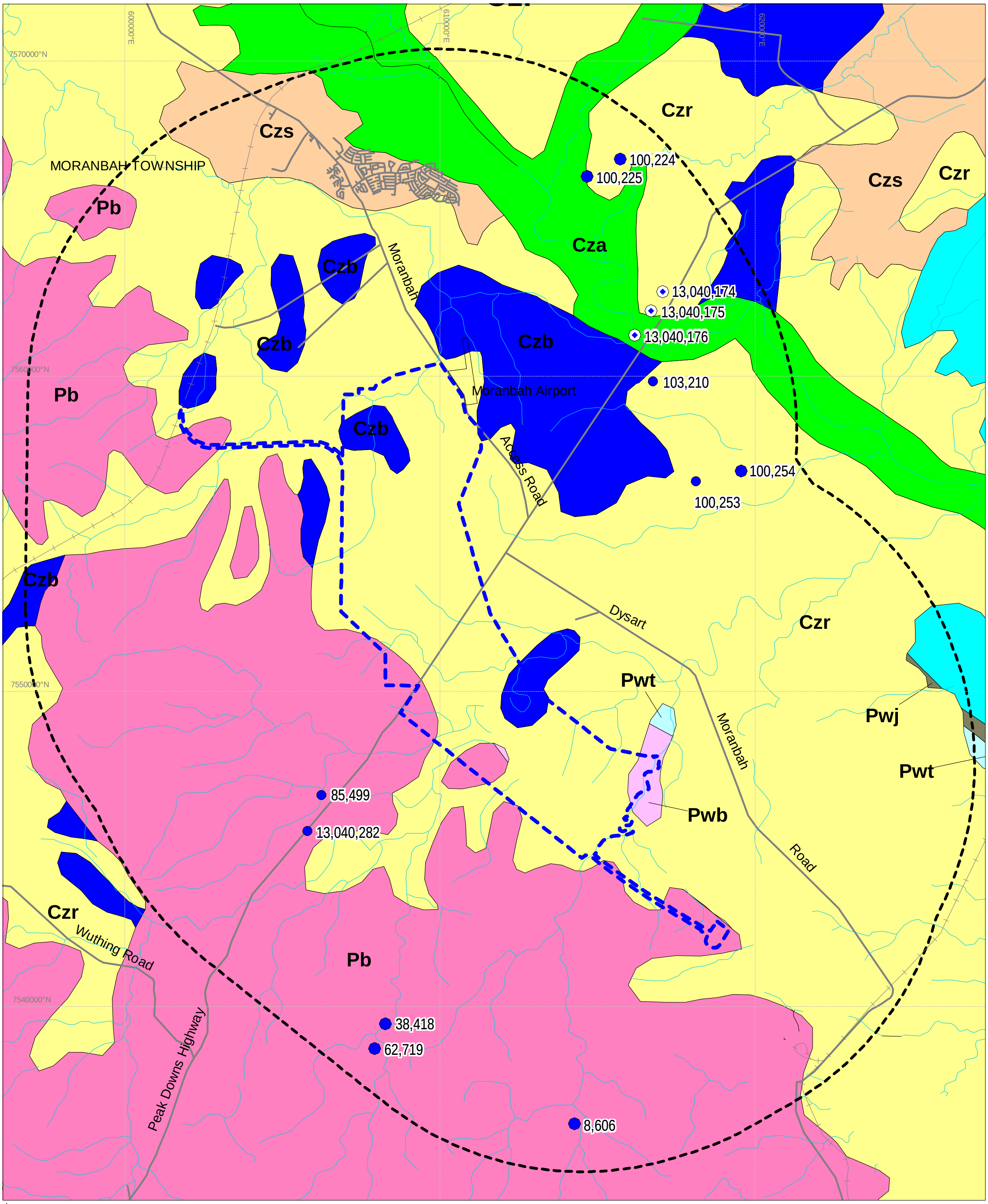
A detailed description of the geology of the area is contained in Section 4.4. The description of the geology with particular relevance to groundwater is summarised below.

The Caval Ridge Mine is located on the relatively undisturbed western limb of the northern Bowen Basin which overlies the Collinsville Shelf (part of the Clermont Block) in the area. The Bowen Basin in the area is characterised by a relatively thin accumulation of sediments, gentle easterly dips and minor to moderate deformation.

characterised by a relatively thin accumulation of sediments, gentle easterly dips and minor to moderate deformation.

Regionally, the stratigraphic sequence is summarised as follows: the Permo-Triassic sediments of the Bowen Basin are overlain by a veneer of unconsolidated Quaternary alluvium and colluvium, poorly consolidated Tertiary sediments and, in places, remnants of Tertiary basalt flows.

The litho-stratigraphy of the area is shown in Table 7.1. The local geology of the area is presented in Figure 7.1. The Moranbah Coal Measures, which contain the coal seams proposed to be extracted by the project, conformably overlie the German Creek Formation and are conformably overlain by the Fort Cooper Coal Measures.



0 2.5 5km

Scale 1:175,000 (A4)

Source: Client Supplied Data (December 2007), Qld Gov. DME Geological Mapping, 2007

Cza	Quaternary Alluvium
Czb	Undifferentiated Tertiary Basalts
Czr	Undifferentiated Tertiary Sediments
Czs	Suttor Creek Formation
Pwj	Rangal Coal Measures
Pwt	Fair Hill Formation
Pwb	Moranbah Coal Measures
Pb	Back Creek Group

- DNRW Registered Bore
- DNRW Registered Bore (Abandoned and destroyed)
- Pb — Geological Boundary and Geological Regime
- Project Site
- 10km Project Buffer

Client: BMA BHP Billiton Mitsubishi Alliance

URS

Project: CAVAL RIDGE PROJECT ENVIRONMENTAL IMPACT STATEMENT

Title: **LOCATION OF BORES WITHIN 10km OF SITE - REGISTERED WITH DNRW OVERLAIN ON GEOLOGY**

Drawn: VH	Approved: RS	Date: 08-05-2009	Figure: **7.1**	Rev:A
Job No: **4262 6158**	File No: 42626158-g-571.wor			A4

Table 7.1 Litho-stratigraphy of the Caval Ridge Area

Age	Group	Formation	Description
Quaternary	Undifferentiated alluvium and colluvium		Alluvium, mainly clay, silt, sand and gravel
Tertiary	Undifferentiated basalts		Olivine basalt lava flows
	Undifferentiated sediments		Soil, alluvium, gravel, scree, sand, duricrust
Late Permian	Blackwater Group	Rangal Coal Measures	Sandstone, siltstone, mudstone, coal, tuff, conglomerate
		Fair Hill Formation,Fort Cooper Coal Measures	Sandstone, conglomerate, mudstone, carbonaceous shale, coal, cherty tuff
		Moranbah Coal Measures	Labile sandstone, siltstone, mudstone, coal
	Back Creek Group	German Creek Formation	Sandstone, siltstone, carbonaceous shale, minor coal and sandy coquinite

All units of the Permo-Triassic sequence generally dip from west to east at between 3 and 6 degrees in the vicinity of the site. The sequence within the northern extension of the Peak Downs Mine (located to the south of the Caval Ridge Mine) shows considerable deformation with strata dipping to 30 degrees and along strike flexures in excess of 10 degrees. Faulting and seam splitting is common, producing local steepening of the coal seam dips to over 10 degrees. Minor faulting occurs in the seams in the Caval Ridge Mine area. Vertical displacement along faults ranges from less than 1 m to 36 m along the regional Harrow Creek Fault in the Peak Downs Mine.

The lithology of the Moranbah Coal Measures is generally characterised by 300 m of fine-grained sandstone, siltstone, mudstone, claystone and coal, which remains uniform throughout the entire site. The Moranbah Coal Measures are characterised by several laterally persistent, relatively thick, coal seams interspersed with several thin minor seams which commonly split and coalesce. The target seams for the Caval Ridge Mine are all the seams in the lease that are > 30 cm thick. The primary targets are the Q seam - P seam zone, the Harrow Creek (H) group of seams, and the Dysart (D) seams.

The poorly consolidated Tertiary sediments unconformably overlie an irregular erosion surface of Permian strata. These sediments consist of lenses of river channel gravels and sands separated by sandy silts, sandy clays, and clays. The Tertiary silts and clays are densely compacted, hard and generally dry. Most of the clean sand and gravel lenses are permeable but are of limited lateral and vertical extent. Lag deposits of sand and gravel are found directly on the Tertiary/Permian unconformity, but can also be present related to recent Quaternary deposition from the drainage lines in the area.

In the north remains of Tertiary basalt flows overlay the Permian sequence. The basalt is typically variably weathered.

7.1.1.2 Groundwater Occurrence

Information on the occurrence of groundwater has been obtained from:

- Interrogation of the BMA exploration drilling borelog database.
- Regional and local aeromagnetic geophysical surveys.
- Environmental impact studies conducted for other coal mines in the area.
- A search of the DERM groundwater and licensing database for registered bores located within a 10 km radius of the site (shown on Figure 7.1).
- Historical groundwater monitoring data for the period 2005 to 2007, recorded by BMA for the Peak Downs Mine.
- Additional groundwater and lithological data collected on-site between May 2008 and March 2009 during a groundwater monitoring bore (Pz series bores shown on Figure 7.3) installation and sampling program conducted for the EIS.

An aquifer is defined as a groundwater bearing formation sufficiently permeable to transmit and yield water in useable quantities. The Quaternary alluvial formations, Tertiary sediment and basalt formations, and the Permian coal measures generally yield low sustainable volumes of poor quality groundwater and are not recognised aquifers in the area. However, as groundwater levels in these formations are likely to be affected by mining, for the purposes of this investigation each unit will be considered as an aquifer.

Quaternary Alluvial Aquifers

Quaternary alluvial deposits in the region occur predominantly along creeks such as Horse Creek and Cherwell Creek. Along Cherwell Creek the alluvium comprises 6 – 9 m of clay and silt at the surface which is underlain by up to 10 m of sand and gravel with varying proportions of clay and silt as observed in monitoring wells Pz07-S and Pz08-S. No alluvium was encountered adjacent to Horse Creek at monitoring well Pz01, and the alluvium encountered at monitoring well Pz11-S (8 m thick) adjacent to Winchester Creek was dry at the time of installation. Potential for groundwater exists within the sand and gravel deposits of the alluvium, and represents an unconfined to semi-confined aquifer. Groundwater movement within the alluvium is predominantly via inter-granular flow.

Recharge to the shallow alluvial aquifer comes from two main sources:

- Recharge from surface water flow or flooding (losing stream).
- Surface infiltration of rainfall and overland flow, where alluvium is exposed and no substantial clay barriers occur in the shallow sub-surface.

Due to their shallow depth and limited extent and continuity, the Quaternary alluvium is not considered a significant aquifer. However, during periods of creek flow, the alluvium may become fully saturated and discharge to sub-cropping coal seams. The groundwater level in the alluvium, measured at Pz07-S and Pz08-S, were approximately 0.5 and 12 m above the piezometric water level in the coal at the same locations (Pz07-D and Pz08-D). This indicates possible slow groundwater movement from the alluvium to the coal seams. It is unlikely that changes in coal water levels would significantly impact on groundwater levels in the alluvium.

Hydraulic testing of the Quaternary alluvium provided hydraulic conductivity rates between 0.09 and 0.4 m/day, which are typical for silt to fine sand. The Quaternary alluvial aquifers are not regionally extensive and, accordingly, groundwater extraction at high rates would not be sustainable in the long term.

Tertiary Sediment Aquifers

The Tertiary sediments of the region consist of lenses of palaeochannel gravels and sands separated by sandy silts, sandy clays and clays. A review of the borehole logs for the project showed the Tertiary sediments vary in thickness from non-existent to approximately 30 m. The silts and clays are densely compacted, hard and generally dry. Potential for groundwater exists within sandy and gravely sections of the sediment pile, and represents an unconfined to confined aquifer depending on location. Most of the clean sand and gravel lenses are permeable but are of limited lateral and vertical extent. Groundwater movement within the Tertiary sediment is predominantly via inter-granular flow.

Recharge to the Tertiary sediment aquifers is likely to come from surface infiltration of rainfall and overland flow, where the Tertiary sediments are exposed and no substantial clay barriers occur in the shallow sub-surface. Recharge may also occur by vertical seepage from overlying Quaternary alluvial aquifers.

The nature of the Tertiary sediment aquifers, and hence their permeability and porosity, is likely to be highly variable, depending on the proportion of fine material. A review of borehole logs for the project area showed that the Tertiary stratigraphy is dominated by clays, sandy clays, and compacted sands with isolated areas of loose sand. The drilling program undertaken as part of this study showed that the Tertiary sediments do not contain significant volumes of groundwater locally. However, where the sediment is coarse in composition, the unit may have local zones of moderate to high hydraulic conductivity. Historically mining issues with Tertiary sediment derived groundwater at the Peak Downs Mine to the south of the Caval Ridge Mine appear to have been limited to pit wall stability rather than ongoing problems with groundwater inflow, indicating the limited lateral extent of the more permeable areas.

Tertiary Basalt Aquifers

An aeromagnetic geophysical survey has been undertaken over the project site. The aeromagnetics show that Tertiary basalt extends from north of the project site, along the ridge adjacent to Horse Creek in a north-south direction as shown in Figure 7.1. The interpretation of the aeromagnetic geophysical survey indicated that there is approximately 81.5 Mm^3 of basalt in the area of Horse Creek. The areal extent of the basalt is approximately 7.2 Mm^2, giving the basalt an average thickness of approximately 11 m. Tertiary basalt also occurs in the area between the Peak Downs Highway and Cherwell Creek on the project site, with a stinger of basalt crossing Cherwell Creek in a southeasterly direction toward the Heyford Pit of the Peak Downs Mine.

For the exploration boreholes and monitoring wells that intersected basalt, the basalt is logged as fresh to highly weathered with variable clay, and is up to 35 m thick. The distribution of less-weathered, water-bearing fractured and vesicular basalt is quite variable.

Recharge to the Tertiary basalt aquifers is likely to come from surface infiltration of rainfall and overland flow, where the basalt is exposed and no substantial clay barriers occur in the shallow sub-surface. Recharge may also occur by vertical seepage from overlying Quaternary alluvial aquifers. The generally clayey nature of the weathered upper basalt and the Tertiary sediments associated with the basalt, indicate that the potential of recharge is low. The groundwater level in the alluvium, measured at Pz03-S and Pz06-S, were ± 4 and 6 m above the piezometric water level in the coal at the same locations (Pz03-D and Pz06-D) which indicates groundwater movement is downwards.

The permeability and porosity of the Tertiary basalt aquifers is highly variable, depending on the degree of weathering and the intensity of fracturing. Interpreted hydraulic conductivity values of 5.18×10^{-3} to 1.91×10^{-1} m/day were obtained from the falling/rising head tests for monitoring wells Pz02, Pz03-S and Pz06-S. However, where the basalt is less weathered and more fractured or vesicular, the unit may have local zones of moderate to high hydraulic conductivity. The drilling program undertaken as part of the EIS showed that the Tertiary basalt appears to be highly heterogeneous and discontinuous locally. Historically mining issues with Tertiary basalt derived groundwaters at the Peak Downs Mine immediately to the south appear to have been limited to pit wall stability rather than ongoing problems with groundwater inflow, indicating the limited lateral extent of the more permeable areas on site.

Permian Strata Aquifers

Primary porosity in the Permian strata is limited, as even the sandstone beds have a significant clay or cement content. Excluding the larger scale discontinuities such as faults, flow in this unit is likely to be predominantly via fracture flow. Aquifer permeability will be controlled by the spacing, aperture size and interconnectivity of the discontinuities. These parameters are not well defined for the site.

In common with other areas in the Bowen Basin, the coal seams constitute the main aquifers in the Permian strata, but the jointed sandstone overburden and interburden may also be locally important for storage and transmittal of groundwater. The vertical anisotropy in the Permian strata may restrict upward/downward leakage, both between layers within the Permian and from the overlying Tertiary formations and alluvium. Consequently, perched water tables may be present above layers of low permeability material, such as mudstones or unfractured rock within or above the Permian. However there will be local interconnection of aquifers along fault planes.

There are three main coal seams in the vicinity of the project site, the Q seam - P seam zone, the Harrow Creek (H) group of seams and the Dysart (D) seams. These main coal seams form the most extensive aquifers locally. The coal seams subcrop in the western half of the site, and the coal seam aquifers are semi-confined to confined depending on location.

Groundwater recharge of coal seams is generally by infiltration of rainfall and overland flow in subcrop areas, and by downward leakage from overlying aquifers in the Tertiary formations and Quaternary alluvium. It is considered that due to the clayey nature of the Tertiary formations unconformably overlying the coal seams, recharge from rainfall infiltration will be limited. Leakage between aquifers through faults is governed by the hydraulic conductivity of the fault, the interburden thickness between the aquifers, and the piezometric level in the aquifers.

Interpreted hydraulic conductivity values determined during investigations as part of the EIS were between 0.025 and 0.59 m/day. The testing indicates that the cleats and joints in the coal are less open with depth, with a corresponding decrease in permeability.

A review of the BMA exploration bore database was undertaken to assess airlift yields determined during drilling. An airlift yield is the rate at which groundwater is removed from a bore during drilling with an air flushed drilling method, and is an estimate of the potential pumping rate of a bore. Of the 2,427 exploration bores identified on site, 164 had recorded airlift yields. Airlift yields recorded during drilling of the exploration bores are summarised in Figure 7.2.

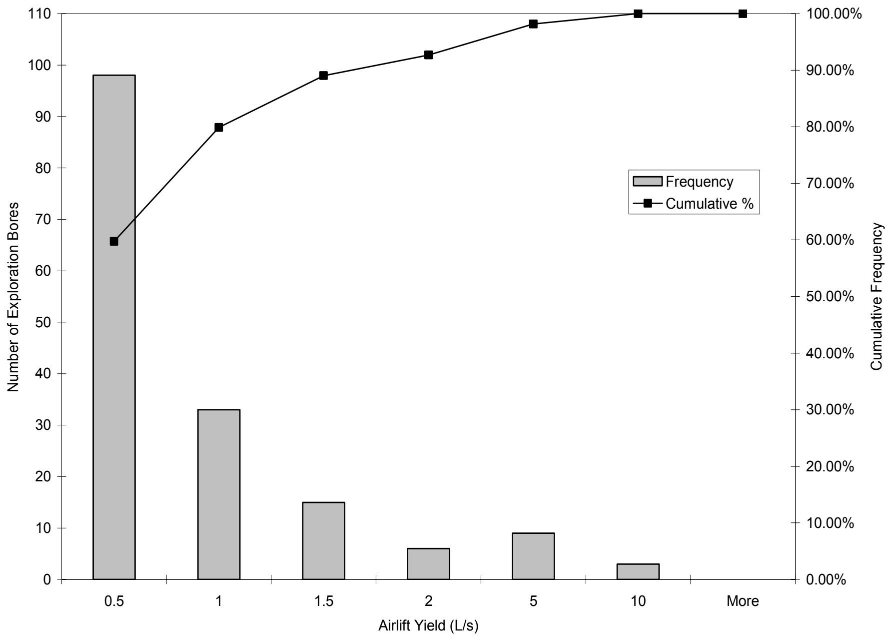


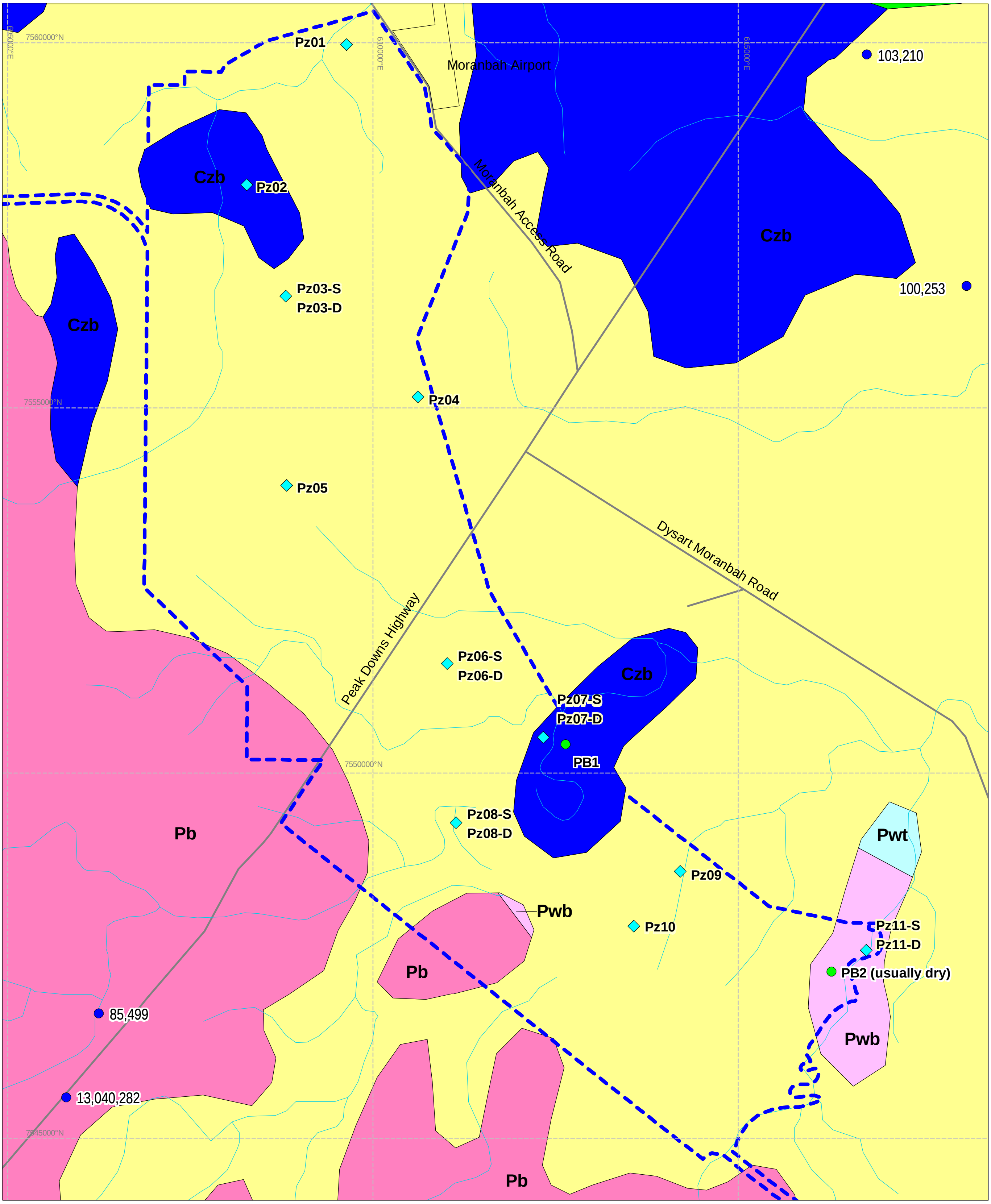
Figure 7.2 Histogram of Airlift Yields of Exploration Bores

The data indicates that approximately 60% of the exploration bores yielded 0.5 L/s or less, with approximately 30% of bores yielding between 0.5 and 2 L/s. Less than 2% of exploration bores yielded greater than 5 L/s. Many of the exploration bores that did not have recorded airlift yields in the exploration database may have been dry, thus the above histogram may overestimate the yield from the Permian strata. The length of time for which the airlifting was conducted was not available, therefore the sustainability of these yields is not known.

Historically, mining issues with the Permian strata derived groundwaters in the Peak Downs Mine immediately to the south of the project site appear to have been limited to pit wall stability rather than ongoing problems with groundwater inflow, indicating the generally low permeability of the Permian strata on site. Groundwater and surface water inflow at Peak Downs Mine are removed by pumping from in-pit sumps.

7.1.2 Groundwater Levels and Flows

Sixteen groundwater monitoring wells installed on-site were accessible for level monitoring during three separate events in June 2008, September 2008, and February to March 2009. The locations of these bores are shown on Figure 7.3. A summary of the hydrogeological conditions encountered at each monitoring well site is summarised in Table 7.2.



Czb	Undifferentiated Tertiary Basalts
Czr	Undifferentiated Tertiary Sediments
Pwt	Fair Hill Formation
Pwb	Moranbah Coal Measures
Pb	Back Creek Group

- Monitoring Wells Installed
- Monitoring Wells - Peak Downs
- DNRW Registered Bore
- Pb — Geological Boundary and Geological Regime
- Project Site

0 1 2km
Scale 1:75,000 (A4)
Datum: AGD84, AMG Zone 55

Source: Client Supplied Data (December 2007),
Qld Gov. DME Geological Mapping, 2007

Client: BMA BHP Billiton Mitsubishi Alliance

URS

Project: CAVAL RIDGE PROJECT ENVIRONMENTAL IMPACT STATEMENT

Title: **LOCATION OF GROUNDWATER MONITORING WELLS INSTALLED AROUND THE PROJECT SITE**

Drawn: VH	Approved: RS	Date: 15-05-2009	Figure: **7.3**	Rev:B
Job No: **4262 6158**	File No: 42626158-g-572b.wor			A4

Table 7.2 Summary of Hydrogeological Conditions Observed at Monitoring Wells

Monitoring Bore ID	Aquifer Material	Screen Interval (mbgl)	Aquifer Type	Standing Water Level June 2008 (mbgl)	Standing Water Level September 2008 (mbgl)	Standing Water Level February-March 2009 (mbgl)	Standing Water Level June 2008 (mAHD)*	Standing Water Level September 2008 (mAHD)*	Standing Water Level February-March 2009 (mAHD)*
Pz01	Coal Seam D04	82.5-85.5	Confined	8.44	8.39	8.21	210	210	210
Pz02	Basalt	24-35	Unconfined	25.65	25.64	25.69	214	214	214
Pz03-S	Basalt	17.5-26.5	Unconfined	25.49	25.53	25.57	221	220	220
Pz03-D	Coal Seam D04	39.8-42.8	Confined	31.76	31.73	31.76	214	214	214
Pz04	Coal Seam Q	87.1-93.1	Confined	67.58	67.53	67.49	211	211	212
Pz05	Coal Seam D04	115-118	Confined	37.60	37.57	37.69	217	217	217
Pz06-S	Basalt	22-31	Unconfined	26.23	26.25	26.21	216	216	216
Pz06-D	Coal Seam P02	81-84	Confined	29.94	29.96	30.00	212	212	212
Pz07-S	Alluvium	9-15	Unconfined	13.49	13.67	13.67	213	212	212
Pz07-D	Coal Seam Q01	41-44	Confined	14.15	14.22	14.27	212	212	212
Pz08-S	Alluvium	9-15	Unconfined	14.05	13.11	13.27	217	218	218
Pz08-D	Sandstone Interburden	60-63	Confined	27.05	25.61	25.29	204	205	206
Pz09	Coal Seam P08	71-77	Confined	19.68	19.44	19.87	204	205	204
Pz10	Coal Seam H08	77-83	Confined	41.56	41.86	Destroyed	192	192	Destroyed
Pz11-S	Alluvium	6-9	Unconfined	Dry	Dry	Dry	Dry	Dry	Dry
Pz11-D	Coal Seam P08	55-58	Confined	11.78	12.00	12.20	207	207	207

* - The standing water level relative to AHD has been determined from GPS location of the bores and the 1m topographical contours for the site. The bores will be accurately surveyed at a later date, however the current accuracy of +/- 1m is sufficient for determination of groundwater level and flow direction.

The main factors influencing natural groundwater levels are groundwater recharge, evapotranspiration, and regional flow patterns. The low number of groundwater wells in the area indicates that groundwater extraction is unlikely to have had a significant impact on historical regional groundwater levels. On a time-frame of years and decades, land-use and land-cover changes may have significantly altered the natural water-balance and groundwater levels. The typical impact in Australia has been a tendency towards deforestation and greater net recharge and therefore higher water-tables.

7.1.2.1 Quaternary Alluvial, Tertiary Sediment and Tertiary Basalt Aquifers

The depth to water in monitoring wells installed on-site in the Quaternary alluvium aquifer as part of this EIS were typically less than 15 metres below ground level (mbgl). The depth to water on-site in the Tertiary basalt aquifer was less than 30 mbgl. No depth to groundwater information exists for the Tertiary sediment at this time as the Tertiary sediment encountered during groundwater monitoring well installation was shallow and dry. The Tertiary aquifers are however likely to be similar to the depth to groundwater in the Quaternary alluvium and basalt aquifers in areas where there is thicker Tertiary sediment accumulation.

Due to the heterogeneity and discontinuity of the Quaternary alluvial aquifers and Tertiary sediment and basalt aquifers, the groundwater flow direction cannot be determined on a regional scale for these aquifers. The groundwater flow direction is likely to be topographically controlled, flowing from higher elevations to lower elevations. The groundwater level in the Cherwell Creek alluvium falls from approximately 218 to 212 mAHD as it traverses the site (Pz08-S to Pz07-S), indicating that groundwater will generally flow along the line of the creek. The groundwater level in the basalt in the north of the site falls in a northerly direction from approximately 220 to 214 mAHD (Pz03-S to Pz02).

Limited data exist on the seasonal fluctuations of groundwater level within the Tertiary or Quaternary aquifers. Water level information collected over the nine months of monitoring showed a variation in water level of less than 1 m. However due to the shallow depth of these aquifers, they are expected to show a relatively rapid response to rainfall in areas where the coarser sediments or fractured basalt are exposed and no substantial clay barriers occur in the shallow sub-surface.

7.1.2.2 Permian Strata Aquifers

The groundwater flow direction in the coal seam aquifers north of Cherwell Creek appears to be from west to east across the site as shown in Figure 7.4. This flow direction is consistent with recharge to the coal seams occurring at the subcrops in the west of the site. The flow direction has been altered locally with groundwater flow towards the existing open cut pits in the Peak Downs Mine to the south of Cherwell Creek.

Limited data exist on the seasonal fluctuations of groundwater level within the Permian aquifers. Water level information collected over the nine months of monitoring showed a variation in water level generally of less than 1 m. Due to the depth and confined nature of these aquifers, they are expected to show a subdued response to recharge.

7.1.2.3 Effects of Geological Structures on Groundwater Flow Patterns

The effects of faults and dykes on local and regional groundwater flow patterns are not known, but could be substantial. Faults may either restrict or enhance flow, depending on the transmissivity of the fault zones, which is not possible to predict with the current level of information.

7.1.3 Groundwater Use

In Queensland, a number of areas have been declared as subartesian areas under the *Water Act 2000* which is administered by DERM. The project site is within the Highlands Declared Subartesian Area and there is a requirement for all wells in this area to be licensed with an allocation by the DERM for uses other than stock and domestic supply. In Queensland, all wells deeper than 6 m, including monitoring wells, must be constructed by, or under the supervision of, a licensed water bore driller who has the correct endorsements on their licence for the type of activity being performed. It is a requirement of the *Water Act 2000* that a licensed water bore driller submit the records of the drilling and installation of a water well to DERM within 30 days of completion of the well. These records are entered in the DERM database.

Thirteen groundwater bores have been installed and registered within a 10 km radius of the proposed project site. Data on registered bores within the vicinity of the project site are presented in the accompanying technical report (Appendix J) and their locations are shown on Figure 7.1. Of the 13 groundwater bores installed, 9 have been installed for private use, and 4 have been installed by DERM for groundwater monitoring and assessment. Of the nine bores installed for private use, none have been installed in the Moranbah Coal Measures, four have been installed in the Back Creek Group underlying the coal measures to the west of the site, four have been installed to unknown depth by Mitsubishi Gas Company (MGC) for coal seam gas exploration, and one (RN 103210) has been installed into the Fort Cooper Coal Measures overlying the Moranbah Coal Measures.

Of the bores recorded in the DERM database, the following have water yield or quality information recorded:

- Bore RN 38418 installed in the Back Creek Group to the west of the site had an estimated yield of 0.9 L/s of ‘brackish’ water;
- Bore RN 85499 installed in the Back Creek Group to the west of the site had a yield of 4.53 L/s of water with a salinity of 1,887 to 2,220 µS/cm; and
- Bore RN 103210 installed in the Fort Cooper Coal Measures to the east of the site had a yield of 0.78 L/s of ‘potable’ water.

No information on sustainability of the bore yields is available. Local groundwater use is primarily for livestock watering purposes owing to the variable salinity levels and generally low yields.

7.1.4 Groundwater Quality

Groundwater chemistry samples were collected from the monitoring wells installed around the site as discussed in Appendix J, Section 4.4. The physico-chemical results have been summarised and presented in Table 7.3, and the laboratory analytical results in Table 7.4.

Table 7.3 Groundwater Physico-Chemical Parameters

Bore ID	Aquifer Type	EC (µS/cm)			pH		
		June 2008	**September 2008**	**February-March 2009**	**June 2008**	**September 2008**	**February-March 2009**
Pz01	Coal Seam D04	PDMW	PDMW	15,610	PDMW	PDMW	6.87
Pz02	Basalt	2,580	1,540	2,180	7.94	NR	7.87
Pz03-S	Basalt	13,520	12,470	10,930	6.78	NR	6.96
Pz03-D	Coal Seam D04	19,970	21,450	16,570	7.10	NR	6.72
Pz04	Coal Seam Q	1,529	1,107	1,111	6.74	NR	6.66
Pz05	Coal Seam D04	PDMW	PDMW	13,630	PDMW	PDMW	7.21
Pz06-S	Basalt	NR	1,639	1,688	7.73	NR	7.67
Pz06-D	Coal Seam P02	1,691	1,981	1,813	6.81	NR	6.89
Pz07-S	Alluvium	NR	351	443	6.35	NR	6.51
Pz07-D	Coal Seam Q01	NR	3,890	3,960	6.84	NR	7.15
Pz08-S	Alluvium	NR	1,861	2,129	6.49	NR	6.99
Pz08-D	Sandstone Interburden	NR	12,510	11,380	6.43	NR	6.83
Pz09	Coal Seam P08	PDMW	12,510	9,790	PDMW	7.15	7.26
Pz10	Coal Seam H08	PDMW	9,090	Destroyed	PDMW	7.24	Destroyed
Pz11-D	Coal Seam P08	PDMW	8,650	7,220	PDMW	7.62	7.47
ANZECC (2000) Water Quality Guidelines for Livestock (Beef Cattle) Drinking Water[1] Upper limits Some reluctance to drink No adverse affects		 7,500 – 15,000 6,000 – 7,500 0 – 6,000					

NR – Not reported due to equipment failure. An undetected fracture of the glass bulb of the pH probe caused pH readings of approximately pH 4 which are inconsistent with the nature of the aquifers and the pH recorded during the previous monitoring round.
PDMW – Not reported due to suspected poor development of monitoring well.
1 – Electrical Conductivity value based on guideline value of Total Dissolved Solids value for livestock (EC [µS/cm] = 1.5 × TDS [mg/L]).

Poor development and purging of five of the monitoring wells during the first round of sampling and two of the monitoring wells during the second round of sampling is suspected due to inconsistent salinity and dissolved solids compared to the third sampling round. It is believed that water used for flushing the screens during development of these monitoring wells was not completely removed from the surrounding aquifer prior to the first round of sampling. An undetected fracture of the glass bulb of the pH probe during the second monitoring round caused erroneous pH readings (approximately pH 4) after the first day of sampling, which are inconsistent with the nature of the aquifers and the pH recorded during the previous monitoring round.

The physico-chemical results indicate the water chemistry is typically of near neutral pH for all formations. The coal seam and basalt formation groundwaters have a variable salinity level (measured as electrical conductivity), ranging from brackish to saline, while the alluvium groundwaters are fresh to brackish.

The laboratory analytical results indicate that sodium is the dominant cation in the groundwater from all monitoring wells apart from Pz07-S in the alluvium which is calcium dominant. The dominant anion is chloride in monitoring wells in the coal measures (Pz01, Pz03-D, Pz05, Pz07-D, Pz08-D, Pz09, Pz10 and Pz11), basalt (Pz03-S) and alluvium (Pz08-S) while the dominant anion is bicarbonate in the other monitoring wells in the coal measures (Pz04 and Pz06-D), basalt (Pz02 and Pz06-S) and alluvium (Pz07-S).

Table 7.4 Summary of Groundwater Quality Compared to Guideline Values

Parameter	Guidelines			Permian Coal Measures				Quaternary Basalts				Tertiary Alluvium			
	ANZECC (2000) and QWQG (2006) - Freshwater Ecosystems[1]	ANZECC (2000) - Livestock Drinking Water[2]	ADWG (2004) - Human Drinking Water[3]	Count[4]	Min (mg/L)	Median (mg/L)	Max (mg/L)	Count[4]	Min (mg/L)	Median (mg/L)	Max (mg/L)	Count[4]	Min (mg/L)	Median (mg/L)	Max (mg/L)
Major Ions															
Sodium	ne	ne	ne	23	187	1280	3600	9	220	319	2250	6	6	131	288
Calcium	ne	1,000	ne	23	29	275	475	9	29	42	203	6	27	42.5	105
Magnesium	ne	ne	ne	23	11	137	708	9	33	77	571	6	16	32.5	82
Potassium	ne	ne	ne	23	<1	9	42	9	4	8	14	6	6	12.5	23
Chloride	ne	ne	ne	22	135	2520	7400	9	114	336	4810	6	26	188	695
Sulphate	ne	1,000	500	22	3	363	1350	9	30	94	497	6	6	49.5	136
Bicarbonate Alkalinity as $CaCO_3$	ne	ne	ne	22	79	466	680	9	462	554	896	6	127	203	348
Carbonate Alkalinity as $CaCO_3$	ne	ne	ne	22	<1	<1	21	9	<1	<1	<1	6	<1	<1	<1
Hydroxide Alkalinity as $CaCO_3$	ne	ne	ne	22	<1	<1	<1	9	<1	<1	<1	6	<1	<1	<1
Fluoride	ne	2	1.5	5	0.2	0.2	0.4	3	0.2	0.6	1.4	2	0.3	0.3	0.3
Nutrients															
Ammonia as N	0.01	ne	ne	18	0.19	1.345	2.77	6	0.04	0.13	0.5	4	<0.01	0.03	0.16
Nitrite + Nitrate as N	0.015	ne	ne	23	<0.01	<0.01	0.26	9	<0.01	<0.01	0.93	6	<0.01	0.015	0.08
Total Kjeldahl	ne	ne	ne	18	0.3	2.05	3.8	6	<0.1	0.2	0.7	4	<0.1	3.25	25.4

Parameter	Guidelines			Permian Coal Measures				Quaternary Basalts				Tertiary Alluvium			
	ANZECC (2000) and QWQG (2006) - Freshwater Ecosystems[1]	ANZECC (2000) - Livestock Drinking Water[2]	ADWG (2004) - Human Drinking Water[3]	Count[4]	Min (mg/L)	Median (mg/L)	Max (mg/L)	Count[4]	Min (mg/L)	Median (mg/L)	Max (mg/L)	Count[4]	Min (mg/L)	Median (mg/L)	Max (mg/L)
Nitrogen as N															
Total Nitrogen as N	0.25	ne	ne	18	0.3	2.05	4	6	<0.1	0.5	1	4	<0.1	3.3	25.4
Total Phosphorus as P	0.03	ne	ne	18	0.01	0.165	3.13	6	0.23	1.225	10	4	0.12	1.68	3.72
Reactive Phosphorus as P	0.015	ne	ne	5	<0.01	<0.01	0.023	3	<0.01	<0.01	0.01	2	<0.01	0.0105	0.011
Metals (Dissolved)															
Aluminium	0.055	5	ne	18	<0.01	0.015	0.03	6	<0.01	0.015	0.03	4	<0.01	0.025	0.04
Antimony	ne	ne	0.003	18	<0.001	<0.001	0.001	6	<0.001	<0.001	0.004	4	<0.001	<0.001	<0.001
Arsenic	0.013	0.5	0.007	23	<0.001	<0.001	0.007	9	<0.001	<0.001	0.006	6	<0.001	<0.001	<0.001
Barium	ne	ne	0.7	23	0.025	0.061	0.398	9	0.055	0.09	0.186	6	0.082	0.156	0.272
Beryllium	ne	ne	ne	23	<0.001	<0.001	<0.001	9	<0.001	<0.001	<0.001	6	<0.001	<0.001	<0.001
Boron	0.37	5	4	18	<0.05	0.335	3.17	6	0.24	0.285	1.28	4	0.07	0.235	0.46
Cadmium	0.0002	0.01	0.002	23	<0.0001	<0.0001	0.0006	9	<0.0001	<0.0001	0.0002	6	<0.0001	<0.0001	0.0002
Chromium	0.001	1	0.05	23	<0.001	0.002	0.013	9	<0.001	0.002	0.014	6	<0.001	<0.001	0.004
Cobalt	ne	1	ne	23	<0.001	<0.001	0.002	9	<0.001	<0.001	0.037	6	<0.001	<0.001	0.006
Copper	0.0014	1	2	23	<0.001	<0.001	0.003	9	<0.001	<0.001	0.002	6	<0.001	<0.001	<0.001
Gallium	ne	ne	ne	18	<0.001	<0.001	<0.001	6	<0.001	<0.001	<0.001	4	<0.001	<0.001	<0.001
Iron	ne	ne	ne	18	0.4	1.215	4.08	6	<0.05	0.17	1.38	4	<0.05	0.17	0.63
Lead	0.0034	0.1	0.01	23	<0.001	<0.001	0.001	9	<0.001	<0.001	0.004	6	<0.001	<0.001	0.001

Parameter	Guidelines			Permian Coal Measures				Quaternary Basalts				Tertiary Alluvium			
	ANZECC (2000) and QWQG (2006) - Freshwater Ecosystems[1]	ANZECC (2000) - Livestock Drinking Water[2]	ADWG (2004) - Human Drinking Water[3]	Count[4]	Min (mg/L)	Median (mg/L)	Max (mg/L)	Count[4]	Min (mg/L)	Median (mg/L)	Max (mg/L)	Count[4]	Min (mg/L)	Median (mg/L)	Max (mg/L)
Lithium	ne	ne	ne	18	0.002	0.416	0.81	6	0.014	0.0825	0.278	4	0.025	0.09	0.182
Manganese	1.9	ne	0.5	23	0.009	0.134	1.09	9	0.123	0.399	2.73	6	<0.001	0.08	0.673
Mercury	0.00006	0.002	0.001	23	<0.0001	<0.0001	0.0001	9	<0.0001	<0.0001	<0.0001	6	<0.0001	<0.0001	<0.0001
Molybdenum	ne	0.15	0.05	18	<0.001	<0.001	0.004	6	0.002	0.013	0.026	4	<0.001	<0.001	<0.001
Nickel	0.011	1	0.02	23	<0.001	0.006	0.02	9	0.002	0.019	0.041	6	<0.001	<0.001	0.005
Selenium	0.005	0.02	0.01	18	<0.01	<0.01	0.038	6	<0.01	<0.01	0.024	4	<0.01	<0.01	<0.01
Strontium	ne	ne	ne	18	0.233	7.31	47.3	6	0.558	1.32	6.35	4	0.233	0.4175	0.749
Thorium	ne	ne	ne	18	<0.001	<0.001	<0.001	6	<0.001	<0.001	<0.001	4	<0.001	<0.001	<0.001
Titanium	ne	ne	ne	18	<0.01	<0.01	0.02	6	<0.01	<0.01	<0.01	4	<0.01	<0.01	<0.01
Uranium	ne	0.2	0.02	18	<0.001	<0.001	0.006	6	<0.001	0.0025	0.013	4	<0.001	0.0015	0.003
Vanadium	ne	ne	ne	23	<0.01	<0.01	<0.01	9	<0.01	<0.01	0.01	6	<0.01	<0.01	<0.01
Zinc	0.008	20	ne	23	<0.005	0.006	0.037	9	<0.005	0.011	0.018	6	<0.005	0.0055	0.01

1 – ANZECC/ARMCANZ (2000) and QWQG (2006) trigger values for moderately disturbed upland stream freshwater ecosystems

2 – ANZECC/ARMCANZ (2000) guidelines for livestock watering of beef cattle

3 – ADWG (2004) health based guidelines for drinking water

4 – Number of samples

ne – No guideline value established

7.1.5 Assessment of Environmental Value

The EPP (Water) identifies environmental values of groundwater to be protected or enhanced in Queensland. The existing groundwater environment has been assessed against these environmental values.

7.1.5.1 Biological Integrity of a Pristine or Modified Aquatic Ecosystem

The local area around the project site has been cleared and used for agriculture, predominantly beef cattle grazing, since at least 1957. These farming practices modify the landscape, affecting the volume and rate of runoff, the flow characteristics of the creeks, and the recharge to groundwater. As such, the aquatic ecosystems of the area have been modified.

Water available to ecosystems may include a mix of groundwater with soil water (unsaturated zone) and surface water. Groundwater Dependant Ecosystems (GDEs) are ecosystems which have their species composition and natural ecological processes determined in part by groundwater. The groundwater parameters that sustain GDEs are flux, level, pressure and quality, with dependence potentially being a function of one or all of these factors.

The water level measurements undertaken for as part of the EIS indicate that the water table within the alluvium of Cherwell Creek is approximately 13 to 14 mbgl, and that other areas of alluvium may be dry. The water level in the coal measures is between 8 and 67 mbgl and the water table in the basalt is approximately 25 to 26 mbgl. These depths to groundwater, and the lack of springs or seeps in the area, indicate that GDEs are not likely to exist in the vicinity of the site. The vegetation species and regional soil/geology types suggest that the level of groundwater dependence is likely to be relatively low and vegetation is likely to be able to satisfy plant water requirements using retained soil moisture.

The groundwater analytical results, as presented in Table 7.4, have been assessed against the ANZECC (2000) and Queensland (2006) water quality guidelines (for the protection of moderately disturbed freshwater ecosystems, central region, upland streams) to consider the potential effect of discharge of groundwater into surface water bodies. The assessment of groundwater quality using surface water guideline values has an inherent level of conservatism due to the assumptions made regarding the behaviour, fate and transport of the analytes detected in groundwater and the subsequent effects in the surface water ecosystem. The existing concentrations of some dissolved metals and nutrients in the groundwater are above the water quality guidelines for freshwater ecosystems. Exceedence of a guideline value does not indicate that an impact has occurred or is likely to occur.

7.1.5.2 Suitability for recreational use

This category of environmental values is considered not applicable to groundwater. There are no groundwater springs or seeps that supply surface water bodies in the area that are used for recreational use.

7.1.5.3 Suitability for minimal treatment before supply as drinking water

The groundwater analytical results, as presented in Table 7.4, have been assessed against the Australian Drinking Water Guidelines (2004) to consider the potential health effects of drinking minimally treated groundwater. The water quality from the monitoring wells indicates that in general, the water is unsuitable for human consumption. This is due to elevated levels of sulphate and some dissolved metals (manganese, nickel and selenium) in some of the groundwaters. The groundwaters also generally have elevated levels of salinity (>1,000 mg/L) which are above the guideline for aesthetics based on unsatisfactory taste. The ease of obtaining a mains-water or rainwater tank supply, and the generally low yield of the water bores in the area, are also factors which preclude the usage and potential for usage of the groundwater as a drinking water source.

7.1.5.4 Suitability for primary industry use

The number of registered bores in the area indicate that water quality suitable for some agricultural use is obtainable.

Use of groundwater within the area is generally as drinking water for beef cattle. The groundwater has been assessed against the ANZECC (2000) guidelines for stock drinking water quality for beef cattle to consider the potential effect of drinking of groundwater by stock. Compared to the ANZECC (2000) guidelines, groundwater present within the monitoring wells is generally useable for livestock drinking water. The groundwater from some monitoring wells has a slightly elevated level of sulphate and/or selenium above the guideline values. The salinity of the groundwater in some of the monitoring wells, as shown in Table 7.3, is above the upper limit for beef cattle, which would cause some loss of production and deterioration in animal health.

The generally low sustainable yield of the water bores in the area precludes the usage and potential for usage of the groundwater as a source of irrigation water or water for aquaculture or the production of aquatic foods.

7.1.5.5 Suitability for industrial use

It is believed that there are no industrial users of the groundwater within the local area. The potential for industrial usage of the water is considered to be greater than that for either agricultural or drinking water usage. Industrial users generally have the capital required to drill and equip bores and if necessary appropriately treat the water before use. However, industrial users tend to require large volumes of water which would be unsustainable in the area due to the low sustainable yield of the aquifers.

7.1.5.6 Maintenance of Cultural and Spiritual Values

There are no known groundwater springs or seeps that supply surface water bodies in the area that may have significant indigenous and/or non-indigenous cultural heritage.

7.2 Potential Impacts and Mitigation Measures

The impacts on groundwater from the development, operation, closure and post-closure of the Caval Ridge Mine have been evaluated.

7.2.1 Potential Impacts during Development and Operation

The Caval Ridge Mine is located adjacent to the BMA operated Peak Downs Mine, along the strike of the Moranbah Coal Measures. Given the close proximity of the two coal mines, this assessment considers the cumulative impact of both mines on the surrounding groundwater resources.

The only other existing mine within a 10 km radius of the Caval Ridge Mine is the Isaac Plains Mine operated by Vale Australia Pty Ltd. This mine is located approximately 8 km north-east of the project site. An EIS has been prepared and submitted for the Integrated Isaac Plains Project, a proposed extension to the Isaac Plains Mine to be located 7 km east of the Caval Ridge Mine.

The Eagle Downs Coal Mine Project, for which an EIS has not yet been submitted by the proponent Bowen Central Coal Joint Venture Parties, is located approximately 3 km east of the Caval Ridge Mine. The Grosvenor Coal Mine Project, for which an EIS has not yet been submitted by the proponent Anglo Coal (Grosvenor) Pty Ltd, is located approximately 5 km north of the proposed Caval Ridge Mine. Neither of these proposed developments have been included in the assessment of cumulative impacts as their EIS' were not available for review.

The locations of these proposed and existing mines are shown on Figure 4.28.

7.2.1.1 Impacts on Regional Groundwater Levels

The project site is within the declared Highlands Subartesian Management area; however limited information is available on groundwater users locally. From a search of the DERM groundwater database, 13 registered bores are located within 10 km of the site boundary as discussed in Section 7.1.3.

Impacts on Permian Formation Aquifers

A good indicator for evaluating the potential impacts of the proposed mine on the groundwater regime is to compare historical and current impacts of the existing mining operations in the area.

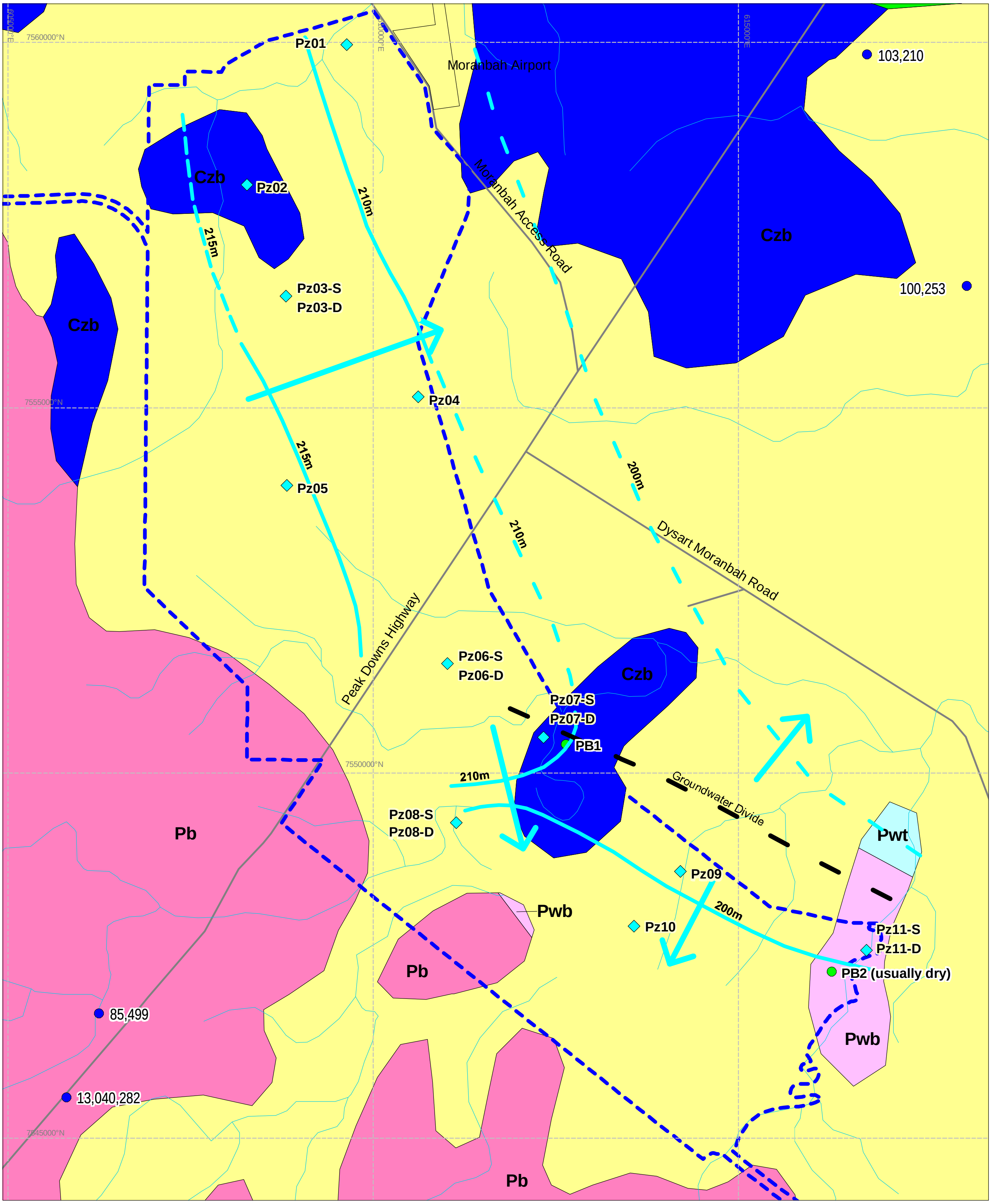
While the main aquifers within the area are associated with the coal seams, inflow from the seams to the current open cut pits at Peak Downs Mine have not been significant. Dewatering in advance of mining is generally not required at the Peak Downs Mine. When wet conditions in the pit (following rainfall) inhibit mining, water is removed from the pit floor by pumping from in-pit sumps. The water collected from these sumps may contain some groundwater inflow but mainly comprises rainwater (direct rainfall and catchment run-off).

Groundwater ingress into the pits will cause drawdown around the pits, which in turn causes regional groundwater levels to lower as seen around the existing Heyford Pit of the Peak Downs Mine, (Figure 7.4). Following the cessation of mining, groundwater will continue to discharge to the final voids until water levels within the surrounding aquifers recover to an equilibrium with the new hydrological regime.

In order to assess the possible impacts of the proposed mining operations on the groundwater resources an estimate of groundwater inflows, and thus dewatering / discharge requirements, was calculated. This estimate is based on the hydrogeological conceptualisation and an assumption of the final pit size as discussed in Appendix J, Section 5.

The available information indicates that the vertical hydrogeology within the Permian formation can be divided into three main zones:

- Zone 1 – the upper weathered overburden which based on drilling results is assumed to act as an aquitard.
- Zone 2 – the interburden sandstone and siltstone which has a permeability an order of magnitude lower than the coal seams and is estimated to be up to 150 m thick.
- Zone 3 – the coal seams with a coalesced thickness of up to 30 m.



0 1 2km

Scale 1:75,000 (A4)

Datum: AGD84, AMG Zone 55

Czb	Undifferentiated Tertiary Basalts	◇	Monitoring Wells Installed
Czr	Undifferentiated Tertiary Sediments	● (green)	Monitoring Wells - Peak Downs
Pwt	Fair Hill Formation	● (blue)	DNRW Registered Bore
Pwb	Moranbah Coal Measures	Pb	Geological Boundary and Geological Regime
Pb	Back Creek Group		Project Site
200m	Groundwater Contour	200m	Groundwater Contour (Inferred)
	Groundwater Divide		Groundwater Flow Direction

Source: Client Supplied Data (December 2007),
Qld Gov. DME Geological Mapping, 2007

Client: BMA — BHP Billiton Mitsubishi Alliance

URS

Project: CAVAL RIDGE PROJECT
ENVIRONMENTAL IMPACT STATEMENT

Title: **GROUNDWATER ELEVATION CONTOURS OF PERMIAN MORANBAH COAL MEASURES**

Drawn: VH	Approved: RS	Date: 15-05-2009	Figure: **7.4**
Job No: **4262 6158**	File No: 42626158-g-573b.wor		Rev:B A4

Based on these assumptions, Table 7.5 presents a summary of the range of groundwater ingress volumes calculated for the Horse Pit and Table 7.6 presents a summary of the range of groundwater ingress volumes calculated for the Heyford Pit at the maximum extent and depth of mine development.

Table 7.5 Groundwater Ingress Data for Horse Pit

Zone	Saturated thickness	K (m/day)	Radius of Drawdown Impact (m)	Ingress (m^3/day)
Interburden (expected)	150	0.03	265	19,100
Interburden (low case)	150	0.003	84	5,800
Interburden (high case)	150	0.3	839	67,100
Coal Seams (expected)	30	0.17	126	8,800
Coal Seams (low case)	30	0.017	40	2,700
Coal Seams (high case)	30	1.7	399	29,500

Table 7.6 Groundwater Ingress Data for Heyford Pit

Zone	Saturated thickness	K (m/day)	Radius of Drawdown Impact (m)	Ingress (m^3/day)
Interburden (expected)	150	0.03	265	15,300
Interburden (low case)	150	0.003	84	4,600
Interburden (high case)	150	0.3	839	55,000
Coal Seams (expected)	30	0.17	126	7,000
Coal Seams (low case)	30	0.017	40	2,200
Coal Seams (high case)	30	1.7	399	23,800

As the pit depth increases, the inflow rate into the pit void increases. The expected total ingress (sum of interburden and coal seam ingress) at the maximum extent and depth of mine development (end of mine life) will be ± 27,900 m^3/day (high case up to ± 96,600 m^3/day) for the Horse Pit and ± 22,300 m^3/day (high case up to ± 78,800 m^3/day) for the Heyford Pit. These ingress rates equate to ± 2 m^3/day (high case up to ± 7 m^3/day) per metre of the circumference of both the Horse Pit and Heyford Pit. This ingress rate is conservative in that it is calculated for an equivalent well at steady state in an infinite homogeneous aquifer and assumes drawdown to the base of the pit. In reality the mine pits are located in or close to the outcrop of the coal seams such that ingress to the pit from upgradient of the pit will be negligible, and the seepage face on pit walls will be above the base of the pit, which will decrease the expected ingress into the pits by at least a half of that calculated. Seepage into the pits will be collected in in-pit sumps and used for dust suppression or as process water where suitable.

The radius of influence of the drawdown of the groundwater level (distance to negligible drawdown) is also calculated to extend up to approximately 800 m down dip from the high wall and along strike from the end wall of the pits. This radius of influence is calculated for an equivalent well at steady state in an infinite aquifer. In reality the mine pits are located in the recharge area of the coal seams such that recharge to the coal seams will be reduced, which will have an additional impact on the extent of drawdown of groundwater levels. The extent of the radius of influence of the current Heyford Pit extends approximately 1,800 m from the highwall. The radius of influence of the proposed pits is thus expected to be in the order of 1,800 m, taking into account the reduction of recharge to the coal measures.

The Peak Downs Mine is located along the strike of the Moranbah Coal Measures to the south of the project site. The cumulative impact of the Peak Downs Mine and the proposed Caval Ridge Mine will be to superimpose the drawdown of each mine along strike, resulting in a greater drawdown between the mines. No groundwater users were identified between the mines. The drawdown of the mines down-gradient of each mine will be as a result of that particular mine such that there will be no cumulative impact of drawdown on groundwater levels.

The Integrated Isaac Plains Project, a proposed extension to the Isaac Plains Mine, located 7 km east of the Caval Ridge Mine site proposes to extract coal from the Permian Rangal Coal Measures. The Rangal Coal Measures overlie and are separated from the Moranbah Coal Measures by the Fort Cooper Coal Measures. The low vertical permeability of the Moranbah and Rangal Coal Measures and the separation by the Fort Cooper Coal Measures would limit vertical flow between these formations such that the cumulative impact of the drawdown in the Moranbah Coal Measures due to the proposed Caval Ridge Mine would be negligible in the Rangal Coal Measures.

The groundwater wells identified on neighbouring properties are greater than 2 km from the site, thus it is anticipated that the proposed mine activities and subsequent groundwater drawdown will not have a significant impact on the regional groundwater users of the Permian aquifers.

Impacts on Tertiary and Quaternary Aquifers

All creeks within the project site are ephemeral and there are no perennial water holes or groundwater dependant environments present as discussed in Section 7.1.5. Under dry season conditions, groundwater does not contribute to surface water flow within these creeks. In exceptionally wet years it is possible that the Quaternary alluvium and shallow Tertiary aquifers may contribute some groundwater to the surface water system along water courses. The drawdown of the potentiometric surface of the Permian strata aquifers during mining is unlikely to have an impact on these discharges as the shallow aquifers sit above, and are generally poorly connected to, the aquifers below.

If the pits encounter the Quaternary alluvium, pit inflow will occur. Due to their shallow depth and lack of continuity and thickness, the Quaternary alluvium is not considered a significant aquifer. However, during periods of creek flow, the alluvium may become fully saturated and discharge to the pits.

Based on the heterogeneity and discontinuous nature of the Tertiary basalt, it is anticipated that the project activities will not have a significant impact on the isolated areas of basalt. No regional groundwater users of the Tertiary basalt aquifers were identified.

7.2.1.2 Impacts on Groundwater Quality

The groundwater quality of the Permian strata is brackish to brine and not suitable for human consumption or irrigation, but has some use for stock water (according to the Australian Drinking Water Guidelines (2004) and Australian and New Zealand Guidelines for Fresh and Marine Water Quality (2000)).

During mining operations, water quality within aquifers surrounding the site are not expected to change from pre-mining conditions. This is expected for the following reasons:

- During mining operations, groundwater will be continually extracted from the open cut pit to ensure a safe working environment within the pit. Extraction of groundwater from the pit will create a depression in the potentiometric (groundwater) surface at this location, and groundwater surrounding the mine pit will travel towards this depression. The net movement of groundwater towards the pit during mine operation will prevent the movement of potentially poorer quality water (that may have been impacted by mining) from moving away from the mine operation area and into the surrounding aquifers.
- Aquifers outside of the mine pit area will continue to receive recharge via the same processes that occurred pre-mining.

Groundwater quality data also suggests that groundwater in the alluvial aquifers and basalt are of similar or better quality compared to the Moranbah Coal Measures with respect to major ions and metals. Hence any inadvertent mixing of groundwater (during mining) by downward movement from the upper to lower aquifers is unlikely to result in a deterioration of water quality in either aquifer but lead to an improvement in water quality in the deeper aquifers.

During mine operation, water quality within aquifers surrounding the mine pit will continue to be suitable for the same purposes applicable during the pre-mining period.

A geochemical assessment was undertaken for the project site and is included in Section 5. The geochemical assessment found that not only are almost all mineral waste materials (overburden and CHPP rejects) NAF, but the high ANC of many of the samples combined with the very low sulphur concentrations, indicates there would be excess alkalinity to buffer the small quantity of acid that could potentially be produced. As the direction of groundwater flow is expected to be towards the pit, the buffering capacity of the groundwater is expected to neutralise any oxidation products of the coal seams due to mine dewatering, and any potential for the development of acid mine drainage is low.

The geochemical assessment found that the water extracts from all composite samples of mineral waste have soluble metal concentrations below applied ANZECC (2000) values for livestock drinking water. It also found that the EC of the materials is moderate to high, ranging from 388 to 1,970 µS/cm (median 679 µS/cm), and is similar for both overburden and potential rejects. This range of electrical conductivity is comparable to the low end of salinity found in the site groundwater monitoring wells (351 to 1,861 µS/cm in the alluvium) and indicates that initial water solubility of these materials with respect to salinity in mineral waste materials from Caval Ridge Mine may contribute some salt load to the shallow groundwater through seepage from the waste or CHPP.

The quality of the groundwater in the shallow aquifers that may exist within the project site (i.e. Quaternary alluvium and Tertiary sediments) have the potential to be impacted by chemical or fuel storage facilities. The risks from chemical or fuel storage will be minimised by implementation of the contractor's construction environmental management plan and site environmental management plan described in Appendix Q, Section 3.4.

The groundwater quality within the aquifers surrounding the project site will be monitored to ensure no marked deterioration in groundwater is occurring as a result of the proposed mining activities.

7.2.1.3 Other Impacts

Compression of the ground surface associated with the construction of roads and building foundations is not expected to greatly alter the permeability of strata immediately beneath the site, and as such will not markedly hinder the recharge of the underlying aquifers.

During mining, mobile and stationary machinery including excavators, cranes, trucks and other vehicles will be required. There is potential for hydrocarbon contamination of the soil associated with leaks or spills from this machinery (or fuel storage areas for the maintenance of machinery). Dissolved and free-phase hydrocarbon may impact on the shallow aquifers underlying and down-gradient of areas of fuel spillage.

Areas of hydrocarbon and chemical storage will have spill control measures and regular inspection regimes in order to prevent and monitor activities that could potentially lead to contamination of groundwater. Spill control measures for hydrocarbon facilities will include concrete slab bases that are bunded with oil-water separators installed on all permanent hydrocarbon above-ground storage, refuelling and washdown areas.

Any accidental spills will be assessed on a case-by-case basis and remediated, which may include excavation and disposal of any contaminated soil in accordance with the requirements of the DERM.

There may be instances of groundwater restrictions where subsurface permanent structures (building foundations, road embankments) are constructed. This type of subsurface construction can cause groundwater flow to be impeded and pressure heads to build up on the up-gradient area and reduced down-gradient. Pressure head relief engineering solutions will be utilised in subsurface constructions, where required.

7.2.2 Potential Impacts Post Mining

The main features of the final landform after mining ceases will consist of waste dumps to the west, and final voids in the east. The final voids will collect and accumulate water from groundwater ingress through the walls of the final void and from areas of backfill material, direct rainfall into the void and from overland surface flows from the slopes of the waste dumps draining into the void. Typically, the final void will contain long-term water levels and water quality dependent on a number of inter-related hydrological and geochemical processes.

A final void study has not been conducted as part of the EIS. It is recommended that a final void study be undertaken towards the end of mine life to determine backfill and contouring requirements for the final voids, the hydrological regime of the final voids, and the expected water quality of the final voids.

Areas of backfill within the pits will have a higher porosity and permeability than the pre-existing Permian strata, forming unconsolidated and unconfined aquifers. These aquifers will be recharged by rainfall and overland flow, and may interact through lateral flow with the adjacent Permian strata aquifers and the final voids.

7.2.2.1 Impacts on Regional Groundwater Levels

After mining is completed, the groundwater system will re-adjust to the new aquifer conditions surrounding the mined area. Water levels/pressures within the regional aquifers will over time attain a new equilibrium level. This new equilibrium for the groundwater system will have a different potentiometric surface from that which was present pre-mining owing to the presence of final voids in the east of the mined area and the different hydrogeological parameters of the backfilled waste material.

Water levels in the pit void will determine whether the void will act as a net groundwater source (if final void water levels are high relative to groundwater levels surrounding the void) or act as a net groundwater sink (if final void water levels are low relative to groundwater levels surrounding the void). Given the climate of the area is semi-arid, experience suggests that a final void water level will form, but the evaporative demand will result in the void behaving as a groundwater sink. Continued evaporation will also produce a rising salinity concentration.

This is likely to result in residual drawdown immediately surrounding the final void area when the potentiometric surface reaches the new equilibrium level. In the Moranbah Coal Measures, drawdown of the potentiometric surface close to the final voids at the cessation of mining is likely to begin to recover immediately following cessation of mining. This initial rise in the potentiometric surface close to the pits is related to the likely rise in the water levels within the final voids as dewatering from in-pit sumps is stopped.

In contrast, outside the immediate vicinity of the final void, the potentiometric surface is likely to continue to fall in the near term following cessation of mining as the groundwater system adjusts to new regional aquifer conditions. This drop in water level at distances away from the final voids (post-mining) occurs as a result of a flattening of the regional hydraulic gradient, as the groundwater system moves towards its new equilibrium state.

7.2.2.2 Impacts on Groundwater Quality

A rise in the final void water salinities may result from evaporative concentration processes, and from atmospheric weathering of excavated exposed bedrock. Although water quality in the final void is expected to deteriorate over time, this deterioration in water quality is not expected to impact the surrounding aquifers as the voids are expected to operate locally as a groundwater sink (i.e. groundwater flow will be toward the void), so that water within the void will not recharge the groundwater system unless water levels in the void rise above existing groundwater levels in the coal seams.

Current and previous geochemical analysis in the Moranbah Coal Measures lithology show the overburden, coal rejects, and fine tailings have low acid generation potential. Thus there is a low risk that metals will be mobilised from spoil and co-disposal dumps.

Post-mining water quality within all aquifers surrounding the project site is expected to remain the same as pre-mining water quality.

7.2.3 Mitigation Measures of Potential Impacts

Groundwater monitoring wells installed around the project site for this investigation, as shown in Figure 7.3, and to be installed down-gradient of potential seepage sources (locations to be determined after finalisation of site layout) will be maintained to enable the long term monitoring of groundwater levels and quality. Routine monitoring will provide early warning of any variation in response of the groundwater system to that predicted. This will enable BMA to undertake mitigation measures to minimise impact on surrounding groundwater users and the environment. In addition, the groundwater monitoring will enable the identification of any cumulative groundwater level drawdown impacts as a consequence of other mining operations in the area.

Groundwater level and quality monitoring will initially be undertaken regularly (see Section 7.2.3.1) to enable the detection of seasonal fluctuations and any groundwater level or quality trends or impacts. In turn, the monitoring data (level and chemistry) will be entered into a BMA environmental monitoring database to enable a regular assessment and interrogation to evaluate potential groundwater impacts.

Should a detrimental impact on landholder groundwater supplies be detected, and shown to be related to the Caval Ridge Mine operations, then BMA will seek to reach mutually agreeable arrangements with affected neighbouring groundwater users for the provision of alternate supplies throughout the mine life, and after mine closure. Regular groundwater monitoring will enable groundwater level drawdown to be identified prior to any impacts being experienced in surrounding landholder bores. In turn, alternative water supplies can be put in place before supplies from relevant existing landholder bores are adversely affected. Options for alternate supplies include:

- Installations of new pumps capable of extracting groundwater from greater depth within existing bores.
- Deepening of existing bores.
- Installation of a new bore at another location on the property.
- Provision of piped water sourced from the mine (i.e. surplus water from the mine pit void dewatering program, depending on quality).

The specific arrangements for affected properties will be discussed with each relevant landholder with a view to reaching a mutually acceptable agreement.

7.2.3.1 General Groundwater Monitoring Program

The following groundwater monitoring routine will be undertaken:

- Groundwater levels will be monitored monthly, in the entire monitoring network, for the first two years following the commencement of construction to assess seasonal, natural, groundwater fluctuations.
- Thereafter, groundwater levels will be monitored quarterly, preferably at a similar time of year to eliminate variation from seasonal changes.
- Groundwater sampling will be undertaken on a quarterly basis from all groundwater monitoring bores for analysis of the parameters:- pH, EC, total dissolved solids (TDS), major cations and anions, nutrients (total N, NO_x, ammonia, phosphorous) and selected dissolved metals (boron, chromium, copper, iron, manganese, nickel, selenium and zinc).
- Measurement of daily precipitation, evaporation and mine dewatering volumes.

An annual review of the monitoring program will be conducted to evaluate the effectiveness of each monitoring location, to assess where new locations and modifications to the monitoring programme may be needed, and to evaluate what impacts may be occurring. A special monitoring round will be considered in the event of a significant environmental incident.

Post-mining groundwater monitoring will be subject to detailed closure/relinquishment conditions. It is expected that during the operational phase of the project, the groundwater data collected for the region will be comprehensive enough to accurately predict the long term recovery of the aquifers and the final void water balance and water quality. The level of data required for advanced hydrologic modelling of final voids for the mine cannot practically be obtained at the pre-mining stage. The mining operation will incorporate opportunistic monitoring of temporary pit storages and groundwater within the spoil to assist in the development and calibration of a long-term predictive model. This will assist in the development and implementation of the closure strategy and the refinement of post-mining groundwater monitoring programs.

Seepage from Stockpiles and Basins

Good environmental practice requires that every reasonable effort be made to minimise the effect of seepage on the groundwater system. Potential sources of seepage, such as sediment basins and water storages, will be lined if the natural material is not of sufficiently low permeability to limit seepage. Additional mitigation measures may include installation of cut-off trenches within the foundation along the alignment of the containment embankments, installation of a seepage collection system, and during construction of the containment embankments any fracture zones identified will be treated to reduce their permeability.

An extensive water management system to prevent discharge of surface storm water contaminants to off-site water bodies is proposed in the surface water section (Section 6) of the EIS. This system will be managed as a non release system under normal operating conditions, with discharge only expected during rainfall events when water courses are underflow conditions. Stockpiles will be contained within hardstand areas and connected via open channel drains to dedicated sediment basins. The sediment basin system will be designed in accordance with criteria outlined in Section 6.

Early detection of seepage will enable management of any potential problems. Potential seepage from the sediment basins and stockpile areas will be regularly assessed through the installation and monitoring of the monitoring bore network on-site, including down-gradient of all potential contaminant sources. This will include monitoring of water in sediment basins for potential contaminants.

Installation of monitoring bores down-gradient of potential seepage sources is proposed to enable early detection of any leachate entering the shallow Quaternary alluvial or Tertiary sediment aquifers. The key indicator parameters of seepage will be monitored including (but not restricted to) standing water level, salinity (as TDS), dissolved metals, and major ions initially on a three monthly basis.

In the unlikely event of groundwater impact, mitigation strategies will include some or all of the following measures (depending on the specific requirements):

- Investigation of water management system integrity.
- Removal of contaminant source and repair/ redesign of any water management structures as required.
- Installation of and pumping from, groundwater interception wells.
- Installation of and pumping from groundwater interception trenches.

At mine closure, shaping and rehabilitation of spoil piles and infrastructure footprints will be required to limit infiltration and runoff of potentially poor quality water and to monitor the effectiveness of rehabilitation.

Hydrocarbon and Chemical Contamination

Areas of hydrocarbon and chemical storage will have spill control measures and regular inspection regimes in order to prevent and monitor construction and operational activities that could potentially lead to contamination of groundwater. Bunded areas for hydrocarbon and chemicals storage will be provided with spill cleanup kits in accordance with the relevant Australian Standards. All transfers of fuels and chemicals will be controlled and managed to prevent spillage outside bunded areas.

Potential for leaks and spills from operating equipment will be reduced by ensuring that all equipment is well maintained.

Installation and monitoring of the monitoring bore network on-site, including down-gradient of all potential contaminant sources, will enable early detection of any contaminated seepage.

Any accidental spills will be assessed on a case-by-case basis and remediated, which may include excavation and disposal of any contaminated soil to a licensed facility and installation of a groundwater monitoring and remediation system, in accordance with the requirements of the DERM.

7.2.3.2 Groundwater Management Strategies and Legislation

The project site is situated within the Highlands Subartesian Declared Area as defined under the *Water Act 2000*. The site is located within the Isaac River sub-catchment of the Fitzroy Basin. Under the Water Act, the DERM is planning to advance the sustainable management and allocation of groundwater within the Isaac River sub-catchment to provide secure supplies for both water users and the environment. When the Fitzroy Basin Water Resource Plan was finalised in 1999, no provision was made for management of the basin's groundwater resources. However, the demand for groundwater, driven mainly by mining and agriculture, in the Isaac-Connors Rivers catchment has increased significantly. The prolonged drought and record low water levels in some aquifers have raised concerns that the groundwater resource may be at risk of being overcommitted. Under provisions of the Water Act, WRP's at risk in these circumstances must be amended to regulate groundwater. Amending the Fitzroy WRP to include the groundwater resources in the Isaac-Connors catchment will enable the integrated management of the surface water and groundwater resources. The amendment will provide for the sustainable use of the groundwater resource, effective water sharing arrangements, improved definition and security of water entitlements, a framework for tradable water entitlements, water for the environment, salinity management and monitoring and reporting.

In November 2006 the minister for Natural Resources and Water announced a moratorium on the use of subartesian water contained in the alluvial aquifers of the Isaac-Connors catchment. The intent of the moratorium is to ensure the water entitlement *status-quo* remains while the draft amendment to the WRP is being developed. At the project site, the moratorium applies to:

- Subartesian water in the alluvial aquifers in the unconsolidated Quaternary deposits in the area associated with the Isaac River, the Connors River and all tributaries of those rivers.
- That part of the site that is declared as the Highlands Subartesian Area, to all applications for or about water licences to take the subartesian water mentioned above, whether made before or after the moratorium notice date.
- That part of the site that is undeclared (i.e. outside the Highlands Subartesian Area), works to take the subartesian water mentioned in the first dot point.

However, Clause 8 of the moratorium notes that the following works to take water are exempt:

- Town water supply
- Stock purposes
- Domestic purposes
- The construction, operation or maintenance of public assets and utilities
- Mining purposes, to the extent that the water is to be taken for dewatering purposes
- A significant project declared under Section 26 of the State Development and Public Works Organisation Act 1979.

The moratorium is expected to apply until the draft amendment has been finalised. In effect, the moratorium does not restrict the development of dewatering activities for the Caval Ridge Mine.

The taking of water from an aquifer within the Declared Highlands Subartesian Area is regulated by the *Water Act 2000* and *Water Regulation 2002* and requires a licence. Furthermore, construction and development of bores required to extract water from an aquifer under a licence is an assessable development under the *Integrated Planning Act 1997*.

If dewatering of the coal measures in advance of mining is required, water licences for the taking of groundwater for the Caval Ridge Mine will have to be obtained by BMA from DERM. The licences will stipulate a maximum annual take from each relevant aquifer. Under the *Water Act 2000*, the DERM has authority to direct the licensee to provide and maintain access to alternative water supplies for other water entitlement holders who would be affected by the granting of a licence.