BHP

Saraji Open Cut Extension Project

Underground Water Impact Report

Contents

1 Introduction and background

1.1 Introduction

The BHP Mitsubishi Alliance (BMA[1]) operates the Saraji Open Cut Coal Mine (Saraji Mine) under Environmental Authority (EA) Permit number EPML00862313.

In 2016, BMA submitted an Environmental Authority (EA) amendment application under the *Environmental Protection Act 1994* (EP Act) to authorise the extension of Grevillea Pit to access further coal resources. A mining lease (ML) application for ML 700021 was submitted in conjunction with the EA amendment application in accordance with requirements under the *Mineral Resources Act 1989*.

In order to meet its requirements under the *Water Act 2000* (QLD) (Water Act), BMA has engaged AECOM to prepare and publically notify an Underground Water Impact Report (UWIR). Pursuant to section 271A of the *Mineral Resources Act 1989*, ML 700021 was granted on 16 October 2018.

The area to which this report relates is ML 700021. ML 700021 is shown in Figure 1 as the Project Site.

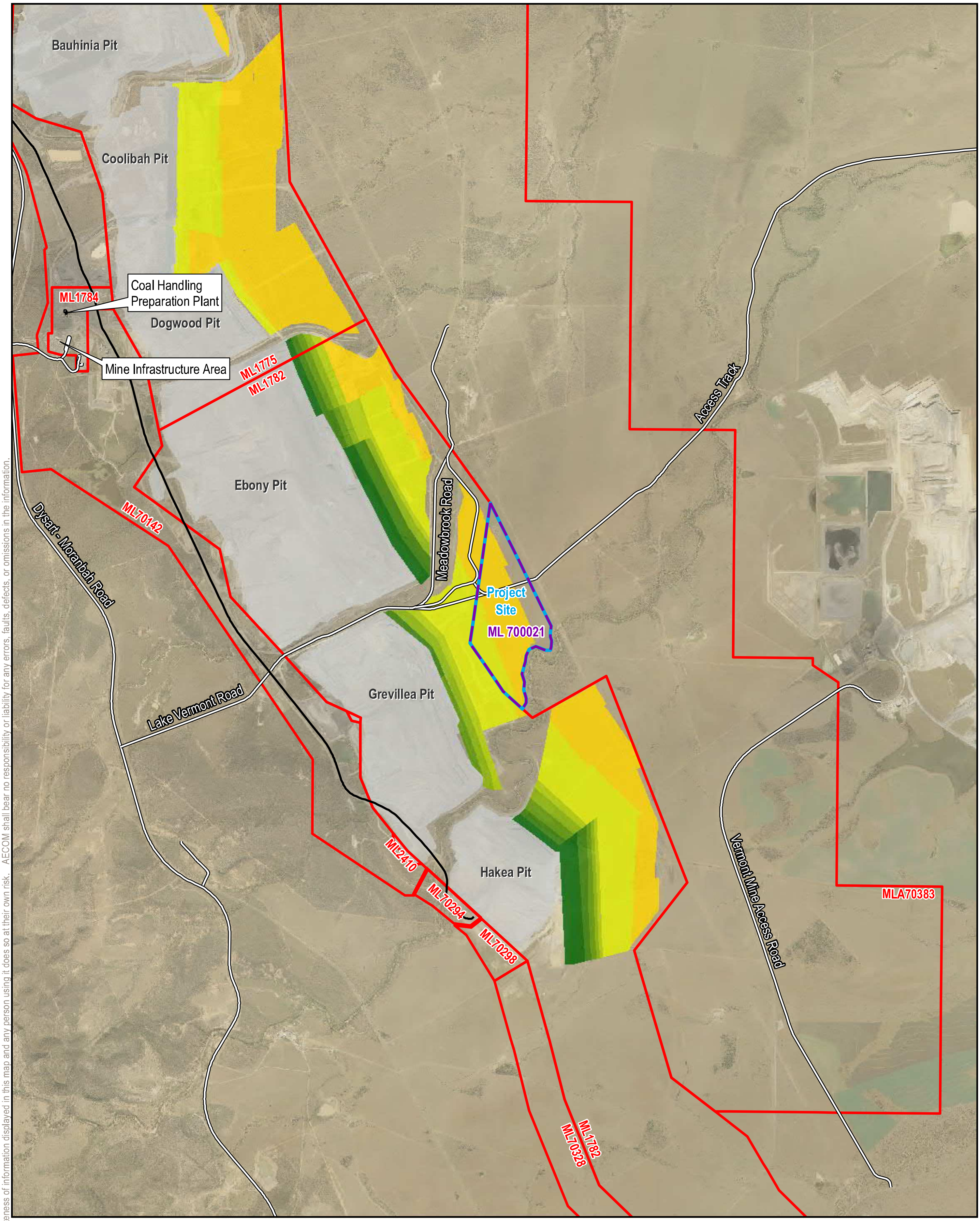
1.2 Purpose of the report

The purpose of this report is to fulfil the legislative requirements of a UWIR in accordance with Chapter 3 of the Water Act.

This UWIR has been prepared as an addendum to the pre-existing Groundwater Technical Report which was prepared for the approved Saraji Open Cut Extension Project EA Amendment application by AECOM (2016). For this purpose, this UWIR is not intended to be read as a standalone report and instead should be read in conjunction with the Groundwater Technical Report (AECOM, 2016) and the approved EA conditions.

This UWIR includes a cross-reference to the relevant UWIR required data presented in the Groundwater Technical Report. Where the Groundwater Technical Report does not address UWIR requirements, additional evaluation of the groundwater is provided in this report. Where any information differs between the Groundwater Technical Report and this report, the approved EA conditions are to be consulted. The groundwater monitoring requirements are provided within the approved EA conditions.

[1] BMA is an unincorporated joint venture also known as the Central Queensland Coal Associates Joint Venture which comprises seven companies including BHP Coal Pty Ltd and which has BM Alliance Coal Operations Pty Ltd ABN 69096412752 as a duly authorised representative.



LEGEND

- Haul Road
- Public Road
- Project Site
- ML 700021
- BMA Tenure / Tenement
- Infrastructure
- Existing Open-Cut Extent

Conceptual Mine Plan

- FY2017
- FY2018
- FY2019
- FY2020
- FY2021
- FY2022 - FY2026
- FY2027 - FY2031

Data sources:

1. Existing Infrastructure, Proposed ML © BMA 2016 (RFI)
2. BMA Imagery 29 May 2016
3. QLD SISP Imagery 2018

N

Figure 1
Project layout

Saraji Open Cut Extension Project - UWIR

0 0.5 1 2
Kilometres

Scale: 1:80,000 (when printed at A4)

Projection: Map Grid of Australia - Zone 55 (GDA94)

BHP

DATE: 10/01/2019 VERSION: 2

Filename: \\aubne1fp003\Projects\605X\60507031\4. Tech Work Area\4.99 GIS\02_MXDs\04 Saraji OC Environmental Assessment Report\02 Project Description\60507031_G019_v2_A4P_UWIR.mxd

1.3 Legislative requirements

The requirements for the management of impacts on underground water caused by the exercise of underground water rights are detailed in Chapter 3 of the Water Act.

Underground water rights and obligations upon ML 700021 are regulated through the *Mineral Resources Act 1989*, Water Act and approved EA conditions.

The main purpose of a UWIR is to describe, make predictions about and manage the impacts of underground water extraction by the resource tenure holder.

A summary of the UWIR requirements under the Water Act and the relevant sections of this report in which they are addressed are included in Table 1.

Table 1 Water Act UWIR Reporting Requirements and Applicable UWIR Report Sections

Water Act Provision	Sub-Provision	UWIR Report Section
S376 (a) - for the area to which the report relates -	(i) the quantity of water produced or taken from the area because of the exercise of any previous relevant underground water rights; and	Section 3.1
	(ii) an estimate of the quantity of water to be produced or taken because of the exercise of the relevant underground water rights for a 3-year period starting on the consultation day for the report;	Section 3.2
S376 (b) - for each aquifer affected, or likely to be affected, by the exercise of the relevant underground water rights -	(i) a description of the aquifer; and	Section 4.1
	(ii) an analysis of the movement of underground water to and from the aquifer, including how the aquifer interacts with other aquifers; and	Section 4.2
	(iii) an analysis of the trends in water level change for the aquifer because of the exercise of the rights mentioned in paragraph (a)(i); and	Section 4.3
	(iv) a map showing the area of the aquifer where the water level is predicted to decline, because of the taking of the quantities of water mentioned in paragraph (a), by more than the bore trigger threshold within 3 years after the consultation day or the report;	Section 5.1
	(v) a map showing the area of the aquifer where the water level is predicted to decline, because of the exercise of relevant underground water rights, by more than the bore trigger threshold at any time;	Section 5.1
S376 (c) a description of the methods and techniques used to obtain the information and predictions under paragraph (b);		Section 5.2
S376 (d) a summary of information about all water bores in the area shown on a map mentioned in paragraph (b)(iv), including the number of bores, and the location and authorised use or purpose of each bore;		Section 5.3
S376 (da) a description of the impacts on environmental values that have occurred, or are likely to occur, because of any previous exercise of underground water rights;		Section 6.1 Section 6.2
S376 (db) an assessment of the likely impacts on environmental values that will occur, or are likely to occur, because of the exercise of underground water rights -	(i) during the period mentioned in paragraph (a)(ii); and	Section 6.2
	(ii) over the projected life of the resource tenure;	Section 6.2

Water Act Provision	Sub-Provision		UWIR Report Section
S376 (e) a program for -	(i) conducting an annual review of the accuracy of each map prepared under paragraph (b)(iv) and (v); and		Section 5.4
	(ii) giving the chief executive a summary of the outcome of each review, including a statement of whether there has been a material change in the information or predictions used to prepare the maps;		Section 5.4
S376 (f) a water monitoring strategy;	S378 (1) A responsible entity's water monitoring strategy must include the following for each immediately affected area and long-term affected area identified in its underground water impact report or final report -	(a) a strategy for monitoring—(i) the quantity of water produced or taken from the area because of the exercise of relevant underground water rights; and (ii) changes in the water level of, and the quality of water in, aquifers in the area because of the exercise of the rights;	Section 7.2
		(b) the rationale for the strategy;	Section 7.1
		(c) a timetable for implementing the strategy;	Section 7.3
		(d) a program for reporting to the commission about the implementation of the strategy.	Section 7.4
	S378 (2) The strategy for monitoring mentioned in subsection (1)(a) must include -	(a) the parameters to be measured; and	Section 7.2
		(b) the locations for taking the measurements; and	Section 7.2
		(c) the frequency of the measurements.	Section 7.2
	S378 (3) If the strategy is prepared for an underground water impact report, the strategy must also include a program for the responsible tenure holder or holders under the report to undertake a baseline assessment for each water bore that is -	(a) outside the area of a petroleum tenure; but	Section 7.2
		(b) within the area shown on the map prepared under section 376(b)(v).	Section 7.2
	S378 (4) If the strategy is prepared for a final report, the strategy must also include a statement about any matters under a previous strategy that have not yet been complied with.		Not Applicable to this UWIR
S376 (g) a spring management strategy			Section 8.0
S376 (h) if the responsible entity is the office -	(i) a proposed responsible tenure holder for each report obligation mentioned in the report; and		Not Applicable to this UWIR
	(ii) or each immediately affected area - the proposed responsible tenure holder or holders who must comply with any make good obligations for water bores within the immediately affected area;		Not Applicable to this UWIR
S376 (i) other information or matters prescribed under a regulation.			Not Applicable to this UWIR

Water Act Provision Sub-Provision	UWIR Report Section
S376 (2) However, if the underground water impact report does not show any predicted water level decline in any area of an affected aquifer by more than the bore trigger threshold during the period mentioned in subsection (1)(b)(iv) or at any time as mentioned in subsection (1)(b)(v), the report does not have to include the program mentioned in subsection (1)(e).	Not Applicable to this UWIR

1.3.1 Bore trigger thresholds

Sections 376(b)(iv) and 376(b)(v) of the Water Act refer to bore trigger thresholds. As defined in the Water Act, a bore trigger threshold for an aquifer means a decline in the water level that is:

- five metres for consolidated aquifers (e.g. sandstones)
- two metres for unconsolidated aquifers (e.g. sand/alluvial aquifers).

The area within which water levels are predicted to be lowered in an aquifer by more than the bore trigger threshold within three years, due to water extraction, is referred to as the Immediately Affected Area (IAA).

The area within which water levels are predicted to be lowered by more than the bore trigger threshold in the long term, due to water extraction, is referred to as the Long-term Affected Area (LTAA).

1.4 Report structure

The structure of this UWIR has been prepared in accordance with that outlined in the *Guideline: (Water Act 2000) Underground Water Impact Reports and Final Reports* (DEHP, 2016) (UWIR Guideline). The UWIR Guideline specifies that a UWIR must contain information that has been outlined in each of the following parts of the guideline:

- Part A: Information about underground water extractions resulting from the exercise of underground water rights.
- Part B: Information about aquifers affected, or likely to be affected.
- Part C: Maps showing the area of the affected aquifer(s) where underground water levels are expected to decline.
- Part D: An assessment of the impacts to the environmental values from the exercise of underground water rights.
- Part E: A water monitoring strategy.
- Part F: A spring impact management strategy.
- Part G: For a CMA, assignment of responsibilities to resource tenure holders.

It is noted that Part G is not required as part of this UWIR as Saraji Mine is not located within a cumulative management area (CMA).

The relevant Water Act requirements for each Part of the UWIR Guideline above are listed at the beginning of the relevant sections in this report.

Where legislative requirements are met in the Groundwater Technical Report, cross-reference to the relevant chapter in the Groundwater Technical Report is provided at the beginning of each section. It is considered that the Groundwater Technical Report provides a more detailed description, assessment approach, and analysis of the relevant groundwater information. The approved EA should also be referenced to with regards to the proposed groundwater monitoring program.

2 Report consultation day

The Consultation Day of a UWIR is defined under Section 322(1) of the Water Act as ‘the day a notice is first published about the proposed report’. The commencement date of the UWIR will be the date that it is approved by the Chief Executive (Commencement Date).

BMA is required to provide a UWIR for its predicted take for the period of 3 years from the Consultation Day and then subsequent reports within 10 days of the day which is 3 years after the Commencement Date.

The exercise of underground water rights associated with the EA amendment application to extend open cut operations at the approved Grevillea Pit is currently forecast to commence in or around 2024.

3 Part A: Underground water extractions

This section addresses the requirements under Section 376(a) of the Water Act.

Table 2 Requirements under Section 376(a) of the Water Act

Requirements under Section 376(a) of the Water Act	Relevant UWIR Report Section	Relevant Groundwater Technical Report Section
To meet the requirements under Section 376(a) of the Water Act, a UWIR must include the following: The quantity of underground water produced or taken from the area because of the exercise of underground water rights; and	Sections 3.1, 3.2	Section 10.2
An estimate of the quantity of water to be produced or taken because of the exercise of underground water rights for a three year period starting on the consultation day for the report.	Section 3.2	Table 20, Section 10.2

3.1 Quantity of water already produced

The taking of water from the Grevillea Pit extension, which was the subject of the EA amendment application, is not scheduled to commence until 2024.

The quantity of water already produced is therefore considered to be zero.

3.2 Quantity of water to be produced in the next three years

The quantity of water estimated to be produced within the next three years due to the extension of the Grevillea Pit operations is considered to be zero because the extension of mining operations is not scheduled to occur until 2024.

Predictive modelling does, however, provide estimates of groundwater ingress into the Grevillea Pit extension over time, including the first three years of the project life.

Estimates of the quantity of water to be produced from the approved Saraji Mine operations are provided in Table 20 of the Groundwater Technical Report. These estimates include predictive model scenarios including the Grevillea Pit extension (With Project) and without the Grevillea Pit extension (No Project, i.e. only the approved open cut mining operations at Saraji Mine).

Estimates of the quantity of water to be produced solely as a result of the Grevillea Pit extension, for the first three years of the open cut extension, are summarised in Table 3.

Table 3 Estimates of Quantity of Water to be Produced in First Three Years of Grevillea Pit Extension

Year	Estimated Volume of Produced Water (ML)
2024	12.35
2025	92.84
2026	190.33

The quantity of water produced in Table 3 was estimated using the predictive groundwater model which is detailed in Section 9.0 of the Groundwater Technical Report.

4 Part B: Aquifer information and underground water flow

This section addresses the requirements under Section 376(b)(i) to 376(b)(iii) of the Water Act.

Table 4 Requirements under Section 376(b)(i) to 376(b)(iii) of the Water Act

Requirements under Section 376(b)(i) to 376(b)(iii) of the Water Act	Relevant UWIR Report Section	Relevant Groundwater Technical Report Section
For each aquifer affected, or likely to be affected, by the exercise of the relevant underground water rights, a UWIR must include: A description of the aquifer;	Section 4.1	Sections 5.3, 6.1, 6.2.1, 6.3.1, 6.4.1, 6.5.1, and Figure 5, Figure 6
An analysis of the movement of underground water to and from the aquifer, including how the aquifer interacts with other aquifers; and	Section 4.2	Sections 6.2.2, 6.2.3, 6.3.2, 6.3.3, 6.4.2, 6.4.3, 6.5.2, 6.5.3, and Figure 18, Figure 19
An analysis of the trends in water level change for the aquifer because of the exercise of underground water rights.	Section 4.3	Sections 6.7.1, 6.7.2, 6.7.3, 6.7.4, 6.7.5, 6.7.6, and Figure 12, Figure 13, Figure 14, Figure 15, Figure 16

4.1 Aquifer descriptions

Aquifer descriptions are provided in the following sections of the Groundwater Technical Report (it is noted that the hydrostratigraphic units within the Saraji Mine study area are assessed to evaluate the aquifer properties as part of the groundwater descriptions allowing for the identification of aquifers and aquitards):

- Section 5.3 – Two northeast-southwest geological cross-sections showing the base of Tertiary sediments, base of weathering and intersected coal seams across the Grevillea Pit extension are provided in Plate 3 and Plate 4.
- Section 6.1 – provides an overview of the hydrostratigraphy of the project area and lithological descriptions of each hydrostratigraphic unit.
- Section 6.2.1 – describes the occurrence of groundwater within the Alluvial sediments.
- Section 6.3.1 – describes the occurrence of groundwater within the Tertiary sediments.
- Section 6.4.1 – describes the occurrence of groundwater within the Permian overburden and interburden sediments.
- Section 6.5.1 – describes the occurrence of groundwater within the Permian coal seam aquifers.
- The surface extent of the relevant hydrostratigraphic units is provided in Figure 5 and the basement geology in Figure 10.

Descriptions of the hydrostratigraphic units (included assessment of aquifer properties) as provided in the Groundwater Technical Report are based on descriptions from available relevant geological reports and site specific observations.

4.2 Underground water flow and aquifer interactions

Underground water flow and aquifer interactions are provided in the following sections of the Groundwater Technical Report:

- Section 6.2.2 and 6.2.3 – describes groundwater recharge and flow, and hydraulic properties within the Alluvial sediments.

- Section 6.3.2 and 6.3.3 – describes groundwater recharge and flow, and hydraulic properties within the Tertiary sediments.
- Section 6.4.2 and 6.4.3 – describes groundwater recharge and flow, and hydraulic properties within the Permian overburden and interburden sediments.
- Section 6.5.2 and 6.5.3 – describes groundwater recharge and flow, and hydraulic properties within the Permian coal seam aquifers.
- Pre-project groundwater contours for the Quaternary and Tertiary sediments is provided in Figure 18.
- Pre-project groundwater contours for the Permian sediments is provided in Figure 19[2].

4.3 Underground water level trend analysis

Underground water level trends and analysis are provided in the following sections of the Groundwater Technical Report:

- Section 6.7.1 – provides water level trends for monitoring bores within Quaternary sediments.
- Section 6.7.2 – provides water level trends for monitoring bores within Tertiary sediments.
- Section 6.7.3 – provides water level trends for monitoring bores within Permian coal seam aquifers.
- Section 6.7.4 – provides pre-project groundwater flow contours.
- Section 6.7.5 – provides an assessment of vertical hydraulic gradients across the area.
- Section 6.7.6 – provides discussion on the impacts of existing mining activities on water levels within the different hydrostratigraphic units.
- Water level hydrographs are provided in Figure 12, Figure 13, Figure 14, Figure 15 and Figure 20.

[2] Sections 9.5.1 and 10.1 of the Groundwater Technical Report include details of the projection of groundwater levels from 2012 to 2016, for the estimate of pre-project steady-state groundwater levels used for the impact predictions

5 Part C: Predicted water level declines for affected aquifers

This section addresses the requirements under Section 376(b)(iv) to 376(e) of the Water Act.

Table 5 Requirements under Section 376(b)(iv) to 376(e) of the Water Act

Requirements under Section 376(b)(iv) to 376(e) of the Water Act	Relevant UWIR Report Section	Relevant Groundwater Technical Report Section
To meet the requirements of the Water Act, a UWIR must include the following: Maps showing the IAA and LTAA (sections 376(b)(iv) and 376(b)(v) of the Water Act);	Section 5.1	-
A description of the methods used to produce these maps (section 376(c) of the Water Act;	Sections 5.1, 5.2	Sections 9.1, 9.2, 9.3, 9.4, 9.5
Information about all water bores in the IAA (including the number of bores in the area, maps showing the location of these bores and the authorised use of each bore) (section 376(d) of the Water Act); and	Section 5.3	Section 7.1, Table 6
A program for conducting an annual review of the accuracy of maps produced and giving the chief executive a summary of outcome of each review, including a statement of whether there has been a material change in the information or predictions used to prepare the maps (section 376(e) of the Water Act).	Section 5.4	-

5.1 Maps of affected area

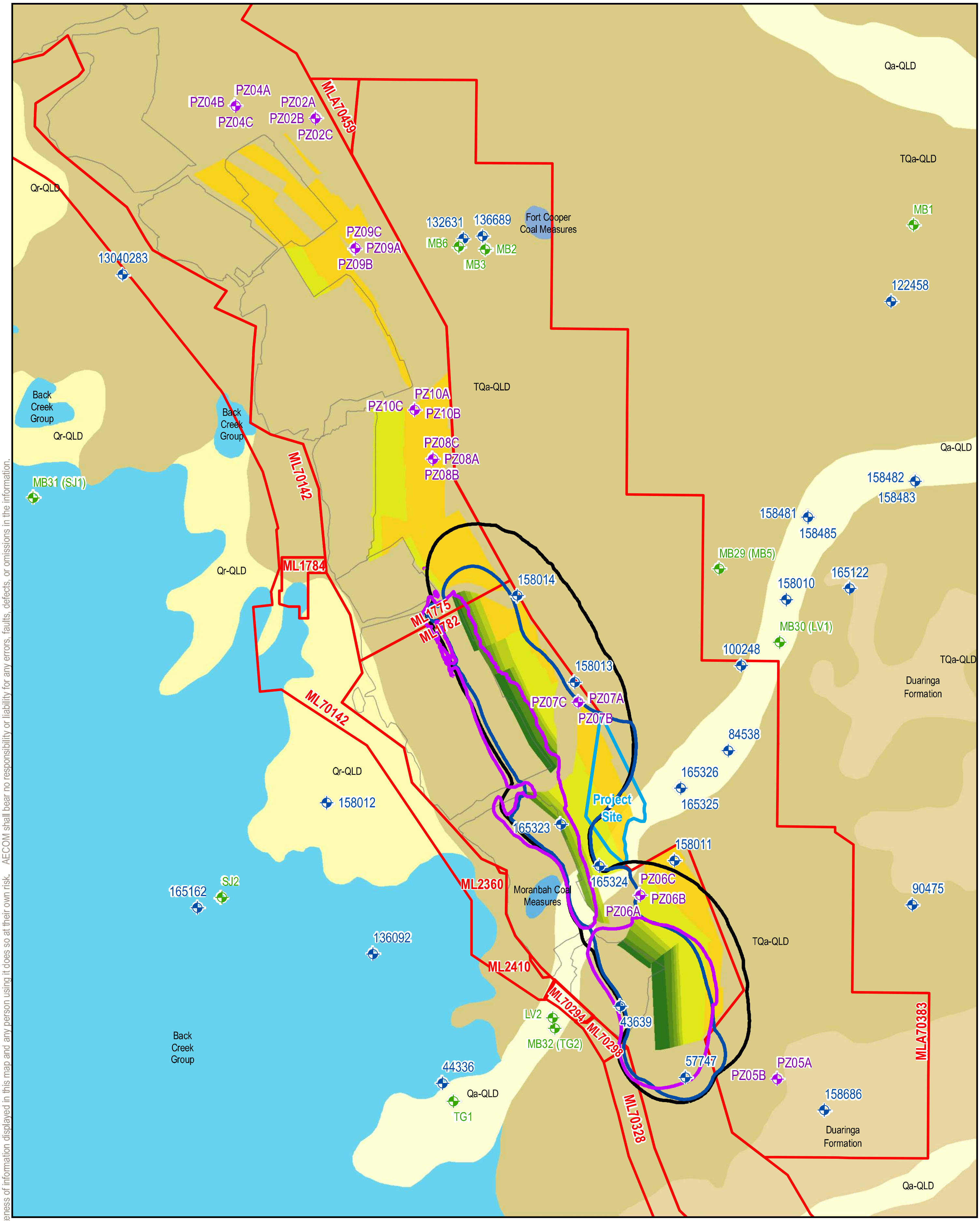
A map showing the predicted IAA for the Quaternary/Tertiary sediments, Harrow Creek (H16) coal seam and Dysart Lower (D14, D24) coal seams are shown in Figure 2.

A map showing the predicted LTAA for each of the potentially affected aquifers is shown in Figure 3.

The Quaternary/Tertiary sediments are considered to be unconsolidated and thus the bore trigger threshold for the Quaternary/Tertiary sediments was assumed to be 2 m (Section 1.3.1).

The Tertiary and Permian sediments are considered to be consolidated and thus the bore trigger threshold for these sediments was assumed to be 5 metres (Section 1.3.1).

It is noted that the drawdown predictions in Figure 2 and Figure 3 include cumulative impacts from both the existing approved Saraji open-cut mining operations and the Grevillea Pit extension (from extension open cut mining commencing in or around 2024). Predictive modelling allows for the simulation of approved mining from pre-mining levels estimated for 2016 (using approved mining and backfill simulations) until 2014, the change in groundwater levels below these starting levels (incorporating both the approved on-going Saraji Mine open cut mining and the Grevillea Pit extension) is utilised to assess the IAA and LTAA bores.



LEGEND

Groundwater Bore
- Census Bore
- Registered Bore
- Saraji Monitoring Bore
- IAA Quaternary/Tertiary (Layer 1)
- IAA Harrow Creek (H16) Coal Seam (Layer 6)
- IAA Dysart Lower (D14, D24) Coal Seam (Layer 10)
- Project Site
- BMA Tenure / Tenement

Existing Open-Cut Extent

Conceptual Mine Plan
- FY2017
- FY2018
- FY2019
- FY2020
- FY2021
- FY2022 - FY2026
- FY2027 - FY2031

Surface Geology
- Back Creek Group (Pb)
- Duaringa Formation (Tu)
- Fort Cooper Coal Measures (Pwt)
- Moranbah Coal Measures (Pwb)
- Qa-QLD (Qa)
- Qr-QLD (Qr)
- TQa-QLD (TQa)

Data sources:

1. Tenements, Bores, Infrastructure © BMA 2016 (RFI)
2. Geology, Bores © State of Queensland (Department of Natural Resources and Mines) 2016

N

Figure 2
Extent of Immediately Affected Area (IAA)

Saraji Open Cut Extension Project - UWIR

0 0.5 1 2
Kilometres

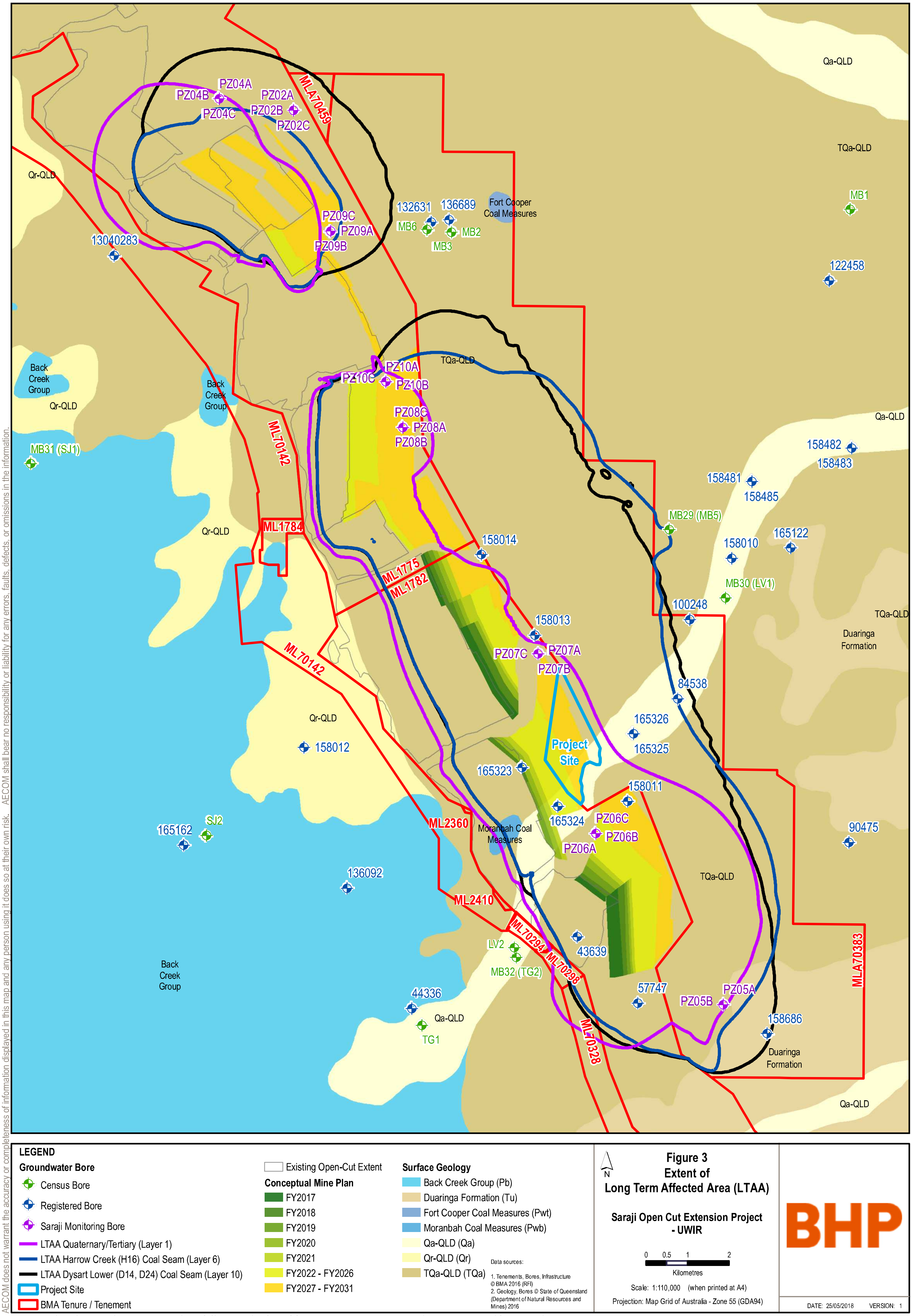
Scale: 1:110,000 (when printed at A4)

Projection: Map Grid of Australia - Zone 55 (GDA94)

BHP

DATE: 25/05/2018 VERSION: 1

Filename: P:\605X\60507031\4. Tech Work Area\4.99 GIS\02_MXDs\04 Saraji OC Environmental Assessment Report\00 Technical Report\Groundwater\60507031_F1_v1_A4P.mxd


PZ04A
PZ04B
PZ04C
PZ02A
PZ02B
PZ02C
MLA70459
Qa-QLD
TQa-QLD
Qr-QLD
MB1
132631
136689
Fort Cooper Coal Measures
MB6
MB2
MB3
PZ09C
PZ09A
PZ09B
13040283
122458
TQa-QLD
PZ10A
PZ10C
PZ10B
Back Creek Group
Qr-QLD
Back Creek Group
PZ08C
PZ08A
PZ08B
ML70142
Qa-QLD
158482
158483
MB31 (SJ1)
158481
158485
MB29 (MB5)
Qr-QLD
ML1784
158014
158010
165122
ML1775
ML1782
MB30 (LV1)
TQa-QLD
100248
158013
Duaringa Formation
ML70142
PZ07C
PZ07A
PZ07B
84538
Qr-QLD
165326
158012
Project Site
165325
165323
158011
SJ2
165162
ML2360
Moranbah Coal Measures
165324
PZ06C
PZ06B
PZ06A
90475
TQa-QLD
136092
ML2410
ML70294
ML70298
LV2
43639
MB32 (TG2)
Back Creek Group
44336
57747
PZ05A
PZ05B
Qa-QLD
TG1
ML70328
158686
MLA70383
Duaringa Formation
Qa-QLD
LEGEND
Groundwater Bore
Census Bore
Registered Bore
Saraji Monitoring Bore
LTAA Quaternary/Tertiary (Layer 1)
LTAA Harrow Creek (H16) Coal Seam (Layer 6)
LTAA Dysart Lower (D14, D24) Coal Seam (Layer 10)
Project Site
BMA Tenure / Tenement
Existing Open-Cut Extent
Conceptual Mine Plan
FY2017
FY2018
FY2019
FY2020
FY2021
FY2022 - FY2026
FY2027 - FY2031
Surface Geology
Back Creek Group (Pb)
Duaringa Formation (Tu)
Fort Cooper Coal Measures (Pwt)
Moranbah Coal Measures (Pwb)
Qa-QLD (Qa)
Qr-QLD (Qr)
TQa-QLD (TQa)
Data sources:
1. Tenements, Bores, Infrastructure © BMA 2016 (RFI)
2. Geology, Bores © State of Queensland (Department of Natural Resources and Mines) 2016
N
Figure 3
Extent of
Long Term Affected Area (LTAA)
Saraji Open Cut Extension Project - UWIR
0 0.5 1 2
Kilometres
Scale: 1:110,000 (when printed at A4)
Projection: Map Grid of Australia - Zone 55 (GDA94)
BHP
DATE: 25/05/2018 VERSION: 1

5.1.1 Yearly predictions

To aid in addressing the Water Act requirements regarding the UWIR, predictive groundwater level changes over time are provided in Appendix A. The water level hydrographs have been compiled for bores identified within and adjacent to the Saraji Mine footprint (Section 6.6 of Groundwater Technical Report).

These hydrographs provide indications of groundwater drawdown trends, each year, in response to the approved and proposed open-cut mining.

5.1.2 Model classification

Section 9.0 of the Groundwater Technical Report includes details of the groundwater model and modelling approach, including an assessment of the model calibration. These statistical results indicate the model has a confidence level classification of Class 2.

The model water budget indicates an accurate numerical solution and stability of the model and is considered to have a mass balance error, which is below the Class 2 model indicator of 1% error.

The model was considered to be suitable for predicting impacts on medium value aquifers.

It is considered that the augmentation of the existing Saraji Mine groundwater monitoring network plus the collection of groundwater ingress data will allow for the regular (every 3 years) assessment of the predictive model (predictions and re-run), which will aid in addressing uncertainty within the current model.

5.2 Methods and techniques used

A groundwater numerical model was used to predict water level declines for the affected aquifers and produce maps of the IAA and LTAA. Methods and techniques used in the groundwater model are provided in the following sections of the Groundwater Technical Report:

- Section 9.1 – provides a conceptual model of the groundwater system.
- Section 9.2 – provides details of the model MODFLOW SURFACT code.
- Section 9.3 – provides details of the modelling strategy.
- Section 9.4 – provides details of the model geometry, model boundaries, model layers, hydraulic parameters, recharge and discharge.
- Section 9.5 – provides details about the model calibration.

The groundwater model used to make predictions of water level impacts in the Groundwater Technical Report was re-run to fulfil the timeframes and bore trigger thresholds that are required under the Water Act.

It is noted that the Quaternary and Tertiary aquifers were represented as a single layer (Layer 1) within the groundwater model. The Harrow Creek (H16) coal seam (Layer 6) and Dysart Lower (D14, D24) coal seams (Layer 10) were also represented as single layers within the groundwater model.

5.3 Water bores within the immediately affected area

Information about water bores is provided in the following sections of the Groundwater Technical Report:

- Table 6 – provides details (coordinates, depth, geology, water level, yield), where known, of all bores identified in the area (including registered bores, unregistered bores identified in a bore census, Saraji monitoring bores, and BMA core bores (with groundwater level data).
- Section 7.1 – provides details of bores which were identified during a bore census undertaken in 2007 and which were considered to be unregistered i.e. not shown on the Department of Natural Resources, Mines and Energy (DNRME) Groundwater Database (GWDB).

Only one bore (RN165323) was identified to be located within the IAA for the Quaternary/Tertiary sediments and screened across those sediments. The bore details for RN165323 are summarised in Table 6.

Table 6 Registered Bores Located within IAA for Quaternary/Tertiary Aquifer

Bore RN	Easting	Northing	Depth (mbGL)	Geology /Aquifer	Model Layer	Use	Comment
165323	637620	7515091	15	Alluvial sand	1	Monitoring	Existing. Not licensed.

It is noted that bore RN165323 is owned by BMA and this bore is located immediately adjacent (west) to the Grevillea Pit (Figure 2).

No bores were identified to be located within the IAA for the Harrow Creek coal seam (Layer 6) and Dysart Lower coal seams (Layer 10) and which were screened across those layers.

It is noted that an additional six bores (RN43639, RN57747, RN158011, RN158013, RN158014 and RN165324) are located within the IAA footprint but are either abandoned or destroyed or not screened within the affected aquifers. The details for these six bores are summarised in Table 7.

Table 7 Registered Bores Located within IAA Footprint but not Affected

Bore RN	Easting	Northing	Depth (mbGL)	Geology /Aquifer	Model Layer	Use	Comment
43639	638939	7511033	43.9	Blackwater Group	-	-	Abandoned and destroyed.
57747	640392	7509441	126.5	Back Creek Group	11	Unknown	Existing. Not licensed. Screened in Layer 11 (Back Creek Group) which is located below MCM and not predicted to be impacted.
158011	640150	7514283	32	Fair Hill Formation	2	Monitoring	Existing. Not licensed. Located in Layer 2 and impacts predicted to be less than 1 metre.
158013	637926	7518269	107	MCM	3	Monitoring	Existing. Not licensed. Located in Layer 3 and impacts predicted to be less than 2 metres.
158014	636640	7520199	37.5	MCM	2	Monitoring	Existing. Not licensed. Located in Layer 2 and impacts predicted to be less than 1 metre.
165324	638481	7514161	12.0	Alluvial Clay	1	Monitoring	Existing. Not licensed. Located outside IAA for Layer 1.

Predicted drawdown hydrographs for potentially impacted registered bores and monitoring bores are provided in Appendix A. The hydrographs include drawdown predictions until the end of projected mining at the Grevillea Pit extension (i.e. 2031). Note: groundwater monitoring bores proposed in the Groundwater Technical Report are included in the hydrographs.

5.4 Review of maps produced

BMA will conduct an annual review of the accuracy of the maps showing the predicted IAA and LTAA for the potentially affected aquifers. The accuracy of the maps will be assessed by comparing the predicted drawdown to actual drawdown in those monitoring bores which are accessible and predicted to be impacted.

BMA will commit to providing a summary of the outcome of the annual review to the chief executive as per condition 376(e)(ii) of the Water Act. The annual review will include a statement of whether there has been a material change in the information or predictions used to prepare the maps.

The first annual review is scheduled to occur in 2025.

6 Part D: Impacts on environmental values

This section addresses the requirements under Section 376(da) and (db) of the Water Act.

Table 8 Requirements under Section 376(da) and (db) of the Water Act

Requirements under Section 376(da) and (db) of the Water Act	Relevant UWIR Report Section	Relevant Groundwater Technical Report Section
To meet the requirements of the Water Act, a UWIR must include the following: A description of the impacts on environmental values that have occurred, or likely to occur, because of any previous exercise of underground water rights (section 376(da) of the Water Act);	Section 6.1	Section 7.2
An assessment of the likely impacts on environmental values that will occur, or are likely to occur, because of the exercise of underground water rights (section 376(db) of the Water Act - For a three year period starting on the consultation day for the report; and over the projected life of the resource tenure.	Sections 6.2, 6.3	Sections 11.1, 11.2, 11.3, 11.4

6.1 Identifying and describing environmental values

Environmental Values related to groundwater are provided in Section 7.2 of the Groundwater Technical Report.

6.2 Nature and extent of the impacts on the environmental values

The nature and extent of impacts on environmental values are provided in the following sections of the Groundwater Technical Report:

- Section 11.1 – discusses potential impacts on groundwater levels and existing groundwater users.
- Section 11.2 – discusses cumulative impacts due to nearby mining operations.
- Section 11.3 – discusses potential impacts on groundwater quality.
- Section 11.4 – discusses the potential environmental impacts from the Project.

The potential environmental impacts of the proposed open cut extension are considered low due to:

- The surface water system in the Project area is ephemeral.
- The Quaternary sediments (recent deposits from Phillips Creek) were reported to be of limited extent and were dry in several bores.
- The Tertiary sediments were recorded to intersect groundwater at depth but often have insufficient groundwater sampling, due to poor groundwater recovery after sampling due to low permeability.
- The largest predicted drawdown extends within the target coal seams, which are not recognised to discharge into the down gradient Isaac River; in addition the drawdown cones do not extent to the Isaac River to the east.
- Groundwater quality is not suitable for drinking, too deep for surface ecosystems, and is often too saline for livestock watering.
- The surface water systems are separated from the predicted impacted groundwater resources by low permeable sediments, which reduce the potential for the Project to impact on the alluvium and surface water flows.

6.2.1 Mitigation measures

The proposed extension of the Grevillea Pit is predicted to have long term locally contained impacts on the quantity and quality of groundwater resources on the Project site.

In order to protect against unexpected impacts and ensure ongoing validation of the predictive modelling in the vicinity of Grevillea Pit it is considered that ongoing groundwater monitoring during and after the Project development be conducted. The groundwater monitoring approach, including adaptive management and the instigation of further investigations, is conditioned within the amended EA.

One of the outcomes of the Grevillea pit extension EA amendment was an augmentation of the Saraji Mine groundwater monitoring program. Three additional bores were conditioned into the EA for implementation into the groundwater monitoring program (Table W10 of the EA). Groundwater contaminant limits and groundwater level thresholds have been conditioned in Table W11 of the EA.

For groundwater chemistry, once a sufficient (statistical) groundwater dataset is available (a minimum of 12 sample events) an assessment of statistical trends for representative parameters within each groundwater unit monitored will be derived. These contaminant trigger levels and contaminant limits will be based on the 85^{th} and 99^{th} percentile values, respectively for each geological unit possibly impacted by mine operations.

For groundwater levels, it is recognised that drawdown, as a result of mine dewatering or depressurisation, can impact on groundwater resources and potentially cause environmental harm. In order to identify potential drawdown impacts the monitoring points will act as early warning and model prediction validation points, when assessing Grevillea Pit extension mine dewatering drawdown. The monitoring points will act as early warning bores for impacts beyond those predicted.

Trends will be identified and follow-up investigations initiated if non-compliance (exceedances to the triggers / limits are reported). The intent of the investigative follow-up is to identify natural exceptions to the non-compliance and evaluate the potential for environmental harm.

If the investigation identifies the cause of an exceedance is due to approved mining operations, then the following will be conducted:

If the groundwater drawdown exceeds the predicted 2 m due to the approved mining operations, it is recommended that the following be implemented:

- Install additional monitoring bores in selected (impacted) aquifers.
- Undertake more frequent monitoring of groundwater EVs.
- Refine and revise the predictive groundwater model.
- Review of the latest numerical groundwater model and estimate the predicted take of water.
- Develop management, mitigation and remediation of impacts as required, including water replacement (make-good) and substitution (mine to supply water so as to reduce overall groundwater extraction).

6.3 Impacts to formation integrity and surface subsidence

Impacts to formation integrity and surface subsidence are not expected to occur as a result of the extension of mining operations at Grevillea Pit.

7 Part E: Water monitoring strategy

An underground water monitoring strategy is required (Section 376(f) of the Water Act) for the IAA and LTAA. The contents of the underground water monitoring strategy are provided in Section 378 of the Water Act.

This section addresses the requirements under Section 378 of the Water Act.

Table 9 Requirements under Section 378 of the Water Act

Requirements under Section 378 of the Water Act	Relevant UWIR Report Section	Relevant EA condition
To meet the requirements of the Water Act, a UWIR must include the following: A rationale for the strategy	Section 7.1	Addressed in this report – not applicable
A timetable for the strategy	Section 7.3	EA Condition W51 and Table W10
The parameters to be measured	Section 7.2	EA Condition W52 and Table W11
The locations for taking measurements	Section 7.2	EA Condition W51 and Table W10
The frequency of the measurements	Section 7.2	EA Condition W51 and Table W10
A program for the responsible tenure holder or holders to undertake a baseline assessment for each water bore that is outside the area of a resource tenure, but within the predicted LTAA, and	Section 7.4	Addressed in this report – not applicable
A program for reporting to the Office of Groundwater Impact Assessment (OGIA) about the implementation of the strategy.	Section 7.4	EA Condition W52, 54

7.1 Rationale

The objective of the groundwater monitoring network is to monitor potential groundwater impacts caused by mining, so that informed management can be undertaken.

The current groundwater monitoring network provides lateral and vertical coverage of the potentially impacted groundwater resources, taking into account the hydrogeological regimes and groundwater resources.

The network provides an early warning of potential impacts, so that early intervention can be implemented to reduce potential environmental harm. Should monitoring indicate an undesirable trend, the requirement for additional monitoring bores, both in other aquifers and laterally away from the Project is to be assessed, and actioned if deemed necessary.

7.2 Monitoring strategy

The EA conditions BMA to a groundwater monitoring program, and includes conditions for:

- Monitoring bores
- Details on the water quality parameters to be measured, the frequency and methodology.

BMA will also monitor the quantity of water produced or taken from the IAA and LTAA as a result of activities related to extension of the Grevillea Pit using the water balance method specified in the DNRME Guideline ‘*Quantifying the volume of associated water taken under a mining lease or mineral development licence*’, March 2018.

7.3 Timetable

The timetable for the monitoring strategy is conditioned in the EA, condition W51 and Table W10.

7.4 Reporting program

Figure 3 shows that there are no registered water bores which are located within the predicted LTAA, but outside of the mining leases associated with Saraji Mine. A program to undertake a baseline assessment is therefore not required.

The EA has conditioned BMA to review the groundwater monitoring data on an annual basis, in which this assessment must be submitted to the administering authority (EA Condition W54). The EA also conditions that exceedances of groundwater contaminant trigger levels are required to be reported within 28 days of receiving analysis results.

BMA will include a summary of the implementation of the Water Monitoring Strategy as part of the annual groundwater monitoring review.

8 Part F: Spring impact management strategy

A spring impact management strategy is required under Section 376(g of the Water Act). The contents of the spring impact management strategy are provided in Section 379 of the Water Act.

This section addresses the requirements under Section 379 of the Water Act.

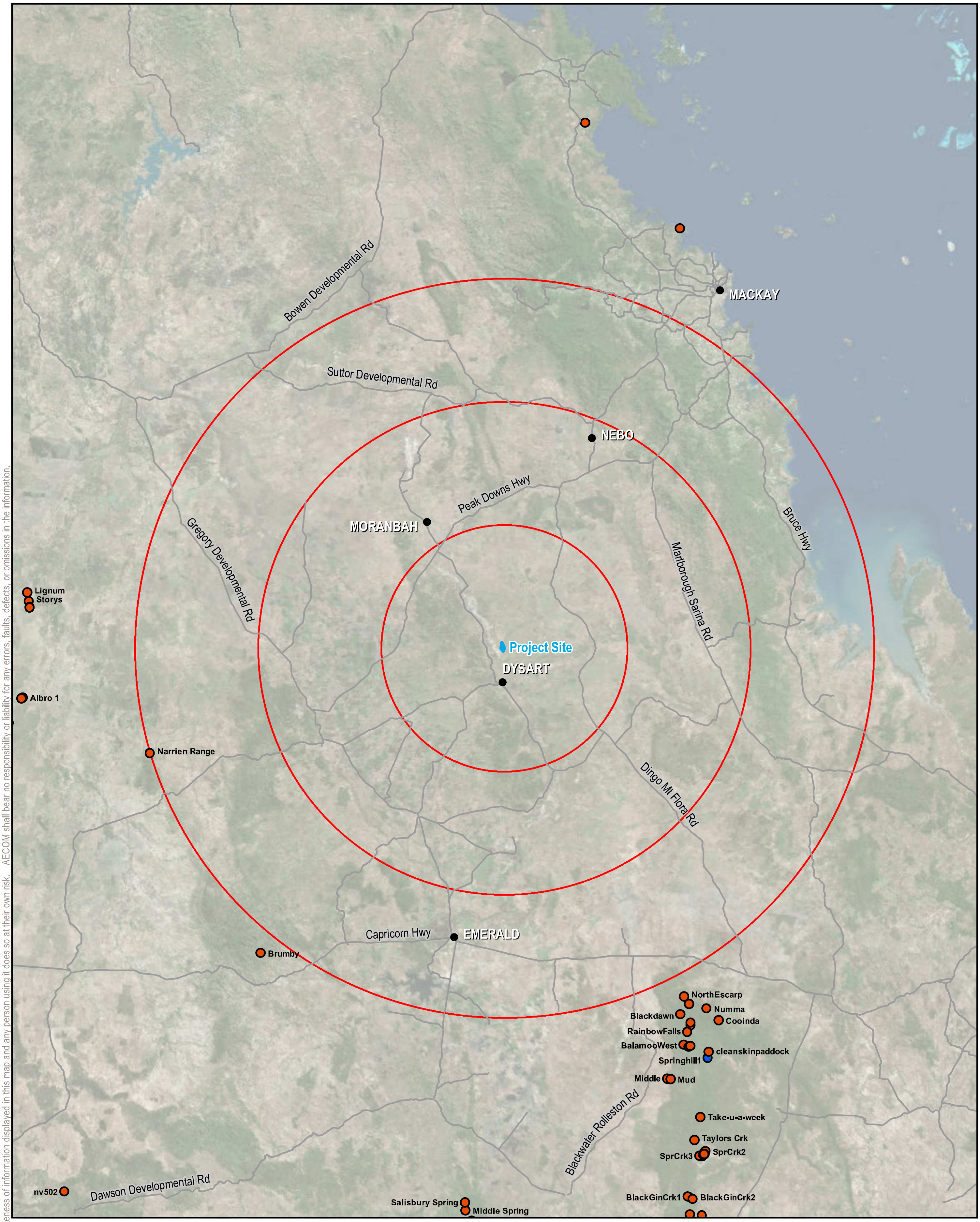
Table 10 Requirements under Section 379 of the Water Act

Requirements under Section 379 of the Water Act	Relevant UWIR Report Section	Relevant Groundwater Technical Report Section
To meet the requirements of the Water Act, a UWIR must include the following: The details of the spring, including its location.	Section 8.1	Sections 6.9, 7.2.3, 7.2.6
An assessment of the connectivity between the spring and the aquifer(s) over which the spring is located.	Section 8.2	Not applicable
The predicted risk to, and likely impact on, the ecosystem and cultural and spiritual values of the spring because of the decline in water level of the aquifer over which the spring is located.	Section 8.3	Not applicable
A strategy for preventing or mitigating the predicted impacts outlined above; or if a strategy for preventing or mitigating the predicted impacts is not included, the reason for not including the strategy.	Section 8.4	Not applicable
A timetable for implementing the strategy.	Section 8.5	Not applicable
A program for reporting to OGIA about the implementation of the strategy.	Section 8.6	Not applicable

8.1 Spring inventory

Sections 6.9, 7.2.3 and 7.2.6 of the Groundwater Technical Report show that there are no springs within the predicted impact area.

A review of registered springs indicates that the closest springs are greater than 150 kilometres from Saraji Mine (Figure 4).



LEGEND

- Locality
- Major Road
- Project Site
- 50km concentric circles from Saraji Mine

Registered Springs

- Palustrine
- Riverine

Data sources:

1. Tenements © BMA 2016 (RFI)
2. rEGISTERED sPRINGS © State of Queensland (Department of Natural Resources and Mines) 2016

N

Figure 4
Registered Springs

Saraji Open Cut Extension Project - UWIR

0 5 10 20
Kilometres

Scale: 1:2,000,000 (when printed at A4)

Projection: Map Grid of Australia - Zone 55 (GDA94)

BHP

DATE: 1/06/2018 VERSION: 1

Filename: P:\605X\60507031\4. Tech Work Area\4.99 GIS\02_MXDs\04 Saraji OC Environmental Assessment Report\00 Technical Report\Groundwater\60507031_G138_v1_A4P.mxd

8.2 Connectivity between the spring and aquifer

Not applicable.

8.3 Spring values

Not applicable.

8.4 Management of impacts

Not applicable.

8.5 Timetable for strategy

Not applicable.

8.6 Reporting program

Not applicable.

8.7 Connectivity between the spring and aquifer

Not applicable.

8.8 Spring values

Not applicable.

8.9 Management of impacts

Not applicable.

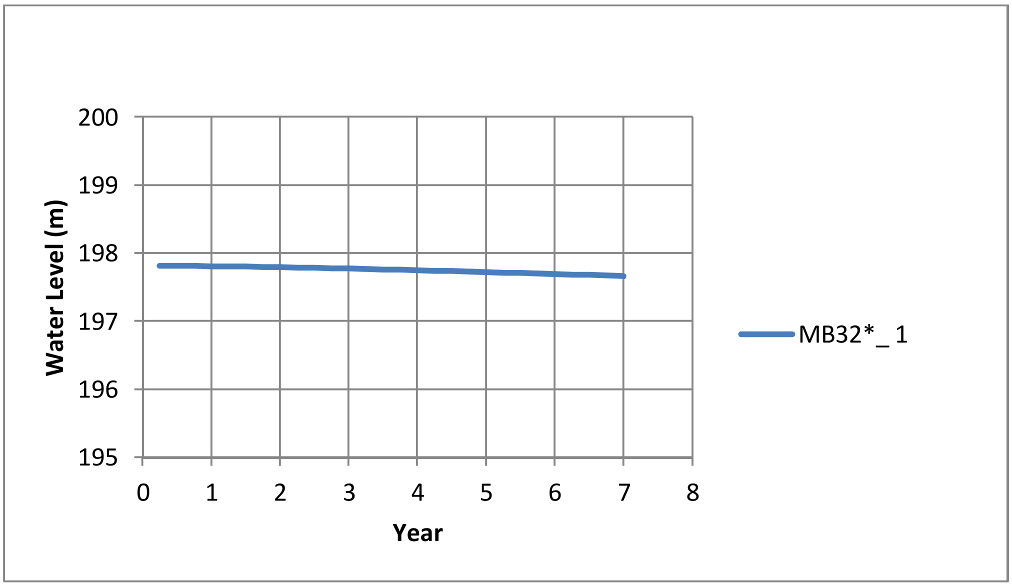
8.10 Timetable for strategy

Not applicable.

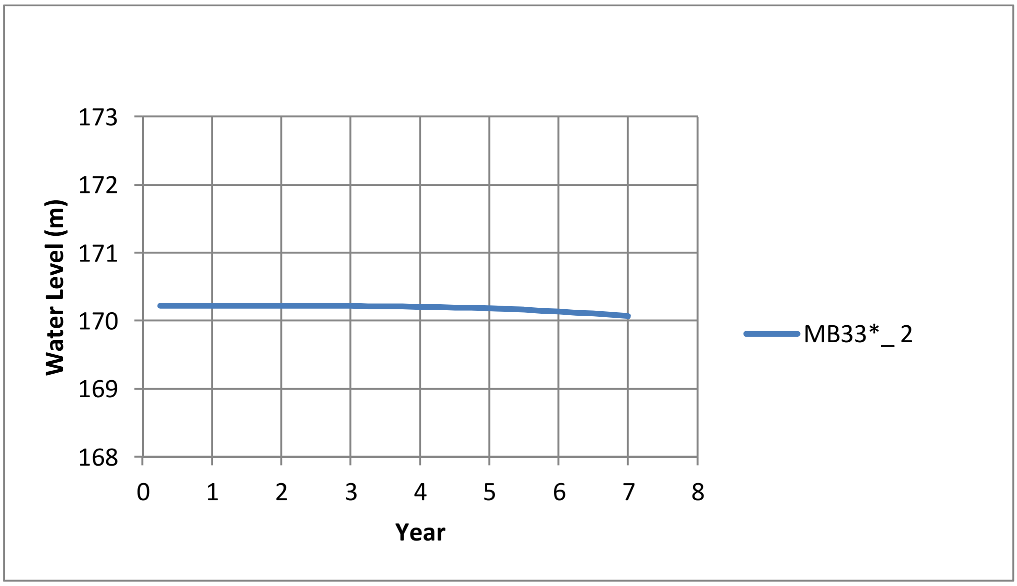
8.11 Reporting program

Not applicable.

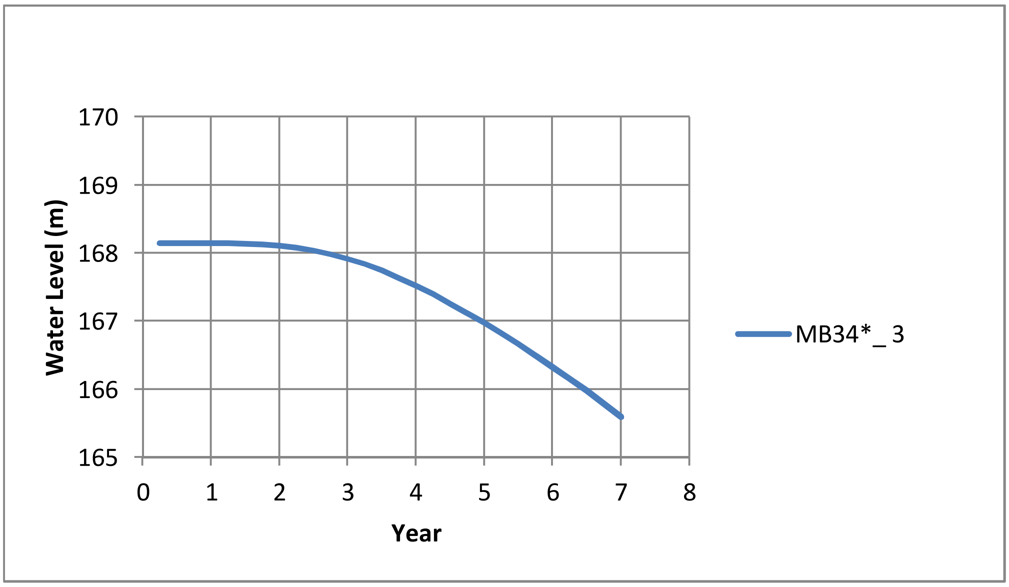
Appendix A - Bore Hydrographs



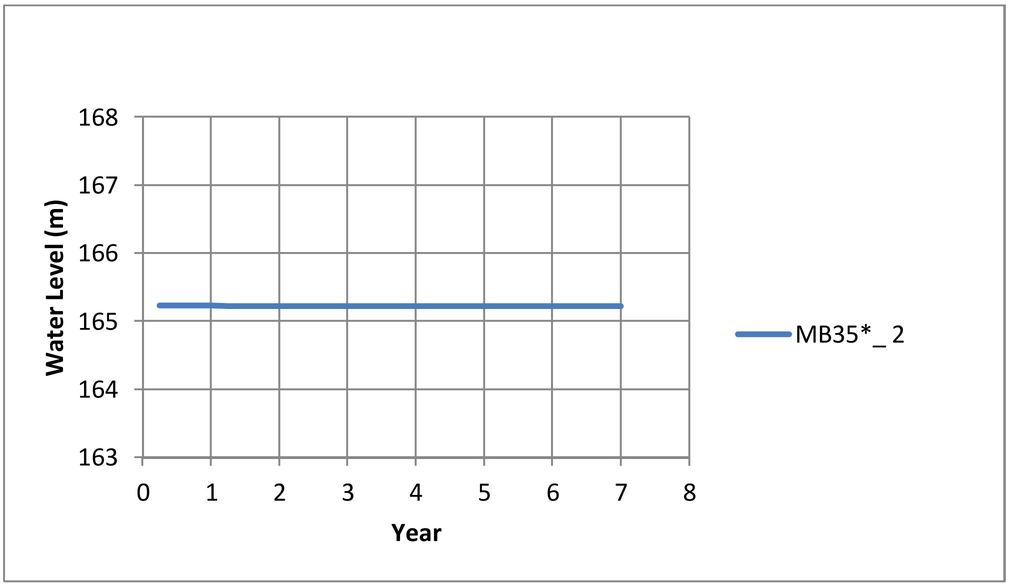
Water Level (m)
200
199
198
197
196
195
0
1
2
3
4
5
6
7
8
Year
MB32*_ 1



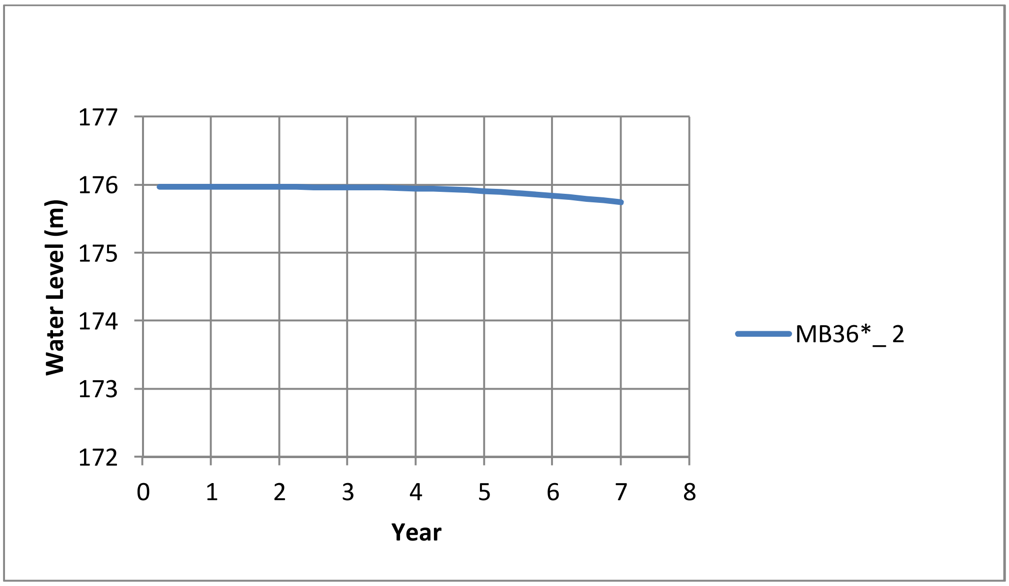
Water Level (m)
173
172
171
170
169
168
0
1
2
3
4
5
6
7
8
Year
MB33*_ 2



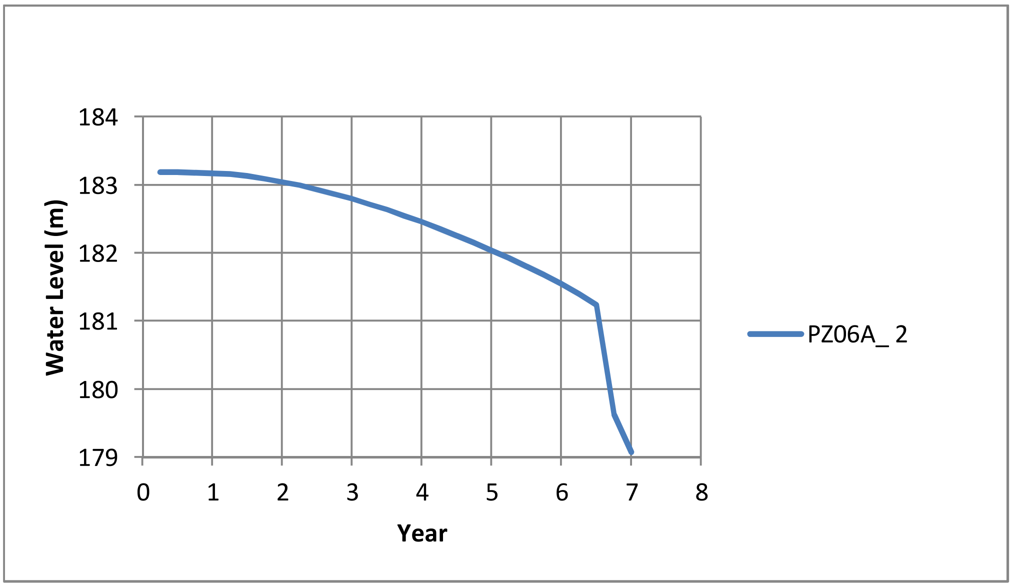
Water Level (m)
170
169
168
167
166
165
0
1
2
3
4
5
6
7
8
Year
MB34*_ 3



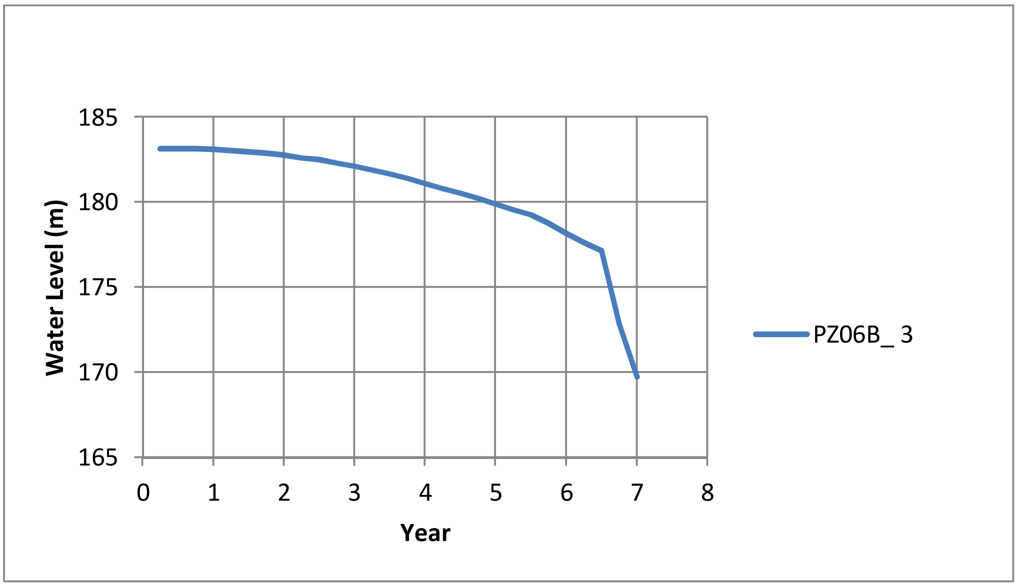
168
167
166
165
164
163
Water Level (m)
0
1
2
3
4
5
6
7
8
Year
MB35*_ 2

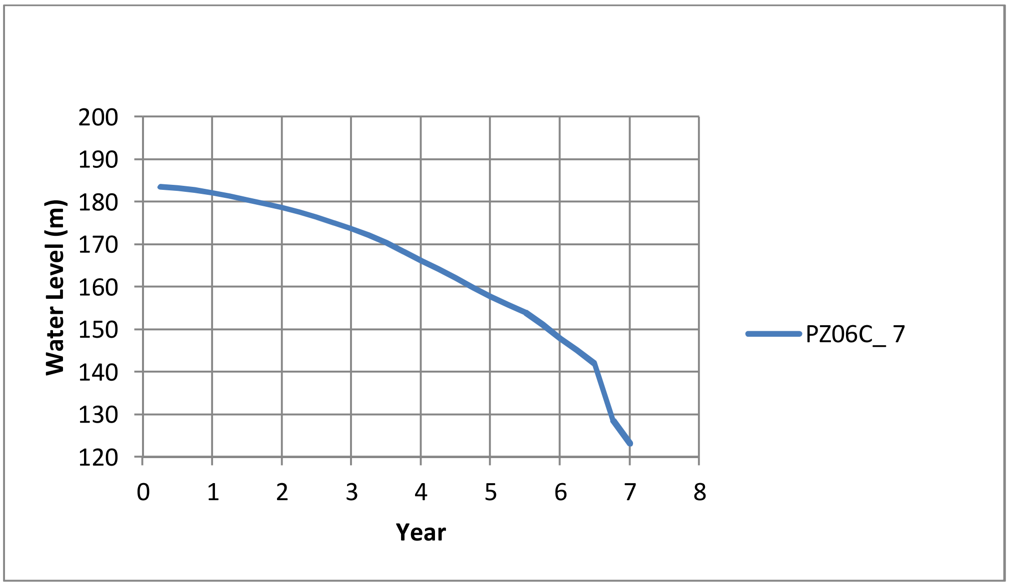


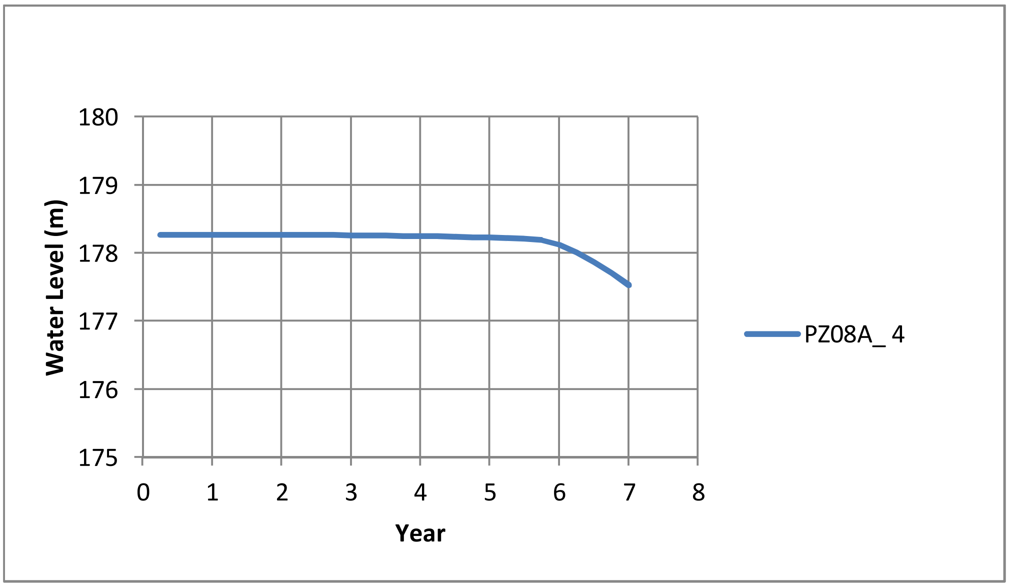
177
176
175
174
173
172
Water Level (m)
0
1
2
3
4
5
6
7
8
Year
MB36*_ 2

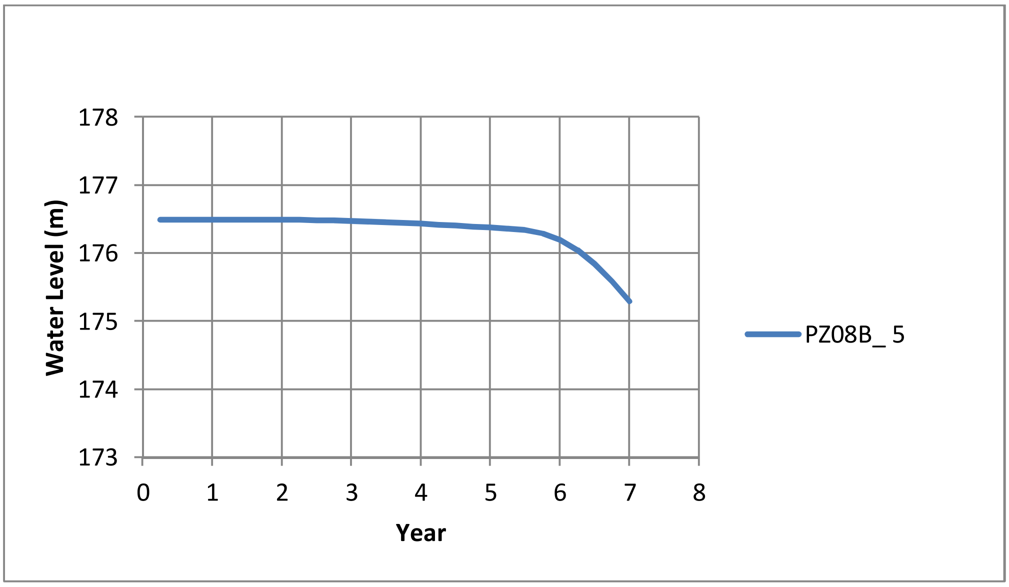


184
183
182
181
180
179
Water Level (m)
0
1
2
3
4
5
6
7
8
Year
PZ06A_ 2

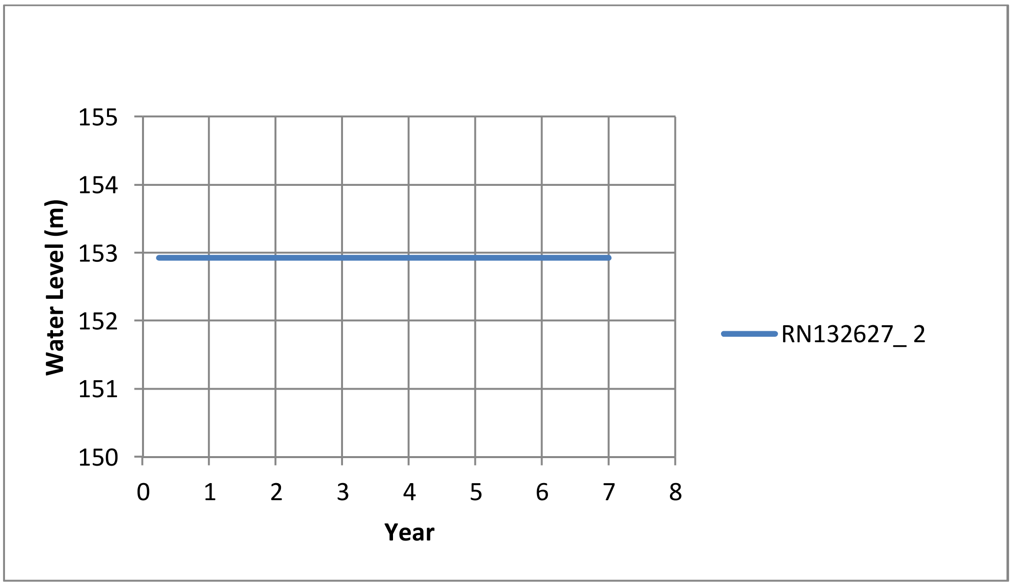

185
180
175
170
165
Water Level (m)
0
1
2
3
4
5
6
7
8
Year
PZ06B_ 3


200
190
180
170
160
150
140
130
120
Water Level (m)
0
1
2
3
4
5
6
7
8
Year
PZ06C_ 7

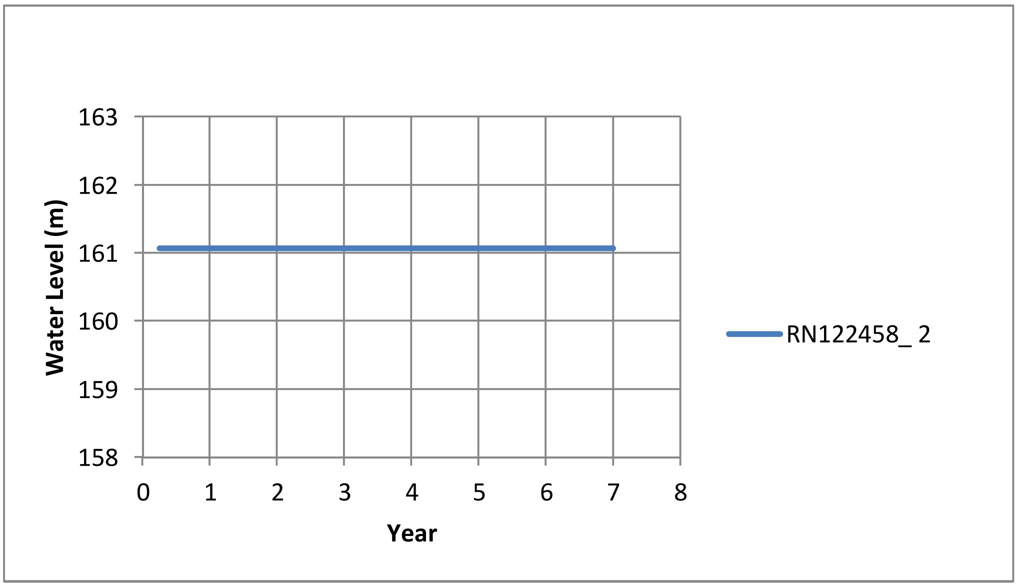

180
179
178
177
176
175
Water Level (m)
0
1
2
3
4
5
6
7
8
Year
PZ08A_ 4



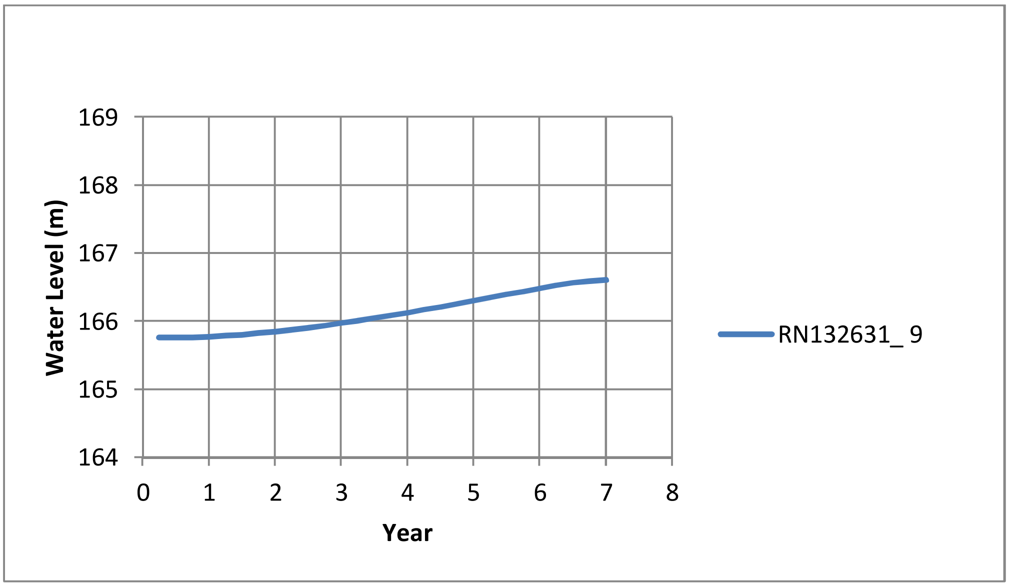
Water Level (m)
178
177
176
175
174
173
0 1 2 3 4 5 6 7 8
Year
PZ08B_ 5



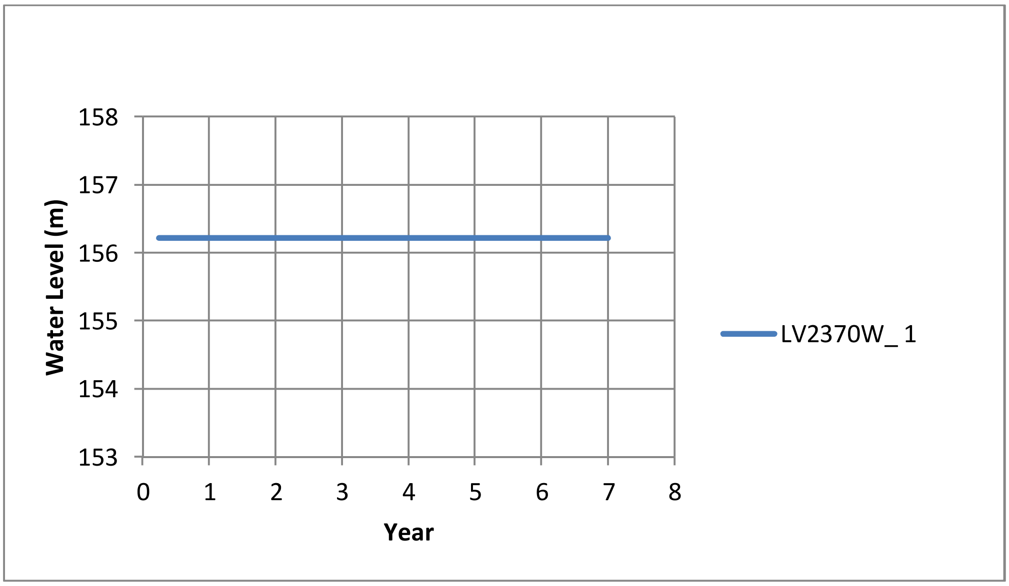
Water Level (m)
155
154
153
152
151
150
0 1 2 3 4 5 6 7 8
Year
RN132627_ 2



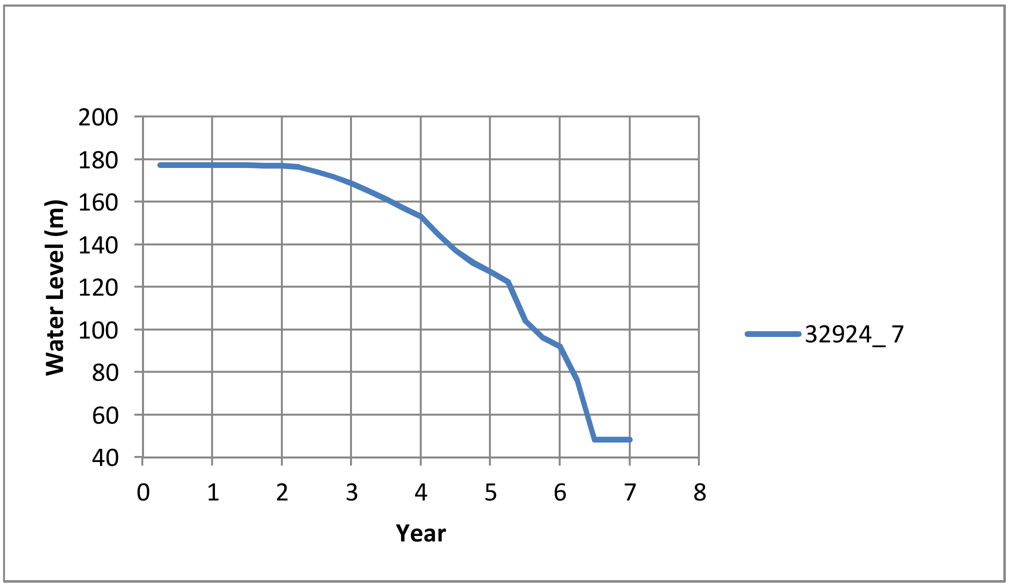
Water Level (m)
163
162
161
160
159
158
0 1 2 3 4 5 6 7 8
Year
RN122458_ 2



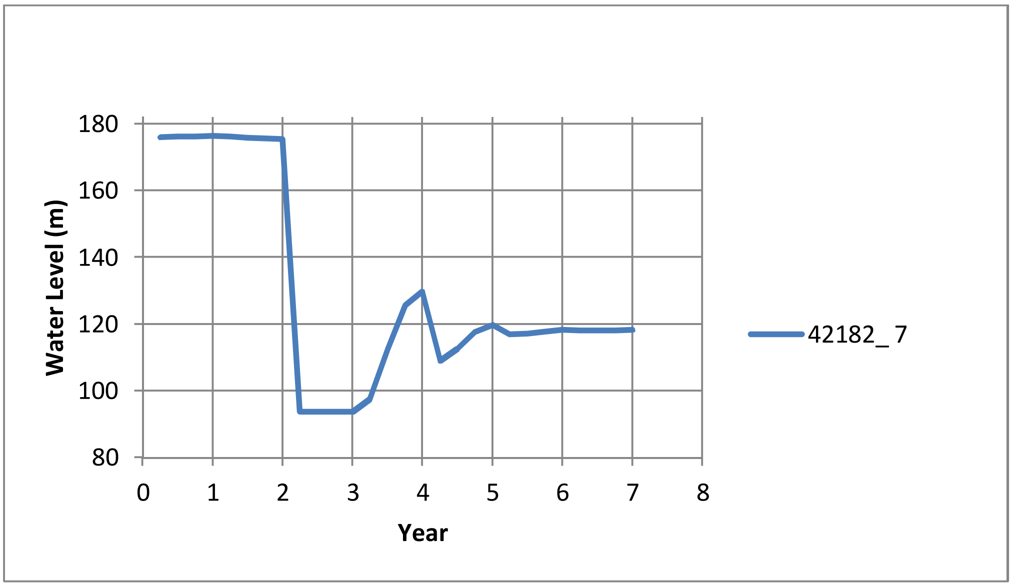
169
168
167
166
165
164
Water Level (m)
0
1
2
3
4
5
6
7
8
Year
RN132631_ 9



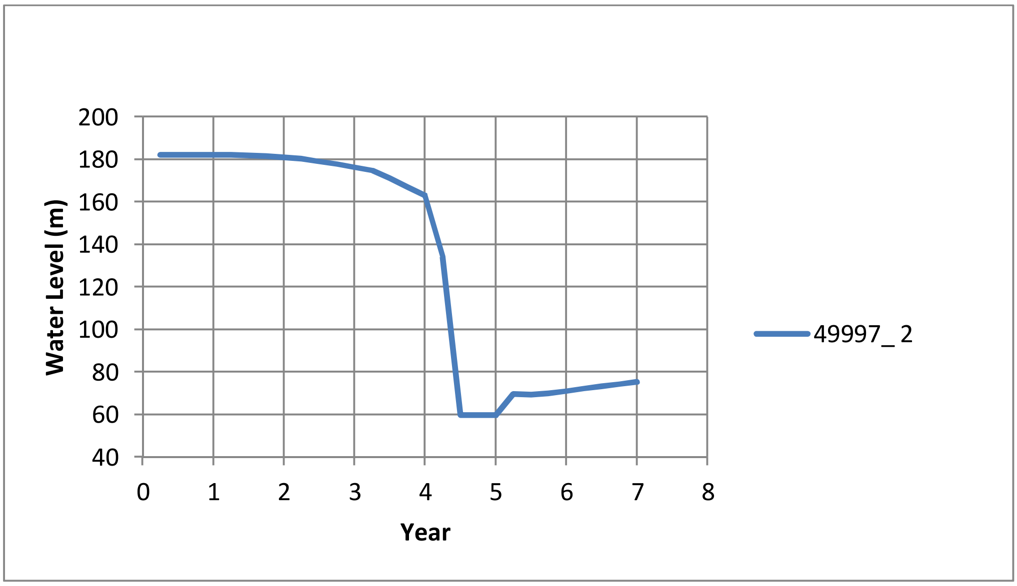
158
157
156
155
154
153
Water Level (m)
0
1
2
3
4
5
6
7
8
Year
LV2370W_ 1



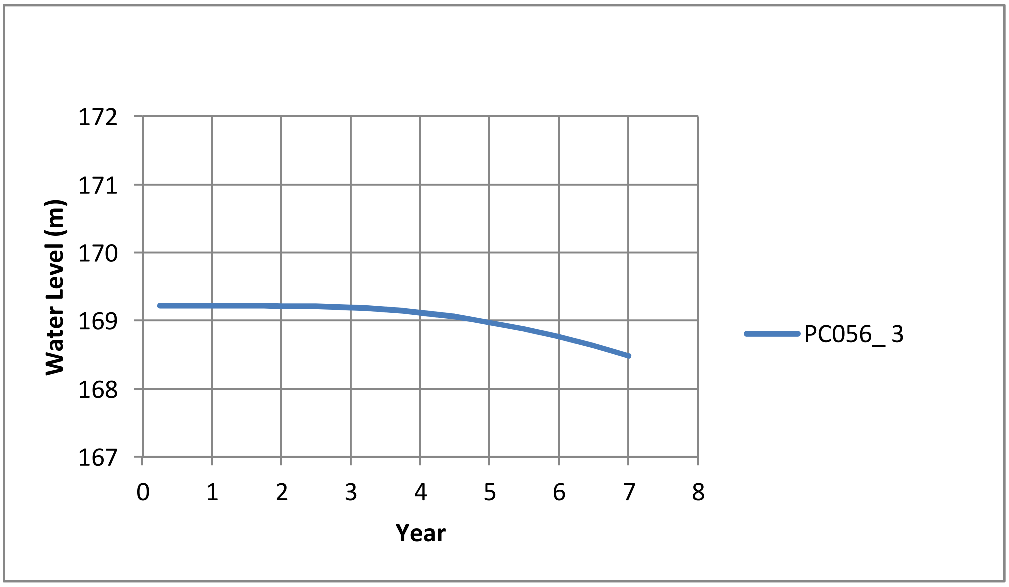
200
180
160
140
120
100
80
60
40
Water Level (m)
0
1
2
3
4
5
6
7
8
Year
32924_ 7



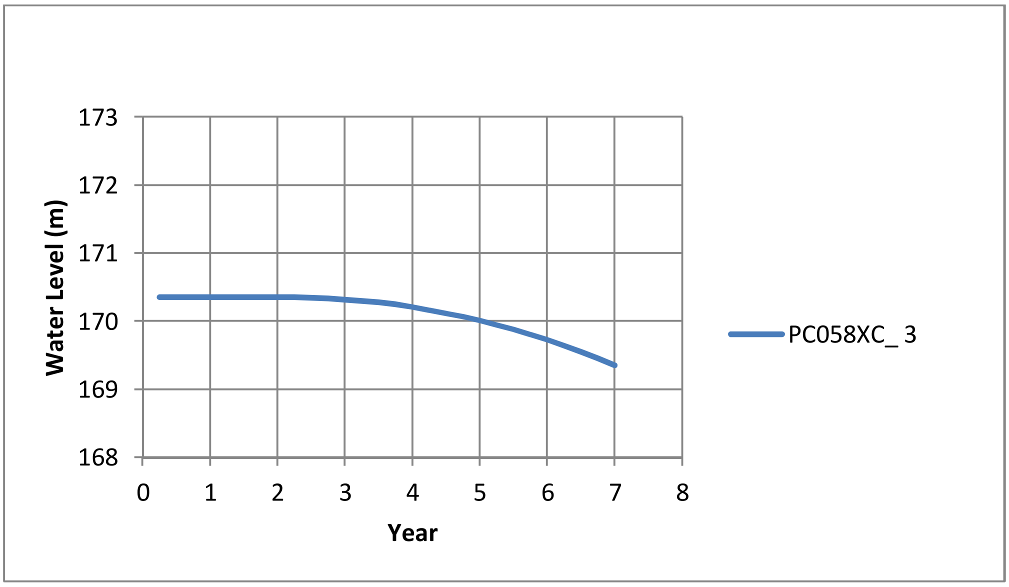
180
160
140
120
100
80
Water Level (m)
0
1
2
3
4
5
6
7
8
Year
42182_ 7



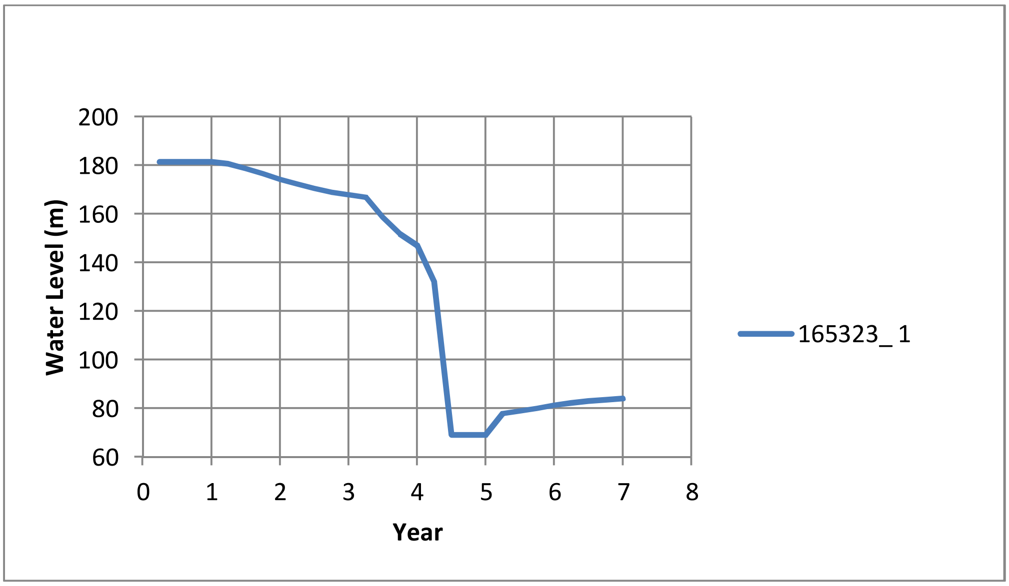
200
180
160
140
120
100
80
60
40
Water Level (m)
0
1
2
3
4
5
6
7
8
Year
49997_ 2



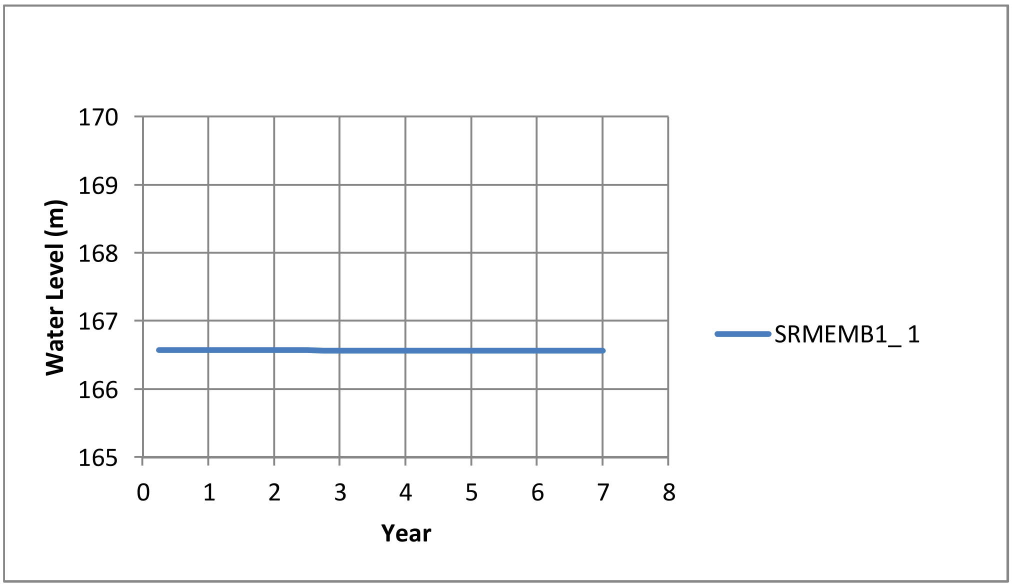
172
171
170
169
168
167
Water Level (m)
0
1
2
3
4
5
6
7
8
Year
PC056_ 3



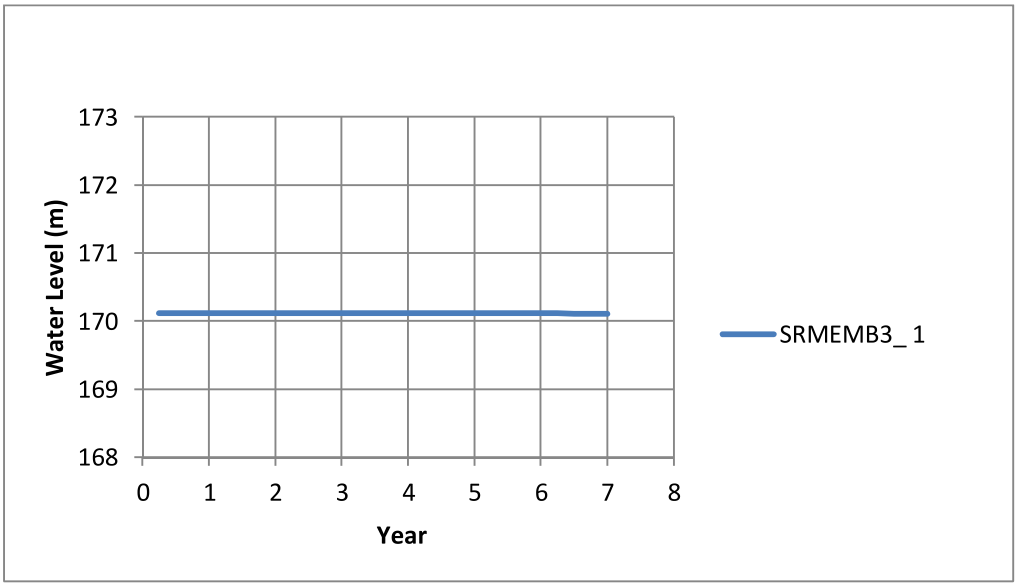
173
172
171
170
169
168
0 1 2 3 4 5 6 7 8
Water Level (m)
Year
PC058XC_ 3

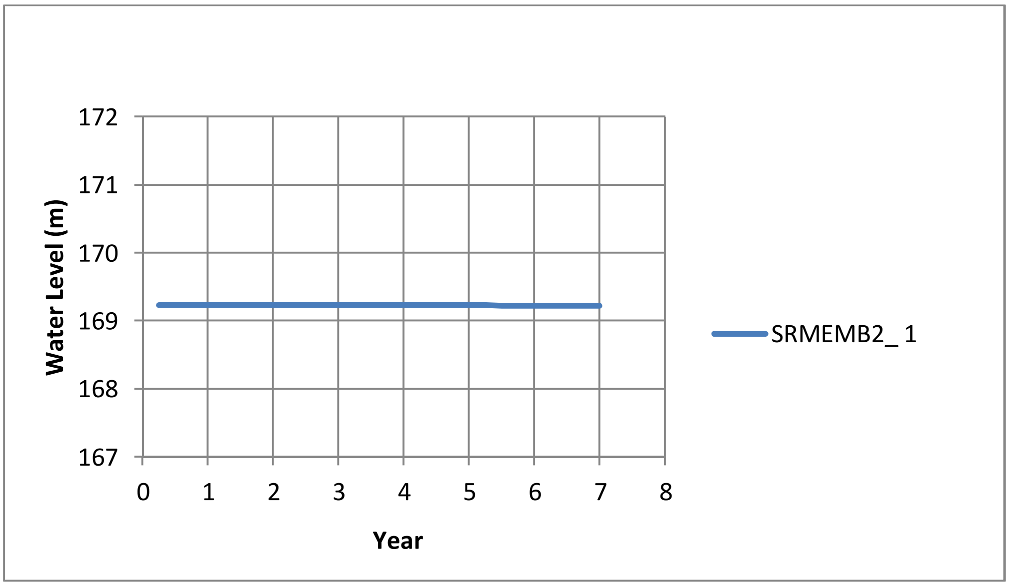


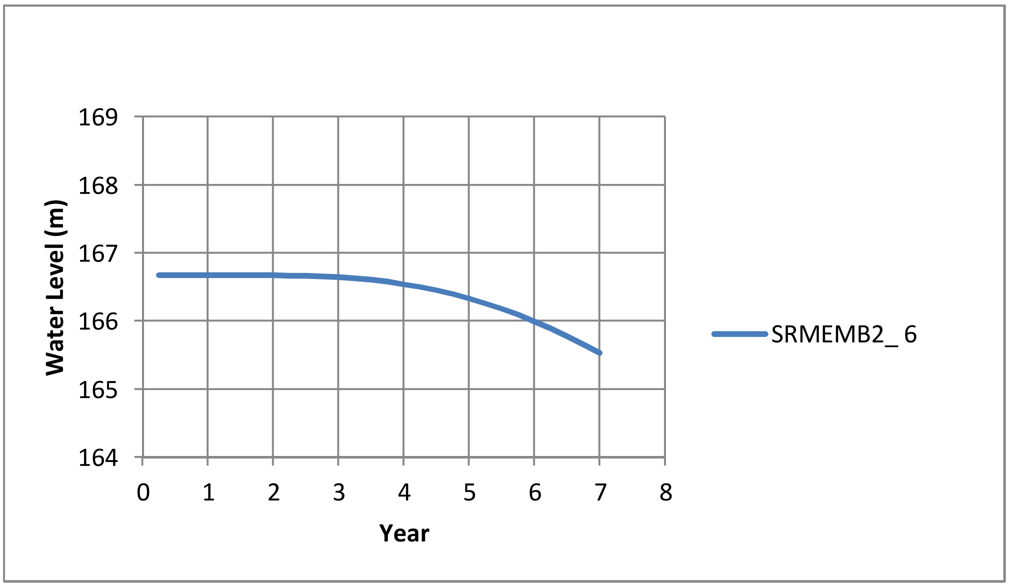
200
180
160
140
120
100
80
60
0 1 2 3 4 5 6 7 8
Water Level (m)
Year
165323_ 1

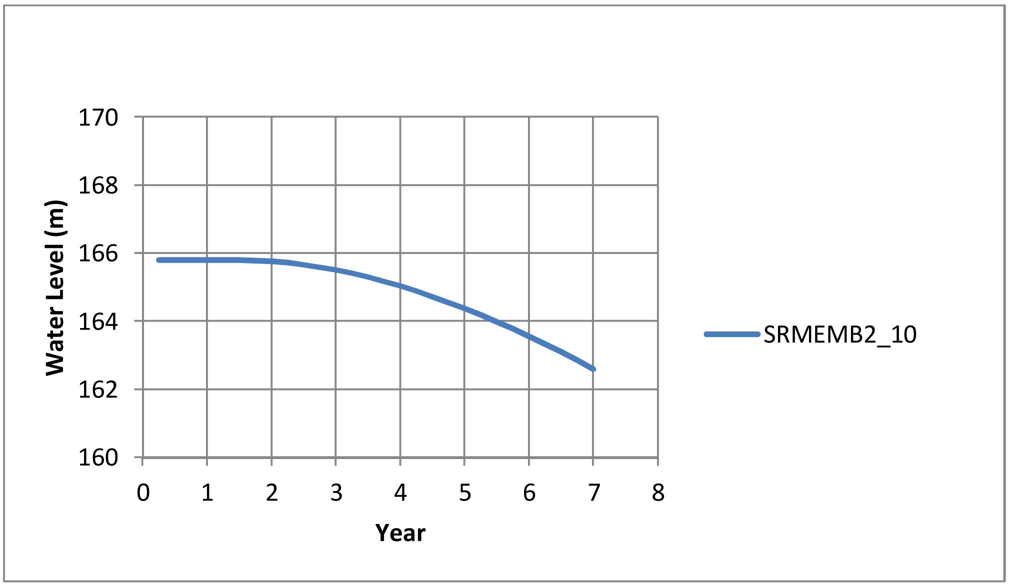


170
169
168
167
166
165
0 1 2 3 4 5 6 7 8
Water Level (m)
Year
SRMEMB1_ 1


173
172
171
170
169
168
0
1
2
3
4
5
6
7
8
Water Level (m)
Year
SRMEMB3_ 1


172
171
170
169
168
167
0
1
2
3
4
5
6
7
8
Water Level (m)
Year
SRMEMB2_ 1


169
168
167
166
165
164
0
1
2
3
4
5
6
7
8
Water Level (m)
Year
SRMEMB2_ 6



170
168
166
164
162
160
Water Level (m)
0
1
2
3
4
5
6
7
8
Year
SRMEMB2_10

Appendix B – Groundwater technical report

Saraji Open Cut Extension Project
BM Alliance Coal Operations Pty Ltd
07-Dec-2016

Groundwater Technical Report

Groundwater Technical Report

Client: BM Alliance Coal Operations Pty Ltd

ABN: 67 096 412 752

Prepared by

AECOM Australia Pty Ltd
Level 8, 540 Wickham Street, PO Box 1307, Fortitude Valley QLD 4006, Australia
T +61 7 3553 2000 F +61 7 3553 2050 www.aecom.com
ABN 20 093 846 925

07-Dec-2016

Job No.: 60507031

AECOM in Australia and New Zealand is certified to ISO9001, ISO14001 AS/NZS4801 and OHSAS18001.

Quality Information

Document Groundwater Technical Report

Ref 60507031

Date 07-Dec-2016

Prepared by K. Nichols

Reviewed by M. Stewart

Revision History

Rev	Revision Date	Details	Authorised	
			Name/Position	Signature
A	18-Nov-2016	Client Review Copy	David Curwen Associate Director	
0	24-Nov-2016	Final	David Curwen Associate Director	
1	07-Dec-2016	Finalised Project Description - Final	David Curwen Associate Director	

Table of Contents

List of Figures

List of Tables

ABBREVIATIONS

Al	Aluminium
ANZECC	The Australian and New Zealand Environment Conservation Council
As	Arsenic
BMA	BM Alliance Coal Operations Pty Ltd
BoM	Bureau of Meteorology
BTEX	Benzene, Toluene, Ethylbenzene, Xylene
Ca	Calcium
CHPP	Coal Handling and Preparation Plant
Cl	Chloride
CO_3	Carbonate
CRD	Cumulative Rainfall Departure
C_x	Hydrocarbon fractions
DNRM	Department of Natural Resources and Mines
EA	Environmental Authority
EC	Electrical Conductivity
EP Act	*Environmental Protection Act 1994*
EPBC Act	*Environmental Protection and Biodiversity Conservation Act 1999*
FCCM	Fort Cooper Coal Measures
Fitzroy Basin WRP	*Fitzroy Basin Water Resource Plan 2011*
ha	hectare
HCO_3	Bicarbonate
Hg	Mercury
FY	financial year
GDE	groundwater dependant ecosystem
GMA	groundwater management area
K	Potassium
k	Hydraulic conductivity
km	kilometre
LOR	Limit of Reporting
m	metres
MB	Monitoring Bore
MCM	Moranbah Coal Measures
Mg	Magnesium
MIA	Mine Infrastructure Area
ML	Mining Lease

MLA	Mine Lease Application
MNES	Matters of National Environmental Significance
mtpa	Million tonnes per annum
Na	Sodium
NO_3	Nitrate
P	Phosphorous
PEST	Parameter Estimation
RCM	Rangal Coal Measures
RN	Registration number
ROM	Run-of-Mine
Sb	Antimony
Sc	Storativity
SEMLP	Saraji East Mining Lease Project
SO_4	Sulfate
Sy	Specific yield
TDS	Total Dissolved Solids
VWP	Vibrating Wire Piezometer
Water Act	*Water Act (Qld) 2000*

Executive Summary

A groundwater environmental assessment has been compiled to evaluate potential impacts associated with the proposed extension of the Grevillea Pit at the Saraji Mine (the Project). The groundwater study included predictive groundwater modelling to evaluate the potential impacts of the proposed open cut activities and operations on groundwater resources. A groundwater technical report was compiled based on the assessment for inclusion in the EA Amendment application.

The Project is located within the Isaac River sub-basin of the Fitzroy Basin where identified environmental values for groundwater to be enhanced or protected are included in Schedule 1 of the Environmental Protection (Water) Policy 2011 for this area.

The Project is located on the western limb of the Bowen Basin and is underlain by Quaternary and Tertiary sediments which unconformable overly the Permian strata, which host the target coal seams. The sediments across the Project are generally undisturbed and gently dip between 2° to 5° to the east. The Permian unit includes less weathered to fresh overburden which comprises sandstone, siltstone, claystone, mudstone, coal, coal parting materials, and sub-coal (under burden) strata. The Permian rocks form a regular layered sedimentary sequence while the Tertiary materials are more complex and irregular. Infilled alluvial channels associated with the present-day creek courses are locally superimposed on the Tertiary Formation.

The alluvium comprises irregular sequences of unconsolidated clay, silt, sand, and gravel. The alluvium deposits are variable in thickness, linear, irregular, and lensoidal, being discontinuous because of bedrock outcrop within the creeks.

The Tertiary aged sediment sequence in the Project area comprises of heterogeneously distributed lensoidal sand deposits separated by a low permeability clay-rich matrix. The Tertiary unit is a predominantly clay matrix with intercalation of clay and sand lithologies. Medium to coarse grained sands and fine gravels occur is places at the base of the Tertiary sediments, which are locally continuous.

The alluvial sediment aquifer is unconfined and limited in lateral extent from the ephemeral Phillips Creek. The alluvial aquifer is not a permanent source of groundwater as bores drilled in close proximity to Phillips Creek were reported to be drilled dry. The records of dry bores indicate the alluvial sediments have limited storage (recharged during flow events and by direct rainfall but do not store groundwater) and are non-continuous (the coarse grained more permeable sediments are not continuous down the length of the creek). Groundwater quality of the alluvium is variable, ranging from fresh to very saline and is typically slightly saline.

The Tertiary sediments maintain permanent groundwater particularly within the deeper basal sediments; these basal sands are locally extensive and discontinuous. Minor groundwater ingress into the Saraji Mine pits indicates that the Tertiary sediments comprise a series of poorly connected low to moderate permeability aquifers, which are separated by low permeable clay. Tertiary groundwater ranges from slightly acidic to slightly alkaline and is dominated by sodium and chloride with total dissolved solids in excess of 6,000 milligrams per litre (mg/L). This means the water is brackish to saline and exceeds the recommended level for cattle.

The Permian overburden/interburden comprises essentially dry sandstone, siltstone, and shale. The Permian coal seams for the main aquifers within this unit, where the cleats and fractures within the coal provide enhanced groundwater potential. Permian coal seam groundwater ranges from slightly acidic to alkaline and is dominated by sodium and chloride with total dissolved solids (TDS) levels ranging from 3,300 mg/L to 20,000 mg/L. The coal seam water is brackish to saline and typically not suitable for stock watering.

Based on the low groundwater yield potential and typically poor quality groundwater resources in the Project area, groundwater environmental values are restricted to include limited stock watering and industrial purposes (coal mine operations).

Predictive groundwater modelling was conducted to assess the potential impacts of the proposed open cut extension. The modelling looked at mine dewatering impacts (groundwater ingress and groundwater level drawdown) considering the approved Saraji Mine with and without the Project. Predictive simulations, including an evaluation of groundwater level drawdown, the prediction of

groundwater ingress and an evaluation of groundwater level recovery was conducted with and without the Project.

Groundwater level drawdown in the Tertiary and Quaternary cover as well as the target coal seams indicated that the Project would result in a minor increase in the drawdown of groundwater levels to the east of the open cut mining. This occurs mainly as a result of the deep nature of the mining, some 300 m, in the open cut extension.

Groundwater ingress estimates for the approved mining (Saraji Mine) and the approved mining plus the Project (for the 15 year period 2017 to 2031) indicates an estimated total of 1.8 gigalitres (GL) of groundwater will be removed (with the coal and evaporation) during the 15 years of mining.

Recovery of groundwater levels, assuming all mining ceases at the end of 2031, were simulated in the predictive model. Limited change to the groundwater levels occurs due to the simulated large final voids, limited natural recharge, and low permeability within the Project area.

The Project is considered to have a minor increase in predicted groundwater impacts, including:

- increased zone of drawdown to the east
- long term impacts due to final voids associated with the Project (after mining ceases)
- alteration of water quality (which will remain within the pit).

It is recommended that the Saraji Mine groundwater monitoring program continue, which will allow for the validation of predictions and allow for the instigation of investigations into potential for environmental harm should groundwater monitoring results differ from predictions.

1.0 Introduction

AECOM was engaged by BM Alliance Coal Operations Pty Ltd (BMA) to undertake the required groundwater environmental assessment in support of an amendment to the Saraji Mine Environmental Authority (EA) Permit No. EPML00862313.

1.1 Project Overview

Saraji Mine commenced mining operations in 1974 on Mining Lease (ML) 1782 and ML 1775. Saraji Mine is an open cut truck and shovel operation producing approximately 18 million tonnes per annum (mtpa) of run-of-mine (ROM) coal. More recent exploration drilling has targeted areas to the east of ML 1782 within Mining Lease Application (MLA) 70383. Mine planning indicates the need to access coal reserves on MLA 70383 extending east from the existing Grevillea Pit. The extension of this pit is the subject of the Saraji Open Cut Extension Project (the Project). The MLA area subject to the Project is approximately 220 hectares (ha) in size. The planned mining area (new disturbance) is approximately 160 ha and represents 2.3% of the existing Saraji Mine disturbed area.

The current approved Saraji Mine Plan sees production in Grevillia Pit extending to approximately 2022. The progression of this pit to FY2031 within MLA 70383 is the subject of the Project. The Project is estimated to produce approximately 55 million tonnes (Mt) run-of-mine (ROM) coal. The Project will not increase the annual product tonnage output from the Saraji Mine. The Project will sustain the current operations of the mine by enabling the Grevillea Pit to extend beyond the current ML boundaries. The production life of the Project will be approximately ten years, followed by a period of rehabilitation. The broader Saraji Mine within the current and proposed new, ML boundaries is expected to extend into the 2040s.

The proposed mine extension will be developed in accordance with current mining operations and techniques and will use existing Saraji Mine infrastructure and facilities. The proposed mine expansion will be incorporated into the Saraji Mine and will:

- use the existing mine infrastructure area (MIA) and coal handling and preparation plant (CHPP)
- use existing power and water networks and supply
- use existing road and rail networks, with some minor access upgrades required
- use open-cut spoil dumps to distribute and dispose of dewatered tailing and rejects from the CHPP.

The low-volatile metallurgical product coal produced by the mine will be destined for the international coal market.

The combined existing approved Saraji Mine and the proposed Project Site is included in Figure 1 within the geological Bowen Basin, approximately 30 kilometres (km) north of Dysart in Central Queensland. The conceptual mine plan is detailed in Figure 2.

1.2 Study Scope and Objectives

The groundwater environmental assessment included predictive groundwater modelling to further assess the potential impacts of the proposed open cut activities and operations on groundwater resources.

The objectives of the groundwater environmental assessment are to:

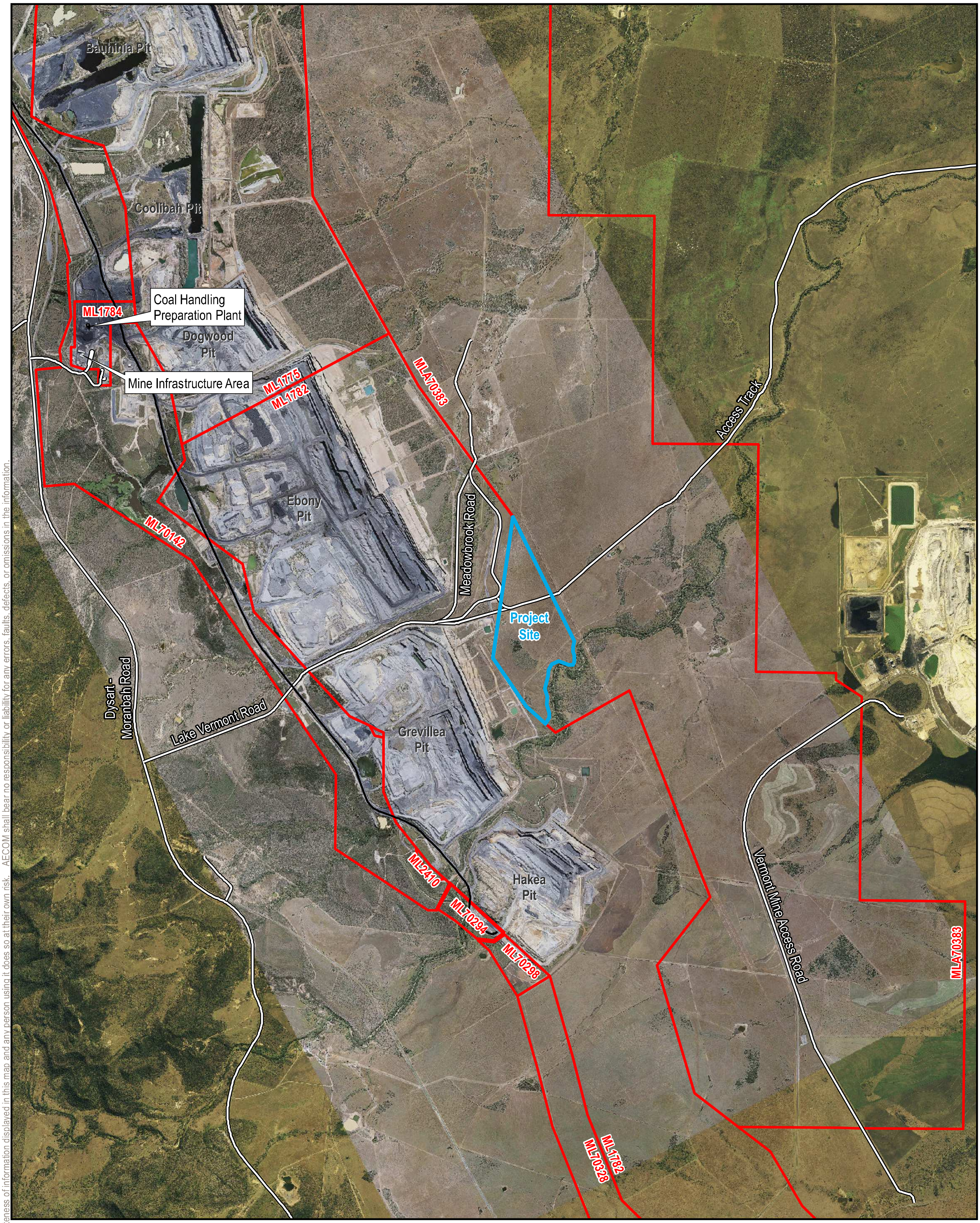
- identify and assess the potential impacts of the proposed open cut mine pit extension on the groundwater resources
- utilise the existing numerical model (constructed for the Saraji East Project in 2012) to predict potential impacts on groundwater, spatially and temporally
- identify and determine suitable mitigation and management strategies for the predicted groundwater potential impacts

- develop an optimal Groundwater Management and Monitoring program
- compile a technical groundwater report suitable to supplement the (EA) Amendment submission.

1.3 Scope of Work

For the purpose of this assessment, AECOM has undertaken the following tasks:

- revised and finalised the existing geological and groundwater baseline descriptions and conceptualisation of current groundwater resources
- assessed the impacts of the Project (taking into consideration the existing approved mining activities at Saraji Mine)
- updated and refined the existing (2012) groundwater model, to allow for the description of:
  - groundwater level drawdown and ingress volumes as a result of the proposed pit extensions
  - impacts on groundwater users
  - any potential surface water and groundwater dependant ecosystem (GDE) impacts
  - long term final voids impacts and decant potential.



LEGEND

- Haul Road
- Public Road
- BMA Tenure / Tenement
- Project Site
- Infrastructure

Data sources:

1. Existing Infrastructure, Proposed ML © BMA 2016 (RFI)
2. BMA Imagery 29 May 2016
3. QLD SISP Imagery 2012

N

Figure 1
Locality Plan

Saraji Open Cut Extension Project
Environmental Assessment Report

0 0.5 1 2
Kilometres

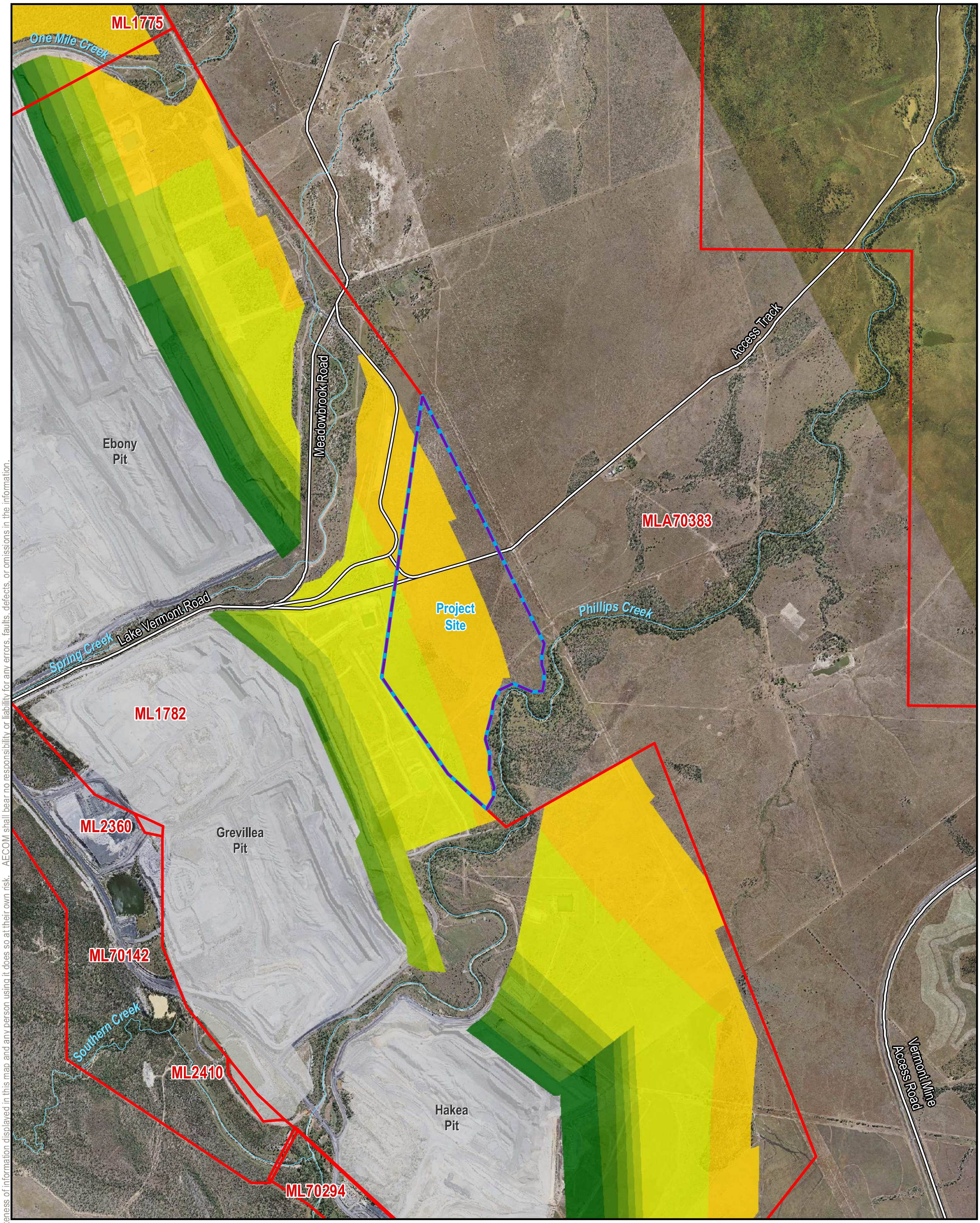
Scale: 1:80,000 (when printed at A4)

Projection: Map Grid of Australia - Zone 55 (GDA94)

BHP Billiton Mitsubishi Alliance

DATE: 23/11/2016 VERSION: 0

Filename: \\aubne1fp003\Projects\605X\60507031\4. Tech Work Area\4.99 GIS\02_MXDs\04 Saraji OC Environmental Assessment Report\00 Technical Report\Groundwater\60507031_G030_v0_A4P.mxd



LEGEND

- Creek
- Public Road
- Project Site
- MLA "Grevillia"
- BMA Tenure / Tenement
- Existing Open-Cut Extent

Conceptual Mine Plan

- FY2017
- FY2018
- FY2019
- FY2020
- FY2021
- FY2022 - FY2026
- FY2027 - FY2031

Data sources:

1. Existing and Proposed Infrastructure, Roads, Tenure © BMA 2016 (RFI)
2. BMA Imagery 29 May 2016
3. QLD SISP Imagery 2012

N

Figure 2
Conceptual Mine Plan

Saraji Open Cut Extension Project
Environmental Assessment Report

0 0.25 0.5 1
Kilometres

Scale: 1:40,000 (when printed at A4)

Projection: Map Grid of Australia - Zone 55 (GDA94)

BHP Billiton Mitsubishi Alliance

DATE: 29/11/2016 VERSION: 0

Filename: \\aubne1fp003\Projects\605X\60507031\4. Tech Work Area\4.99 GIS\02_MXDs\04 Saraji OC Environmental Assessment Report\00 Technical Report\Groundwater\60507031_G063_v0_A4P.mxd

AECOM has compiled a groundwater technical report, for inclusion in the EA amendment application, which provides:

- a detailed geological description of the area containing the Project
- the update and refinement (including revised calibration details) of the pre-existing groundwater model[1], inclusive of the model simulation scenarios and predictions for the proposed open-cut expansions
- details of long-term groundwater impacts (ongoing extraction due to evaporation from the pits)
- cumulative impacts with the approved Saraji Mine operations
- the compilation of groundwater monitoring recommendations for the entire project life inclusive of pre-mining, operations, and post closure stages.

[1] A numerical groundwater model was constructed and calibrated by AGE Consultants in 2012 for the then proposed underground mining on MLA 70383

2.0 Legislation and Policies

The primary legislative requirements that guide the management and development of groundwater components for the Project are listed below and summarised in Table 1 below:

- *Environmental Protection Act 1994* (EP Act)
- *Water Act 2000 (Qld)* (Water Act)
- Environmental Protection (Water) Policy 2011 (EPP (Water))
- *Sustainable Planning Act 2009* (SP Act)
- Fitzroy Basin Water Resource Plan 2011 (Fitzroy Basin WRP).

The Project site (Figure 1) is located within the Isaac River sub-basin of the Burdekin Basin as described in Schedule 1 of the EPP (Water). The identified environmental values for groundwater to be enhanced or protected in these areas include:

- Aquatic Ecosystems Environmental Values:
  - For high ecological value waters – the biological integrity of an aquatic ecosystem that is effectively unmodified or highly valued.
  - For slightly disturbed waters – the biological integrity of an aquatic ecosystem that has effectively unmodified biological indicators, but slightly modified physical, chemical or other indicators.
  - For highly disturbed waters – the biological integrity of an aquatic ecosystem that is measurably degraded and of lower ecological value than waters mentioned in paragraphs (a) to (c).
- Human Use Environmental Values:
  - For waters that may be used for agricultural purposes – the suitability of the water for agricultural purposes, including crop irrigation, farm use, stock watering.
  - For waters that may be used for aquaculture – the suitability of the water for aquacultural use.
  - For waters that may be used for producing aquatic foods for human consumption – the suitability of the water for producing the foods for human consumption.
- For waters that may be used for recreation or aesthetic purposes, the suitability of the water for:
  - primary recreational use
  - secondary recreational use
  - visual recreational use.
- For waters that may be used for drinking water – the suitability of the water for supply as drinking water.
- For waters that may be used for industrial purposes – the suitability of the water for industrial use.
- The cultural and spiritual values of the water.

Environmental Values relevant to the Project are presented in detail in Section 7.2 of this report.

Table 1 Summary of Relevant Legislation and Policies to the Project

Policy or Legislation	Description	Relevance to the Project (Groundwater)
EP Act	The objective of the EP Act is to protect the Queensland environment while allowing for development that improves the total quality of life, both now and in the future, in a way that maintains the ecological processes on which life depends (Queensland Government 2012). Subordinate to this act is the Environmental Protection Regulation 2008, which provides for the effective administration and enforcement of the objectives and provisions of the EP Act.	All persons must not carry out any activity that causes, or is likely to cause, environmental harm unless the person takes all reasonable and practical measures to prevent or minimise the harm (Section 319 of the Act). This general duty to the environment requires the implementation of proactive measures to prevent environmental degradation and act in accordance with the precautionary principle. This requirement is underpinned by the impact assessment and mitigation process in this study.
Water Act	The purpose of the Act is to provide for the sustainable management and efficient use of water and other resources, a regulatory framework for providing water services, and the establishment and operation of water authorities. Water resource plans have been developed to define the availability and allocation of water and to ensure the sustainable management of water in Queensland. The objectives of the water resource plans are to balance the needs of humans and the environment in a sustainable manner.	The Project area is located in the Highlands Sub-artesian Area of the Fitzroy Basin where a water entitlement, water permit, or seasonal water assignment notice is required to take or interfere with sub-artesian water (within the Project area), other than for a purpose mentioned in Schedule 11 (column 2) of Water Regulation 2002 (subordinate legislation to the Act).
EPP (Water)	The purpose of the Policy is to achieve the objectives of the EP Act in relation to Queensland waters while allowing for ecologically sustainable development.	The environmental values are to be enhanced or protected (Section 6 of the Act). The relevant environmental values vary depending on the ecological value of the water, level of disturbance and intended use of the water. The management controls/ mitigation measures in this study were prepared to meet the requirements of this policy.
SP Act	The purpose of the Act is to regulate the development of infrastructure outside mining and/or petroleum tenures.	The Project is located within the Highlands Sub-artesian Area of the Fitzroy Basin where any works for taking or interfering with water for purposes other than stock or domestic use (other than small diameter groundwater monitoring bores) are assessable activities and require a development permit.

3.0 Physical Setting

3.1 Location

The Project site is located within the central region of the Bowen Basin, approximately 170 km southwest of Mackay and 30 km north of Dysart in central Queensland. The Project is an extension of the existing operational Saraji Mine, located adjacently west of the Project area. Figure 1 depicts the Project site.

3.2 Land Use

The Project site is located on land which includes both freehold land and a number of utility and access easements. Generally, the land has been cleared of vegetation. Activities associated with the Saraji Mine have substantially altered the surface profile west of the Project.

Adjacent land uses north, east, and south of the Project site are predominantly for beef cattle grazing.

The land is owned by BMA and is currently used for cattle grazing purposes by the previous land owner in accordance with a licence from BMA until the land is required for mining purposes.

3.3 Topography and Drainage

Overall the area containing the Project is relatively flat with gentle undulations towards the east, from the Harrow Range in the west to the Isaac River east of the Project area.

The area containing the Project site includes a number of ephemeral creeks which drain from west to east. These ephemeral creeks are considered to have limited flow, typically only after heavy rainfall events. Operations at the Saraji Mine have altered the courses of these creeks which include dams and route direction (Figure 1).

The main surface water drainage feature immediately adjacent to the Project is Phillips Creek. Figure 3 depicts the general topography and surface water features of the Project area.

3.4 Climate

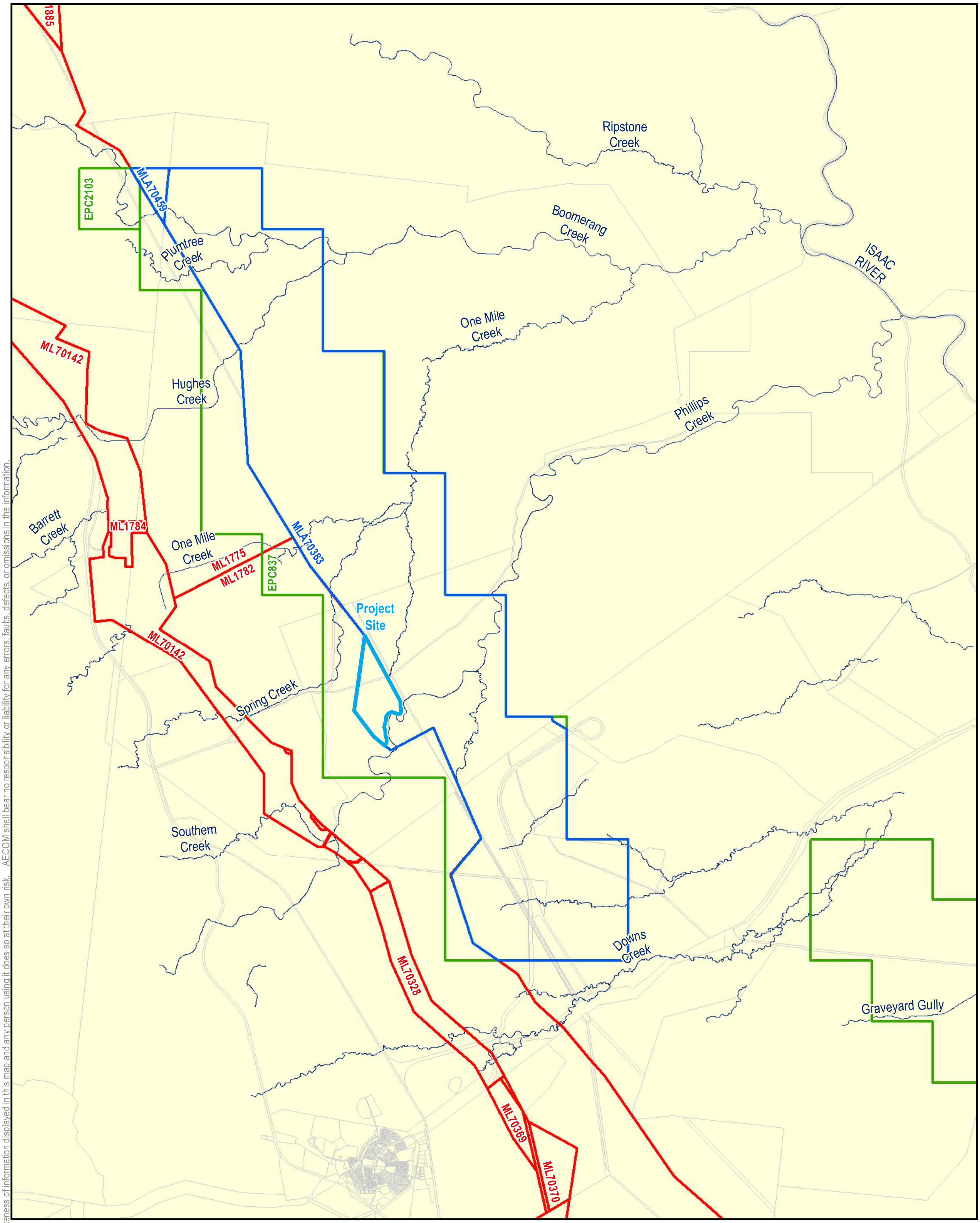
Monthly climate statistics based on data collected from Bureau of Meteorology (BoM) operated stations located in the study area were analysed. The nearest operational climate weather station is BoM Station 03403, which is located at the Moranbah Airport, approximately 48 km north of the Project site. This station has only been operational since 2012, which is considered too short of a timeframe to assess climate information. As such, BoM Station 035019, located at the Clermont Post Office (approximately 85 km southwest of the Project area) has been selected to assess long term temperature data (1910 to 2011), rainfall data (1929 to 2016), and evaporation (1979 to 2011).

In general, the climate for the Project area can be classified as sub-tropical with hot, humid summers, and warm, dry winters. Temperatures range from 34 degrees Celsius (°C) summer to 20 °C in winter and winter minimums can drop below freezing; however, it seldom gets colder than −3 °C.

Rainfall is considered mild and while rainfall can occur at any time the majority of events occur between November and March in the form of frequent showers and thunderstorms. The annual average rainfall is approximately 664 (mm). Average annual evaporation is 2,070 mm.

A summary of climate data for the Project area, obtained from BoM Station 035019 is presented in Table 2.

Evaporation exceeds rainfall every month indicating a negative climate budget.



LEGEND

- Creek
- Project Site
- Cadastre

Mining Tenement

- Exploration Permit Coal (EPC)
- Mining Lease (ML)
- Mining Lease Application (MLA)

Data sources:

1. Tenements, Tenure, Creeks © BMA 2016 (RFI)
2. Drainage © PitneyBowes (Streetpro) 2014
3. Water Licences © State of Queensland (Department of Natural Resources and Mines) 2016

N

Figure 3
Surface Water Features

Saraji Open Cut Extension Project
Environmental Assessment Report

0 1 2 4
Kilometres

Scale: 1:150,000 (when printed at A4)

Projection: Map Grid of Australia - Zone 55 (GDA94)

BMA
BHP Billiton Mitsubishi Alliance

DATE: 29/11/2016 VERSION: 1

Filename: \\aubne1fp003\Projects\605X\60507031\4. Tech Work Area\4.99 GIS\02_MXDs\04 Saraji OC Environmental Assessment Report\00 Technical Report\Groundwater\60507031_G044_v1_A4P.mxd

Table 2 Climate Summary

Month	Average Rainfall (mm)	Average Daily Pan Evaporation (mm)	Average Monthly Pan Evaporation (mm)
January	117.5	7.5	232.5
February	115.1	6.8	190.4
March	74.2	6.4	198.4
April	39.1	5.1	153.0
May	34.8	3.7	114.7
June	34.0	3.0	90.0
July	24.8	3.2	99.2
August	19.1	4.2	130.2
September	20.2	5.7	171.0
October	35.5	7.0	217.0
November	58.3	7.4	222.0
December	92.5	8.1	251.1
Annual Total	**663.6**		**2,069.5**

Source: BoM

3.4.1 Cumulative Rainfall Departure

The Cumulative Rainfall Departure (CRD) is a summation of the monthly departures of rainfall from the long-term average monthly rainfall, which is calculated as follows:

$$CRD_n = CRD_{n-1} + (R_n - R_{ave})$$

Where:

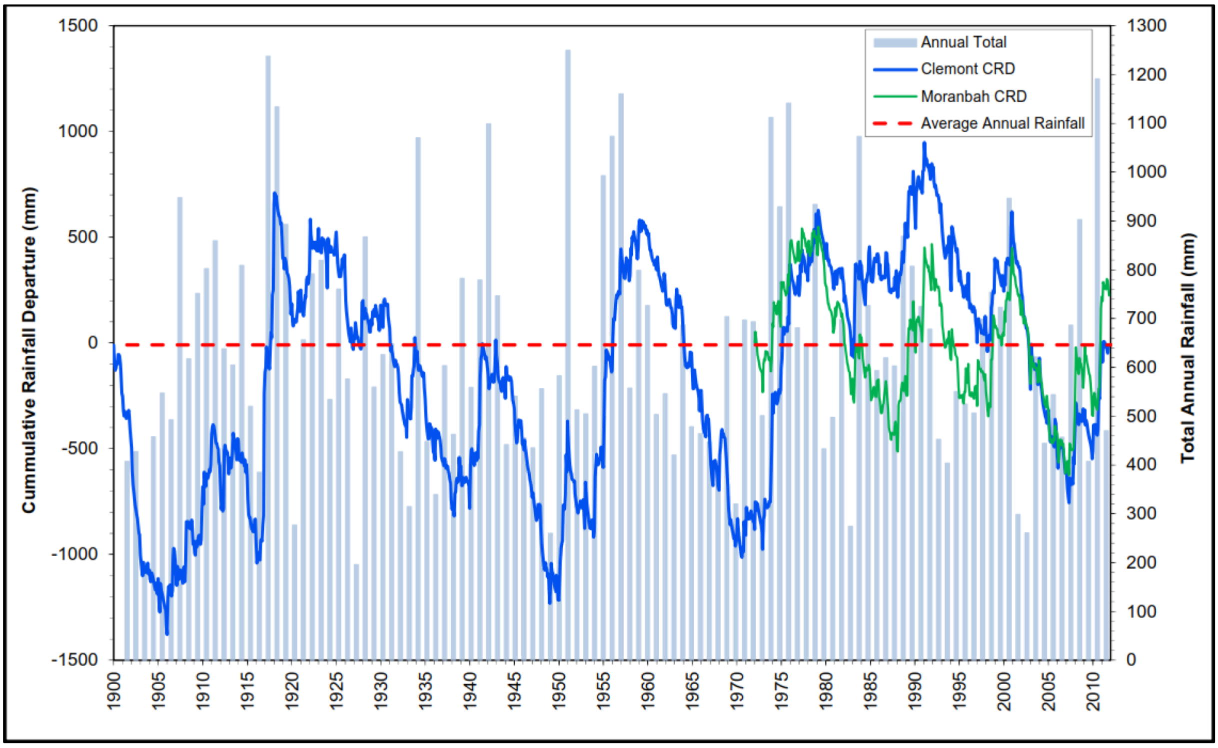
CRDn = CRD for a given month
CRDn-1 = CRD for a preceding month
Rave = Long term average monthly rainfall
R_n = Actual monthly rainfall

The calculated CRD for the Clermont and Moranbah weather station data is presented in Figure 4. A rising slope on the CRD plot indicates of above average rainfall (and possibly increased groundwater recharge to unconfined aquifers) and conversely a falling slope indicates periods of below average rainfall.

Figure 4 indicates:

- a prolonged drought period with below average rainfall between 2001 and 2007 in the region
- above average rainfall is currently being experienced
- the CRD indicates the likelihood of average groundwater levels being measured in the aquifers.

Figure 4 CRD Plot



Source: AGE, 2012a

4.0 Review of Information

A number of previous groundwater studies have been undertaken at the Saraji Mine to address groundwater issues in regards to geotechnical and dewatering feasibility studies and to characterise the hydrogeological regime and review groundwater monitoring data at the mine. These reports and associated data were reviewed to refine our understanding of the hydrogeologic system at the site for impact assessment of the Project on this system.

The draft Saraji East Project Groundwater Impact Assessment (AGE, 2011) was also reviewed as a component of the impact assessment.

Additional reports and data from nearby projects were reviewed as well to gain an appreciation of the regional groundwater system and to understand and assess cumulative impacts of these projects on the system at the Project site.

Key reports considered for the groundwater impact assessment included:

- AGE, 2007. Report on Hydrogeological Regime and Impact Assessment Saraji Mine, Project No. G1387, December 2007
- AGE, 2011. Report on Saraji East Project Groundwater Impact Assessment, Project No. G1549, December 2011
- AGE, 2012a. Australian Groundwater & Environmental Consultants Memorandum – Predicted Inflows and Drawdown Extents – Saraji East Underground Mine, ref. G1549, dated 24 February 2012
- Arrow, 2012. Arrow Bowen Gas Project EIS Chapter 14 Groundwater
- BMA, 2012. Saraji East Project Environmental Impact Statement Groundwater Resources – Chapter 7, 19 April 2012
- Gauge, 2015. Annual Groundwater Monitoring Report Saraji Coal Mine June 2015 Gauge Industrial and Environmental Version 1.0 dated 25 June 2015
- JBT, 2014. Lake Vermont Northern Extension Groundwater Impact Assessment report prepared by JBT Consulting for AARC on behalf of Bowen Basin Coal Pty Ltd, ref. JBT01-036-001, August 2014
- SKM, 2010. High Level Review of Hydrogeological Data, ref. QE09634, dated 7 May 2010
- URS, 2012. Report Groundwater Impact Assessment Bowen Gas Project, Ref. 42626960, November 2012
- URS, 2014. Groundwater Chapter for the Dysart Coal Mine Project prepared for Bengal Coal Pty Ltd, ref. 42627233/GW dated 10 February 2014.

5.0 Geology

5.1 Geological Setting

The Project is located on the western limb of the Bowen Basin, a north-south trending Early Permian to Middle Triassic geological basin. Comprised of a sedimentary sequence of Permo-Triassic clastics, which attain a maximum thickness of 9,000 metres (m) in the depocentre of the basin, the Taroom Trough, the Bowen Basin is vast and covers an area of approximately 200,000 square kilometres (km^2), from Collinsville in the north to Rolleston in the south.

Divided into a number of tectonic units which comprise north north-west to south south-east trending platforms / shelves, separated by sedimentary troughs, the major structural features of the Project area include the Collinsville Shelf to the north and the Nebo Synclinorium[2] to the east.

Folds within the Basin are gentle and generally the results of drag on thrust faults along the eastern boundary of the basin. The boundary between the Collinsville Shelf and the adjoining major axis of deposition, the Nebo Synclinorium of the Taroom Trough, is indicated by a major thrust fault, the Jellibah Thrust Fault (URS, 2012). Limited regionally significant fault zones or structures differentiate the sediments of the Collinsville Shelf from the tightly folded and intruded sediments of the Nebo Synclinorium (Elliot, 1989).

The regional stratigraphic sequence is presented in Section 5.4. Summarised, the sequence comprises:

- Middle Permian Back Creek Group (basement)
- the Late Permian Blackwater Group sediments (and coal measures)
- unconsolidated Tertiary sediments
- unconsolidated Quaternary alluvium sediments.

The Tertiary Duaringa Formation is also present, but limited, in the region.

The surface geology for the study area is shown in Figure 5.

5.2 Geological Evolution

5.2.1 Bowen Basin

Deposition in the Bowen Basin commenced during an Early Permian extensional phase, with fluvial and lacustrine sediments and volcanics being deposited in a series of half-grabens in the east while in the west a thick succession of coals and non-marine clastics were deposited.

Following rifting there was a thermal subsidence (sag) phase extending from the Early to Late Permian, during which a basin-wide transgression allowed deposition of deltaic and shallow marine, predominantly clastic sediments as well as extensive coal measures. Foreland loading of the basin spread from east to west during the Late Permian, resulting in accelerated subsidence, which allowed the deposition of very thick successions of Late Permian marine and fluvial clastics, again with coal and Early to Middle Triassic fluvial and lacustrine clastics.

Sedimentation in the basin was terminated by the Middle to Late Triassic (URS, 2012).

5.2.2 Permian Age

The extensional phase of basin development resulted in an Early Permian marine sequence. The Back Creek Group is regionally developed, lithologically variable, and comprises four formations: the Tiverton, Gebbie, Blenheim, and Exmoor, in ascending stratigraphic order. The northern Collinsville Coal Measures are considered to be a non-marine facies equivalent of the Gebbie Formation.

---

[2] A regional structure of general synclinal form that includes a series of smaller folds

LEGEND

- Existing Open-Cut Extent
- BMA Tenure / Tenement
- Project Site

Surface Geology

- Back Creek Group (Pb)
- Duaringa Formation (Tu)
- Fort Cooper Coal Measures (Pwt)
- German Creek Formation (Pbd)
- MacMillan Formation (Pbn)
- Moranbah Coal Measures (Pwb)
- Peak Range Volcanics (Tp)
- Qa-QLD (Qa)
- Qr-QLD (Qr)
- Qr\b-QLD (Qr\b)
- TQa-QLD (TQa)

Data sources:

1. Tenements © BMA 2016 (RFI)
2. Geology © State of Queensland (Department of Natural Resources and Mines) 2016

N

Figure 5
Saraji Open Cut Extension Project Surface Geology

Saraji Open Cut Extension Project Environmental Assessment Report

0 1 2 4
Kilometres

Scale: 1:200,000 (when printed at A4)

Projection: Map Grid of Australia - Zone 55 (GDA94)

BMA
BHP Billiton Mitsubishi Alliance

DATE: 29/11/2016 VERSION: 1

A sag phase (post-extension thermal subsidence) during the mid-Permian resulted in basin-wide marine transgression and regression cycles for the remainder of the Middle Permian and much of the Late Permian (URS, 2012).

The Late Permian resulted in reactivation of the volcanic arc (uplift of the New England Orogeny) and westward thrusting in the New England Orogeny, which altered the Bowen Basin into a foreland basin. The resultant infill allowed for widespread, coal-forming alluvial and delta plain depositional environments, preserved as the equivalents of the Blackwater Group. The northern half of the basin saw eastward prograding deltas combined with major axial fluvial systems which resulted in the deposit of the upper delta plain Moranbah Coal Measures (MCM) and equivalents (lower delta plain German Creek Formation and the MacMillan Formation) (URS, 2012).

The non-marine deposition of the Fort Cooper Coal Measures (FCCM) and equivalents (Burngrove and Fairhill formations) then followed. Subsequent subdued volcanic activity in the east may have produced the basin-wide peat forming environments of the prograding alluvial and delta depositional systems that resulted in the Rangal Coal Measures (RCM).

5.2.3 Cainozoic

Post-basin faulting and subsequent Tertiary basin development (i.e. the Duaringa Basin) happened concordantly with the emplacement of post-Triassic-aged intrusions (Main Range Volcanics) as the entire basin was subjected to a long period of deep weathering where lateritic profiles were strongly developed. Terrestrial Tertiary deposits are widespread, where basalt and associated intermediate and acid rocks are found over large areas across the Bowen Basin (Arrow, 2012).

5.3 Structural Features

5.3.1 Regional

The Project is located on the western limb of the northern Bowen Basin, a northerly plunging syncline, at the southern end of the Collinsville Shelf. A cross-section west to east through the Bowen Basin in the Saraji Mine area indicates the complex horst and graben structures, faulting, and repeating geology (Figure 6).

Faults in the area comprise both normal and thrust faults with mapped trends which describe two structural domains: one trends north north-west, the second trends north-south. Major faults of the Project area include the Saraji South Fault, Downs Creek Fault, and the Isaac Thrust Fault.

5.3.2 Site Specific

The sediments across the Project are generally undisturbed and have a gentle regional dip of 2° to 5° towards the east. Faults are mapped within the existing Saraji Mine (as depicted in Figure 7), which are typically minor; steepen locally to approximately 9° to 10°.

The Saraji South Fault is located south of the site, near Phillips Creek; a high angle, north north-west trending normal fault, throws have been mapped between 10 and 50 m (AGE, 2011).

The Downs Creek Fault is a north north-west trending normal fault with a maximum throw of 60 m and is located south of the Project area, near Lotus Creek Road.

Structural features within and adjacent to the Project are presented on Figure 7.

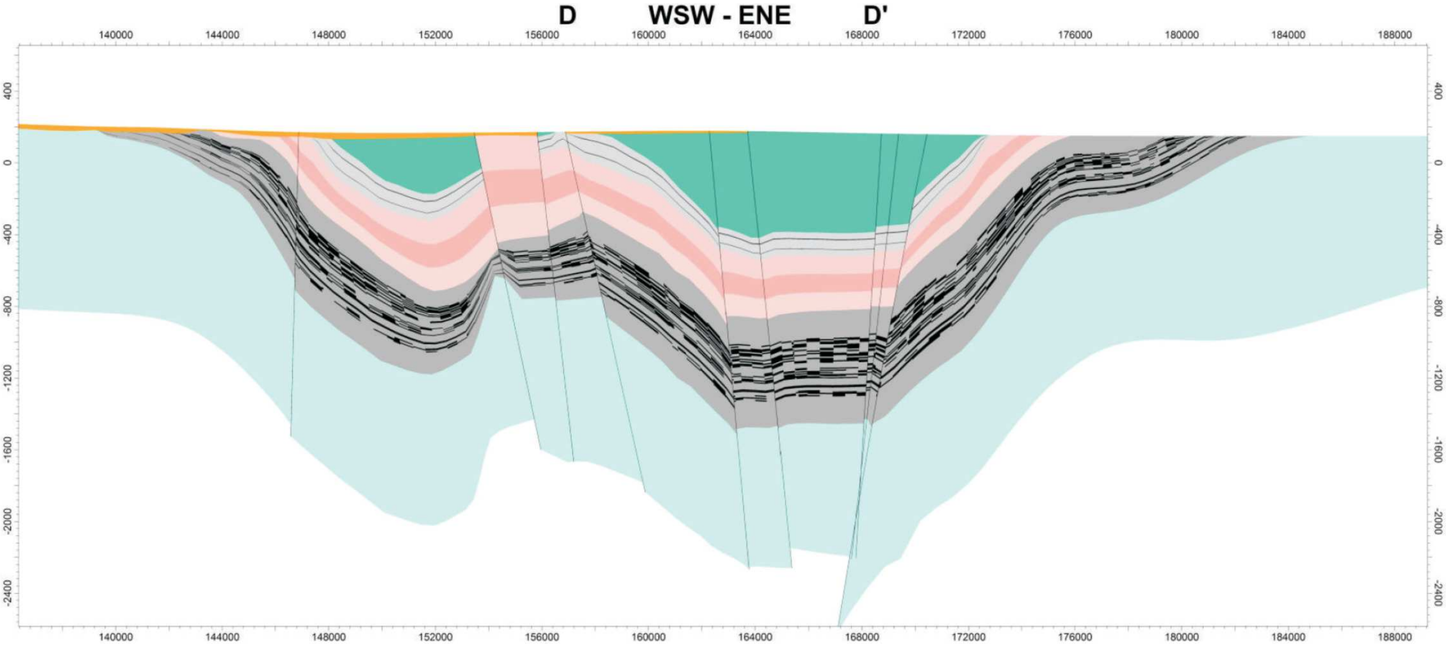
Cross-sections

To further assess possible structural features, such as faults and folding, within the Project site two geological cross-sections were generated from exploration bore logs.

The locations of the two cross-sections are included in Plate 1 and Plate 2.

The resultant geological fence diagram cross-sections (Plate 3 and Plate 4), from southwest to northeast do not indicate any marked folding or disruption of coal seams as a result of faulting.

The coal and interburden strata within the Project site is not recognised to have been altered by secondary structural features.



Zones

- Vermont
- RCM IB
- Fort Cooper Coal Measures
- FCCM1
- FCCM2
- FCCM3
- Moranbah Coal Measures
- MCM IB
- Q(GMU)
- MCM IB
- P
- MCM IB
- GM
- MCM IB
- GML
- MCM IB
- Collinsville Coal Measures
- Back Creek Group

Data sources:

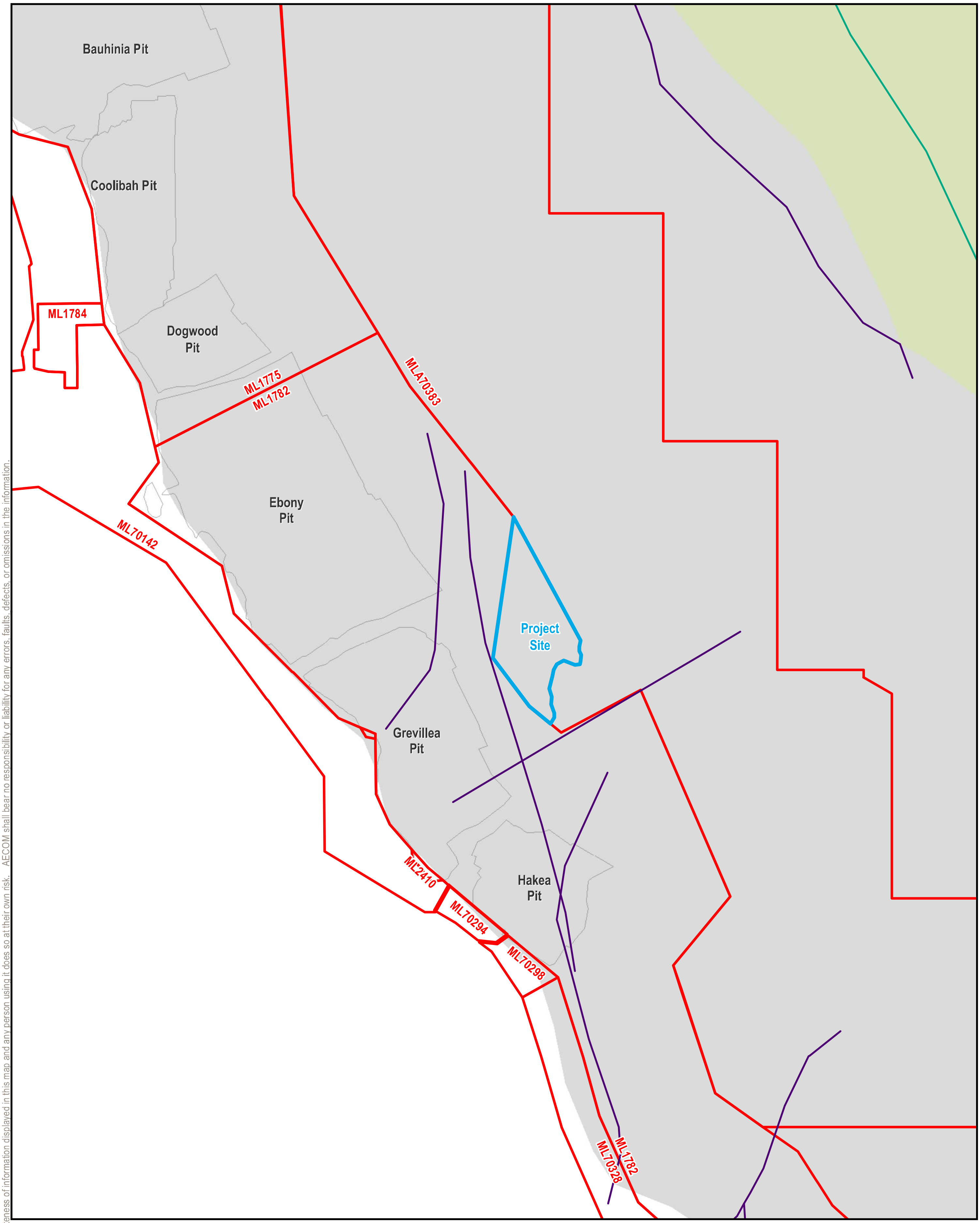
1. Petrel geological model cross-section provided by Arrow Energy Pty Ltd 2012

Figure 6
Regional Geological Cross Section (Source Arrow, 2012a)

BMA
BHP Billiton Mitsubishi Alliance

Saraji Open Cut Extension Project
Environmental Assessment Report

DATE: 29/11/2016 VERSION: 1



LEGEND

- Existing Open-Cut Extent
- BMA Tenure / Tenement
- Project Site
- Anticline / Syncline
- Fault
- Rewan Formation (Triassic)
- Coal Measure (Late Permian)

Data sources:

1. Tenements © BMA 2016 (RFI)
2. Geology © State of Queensland (Department of Natural Resources and Mines) 2016

N

Figure 7
Mapped Faults Across the Saraji Open Cut Extension Project

Saraji Open Cut Extension Project Environmental Assessment Report

0 0.5 1 2
Kilometres

Scale: 1:80,000 (when printed at A4)

Projection: Map Grid of Australia - Zone 55 (GDA94)

BMA
BHP Billiton Mitsubishi Alliance

DATE: 29/11/2016 VERSION: 1

Plate 1 Cross-Section Locations

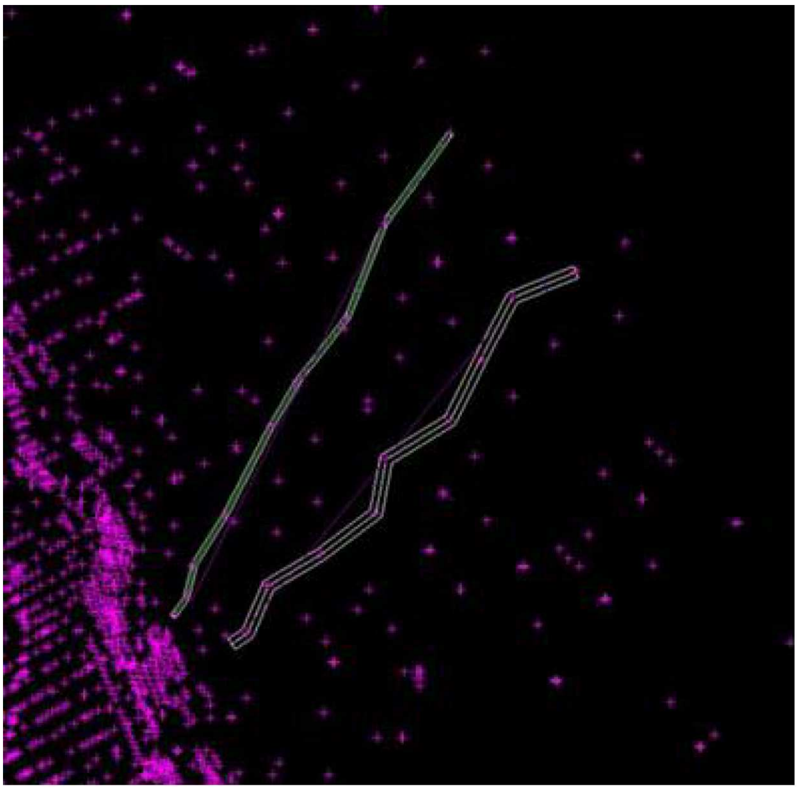


Plate 2 Geological Cross-Section Locations and Exploration Bores

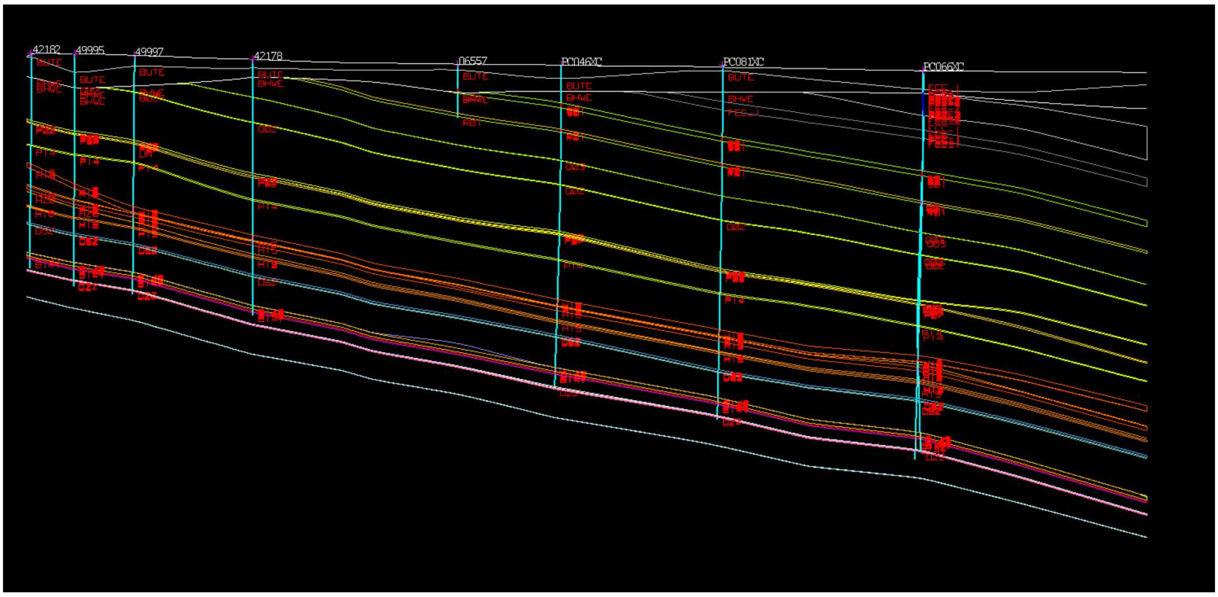


Plate 3 Geological Cross-Section 1

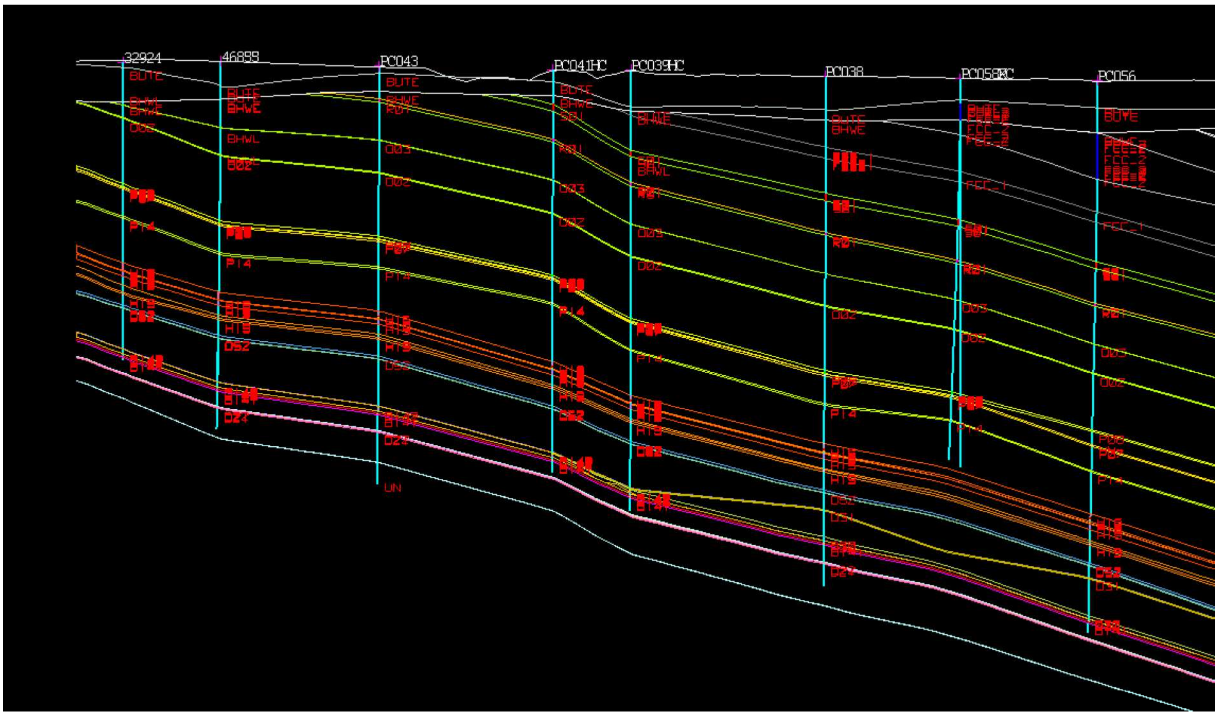


Plate 4 Geological Cross-Section 2

5.4 Lithostratigraphy

The stratigraphy underlying the Project consists of Permian-age sediments overlain by a thin layer of unconsolidated to poorly consolidated Cainozoic (Tertiary and Quaternary) sediments.

Specifically, the Permian Blackwater Group, which consists of the economic Moranbah Coal Measures (MCM), is unconformably overlain by up to 57 m of unconsolidated to semi-consolidated Tertiary sediments followed by localised unconsolidated Quaternary alluvial sediments.

The Quaternary alluvial deposits are thickest along the surface waters (creeks) that traverse the Project area, from west to east (see Figure 3).

The Permian rocks form a regular layered sedimentary sequence (Plates 3 and 4), while the Tertiary materials are more complex and irregular. Infilled alluvial channels associated with the present-day creek courses are locally superimposed on the Tertiary Formation.

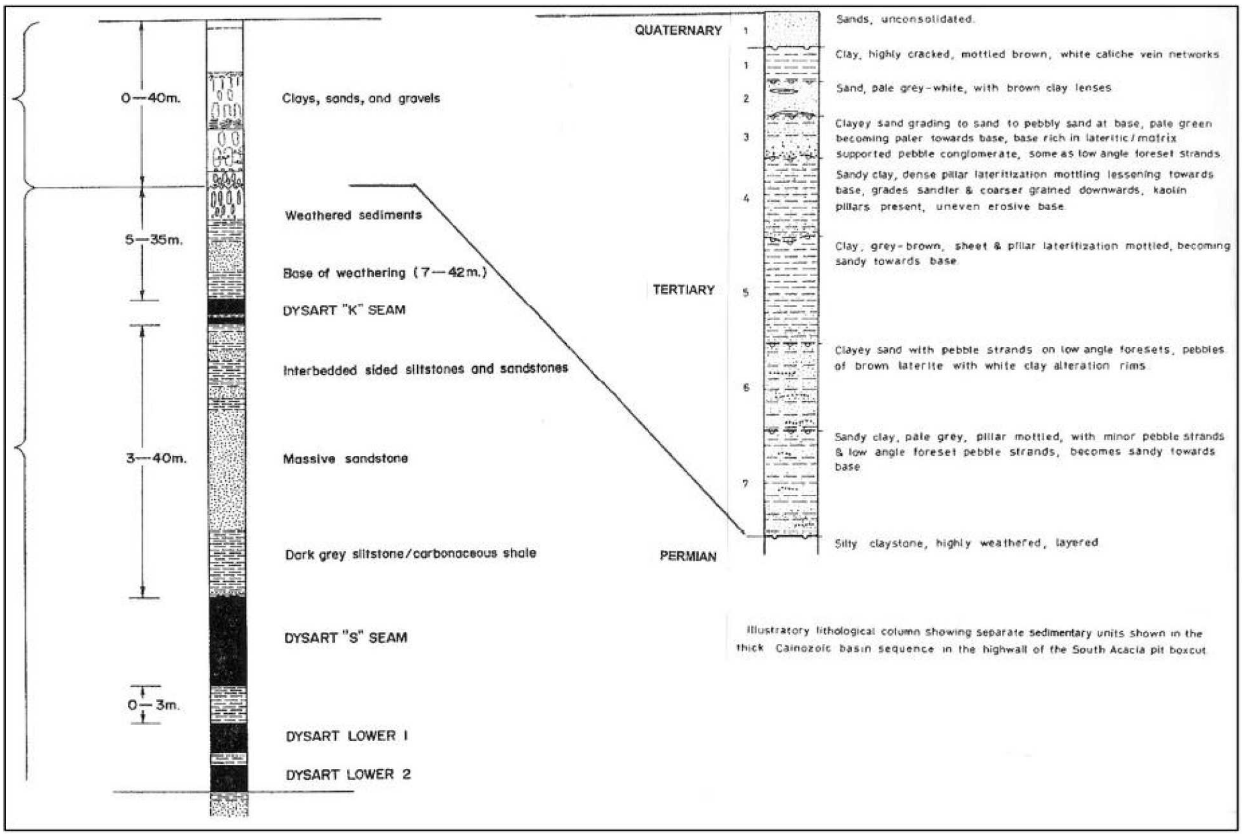
The stratigraphy of the Project site is summarised, from youngest to oldest, in Table 3 and a typical stratigraphic profile is depicted on Figure 8.

Table 3 Lithostratigraphy

Period	Stratigraphic Unit		Description	Average Thickness (m)	Occurrence
Quaternary	Alluvial sediments		Clay, silts, sand, gravel, floodplain alluvium	0 - 25	Confined to present day stream and creek channels, specifically Phillips Creek
Tertiary	Clay		Clay, clayey sand, sandy clay, sand	4 - 45	Covers Project with regular distribution; individual lenses are discontinuous and lensoidal
	Basal Sand		Sand	0 - 3	Irregular distribution, generally observed where Tertiary sediments are thickest
	Duaringa Formation		Mudstone, sandstone, conglomerate, siltstone, oil shale, lignite and basalt	~ 20	Extensive outside the Project to south and north
Permian	Fort Cooper Coal Measures (FCCM)	Burngrove Formation	Coal, brown and green sandstone, conglomerate, carbonaceous shale, tuff	Up to 400	Located to the east of the Project
		Fairhill Formation	Labile sandstone, quartzose sublabile sandstone, siltstone, mudstone, calcareous and tuffaceous sandstone, volcanic conglomerate, carbonaceous mudstone, coal		

Period	Stratigraphic Unit		Description	Average Thickness (m)	Occurrence
	Moranbah Coal Measures	MacMillan Formation	Sandstone dominates with lesser siltstone, interbedded sandstone/ siltstone, coal, mudstone and carbonaceous shale. The Dysart and Harrow Creek coal seams are the predominate seams of economic significance.	250 – 350	Entire Project footprint
		German Creek Formation			
Early to Middle Permian	Back Creek Group		Quartzose to lithic sandstone, siltstone, carbonaceous shale, minor coal and sandy coquinite		Underlies Project area; Outcrops west of Saraji Mine and extends under mined areas to the east

Figure 8 Typical Lithological Column



Source: AGE, 2007.

5.4.1 Quaternary Sediments

Quaternary deposits of alluvial sand and gravel are associated with ephemeral surface drainage features such as creeks which have eroded into the underlying Tertiary sediments.

The alluvium comprises of irregular sequences of unconsolidated clay, silt, sand, and gravel. The alluvium deposits are variable in thickness, linear, irregular, and lensoidal. This is due to the meandering and braided nature of the depositional environment that includes cross-cutting and reworking of older alluvial deposits. The alluvium is also discontinuous because of bedrock and clay (non-continuous coarse material) (Arrow, 2012).

The alluvial sediments in the Project area have been reported to have a maximum thickness of 25 m at Phillips Creek (AGE, 2007) as a result of infilling a paleo-channel carved through Tertiary sediments and into the underlying Permian Coal Measures.

Similar thicknesses of alluvial sediments occur within the Isaac River alluvium, east of the Project area.

5.4.2 Tertiary Sediments

The Tertiary aged sediment sequence in the Project area is comprised of heterogeneously distributed lensoidal sand deposits separated by a low permeability clay-rich matrix. Tertiary age sediments comprise unconsolidated to semi-consolidated fluvial sediments which include clay, silty clay, sandy clay, clayey sand, sand and gravel with clay predominant.

The Duaringa Formation, mapped across the study area containing the Saraji Mine and Project site (Figure 5), contains mudstone and siltstone (i.e. low permeability strata).

Typically these sediments are less than 15 m thick; the Tertiary sediments have been reported up to 57 m thick in the western portions of Saraji Mine.

The presence of paleo-channels and lensing of units within the Tertiary prevent correlation of discrete units; individual units are laterally discontinuous with varied thickness.

The Tertiary sequence is defined by an unconformable boundary with the underlying Permian sequence which characterises the Permian topography prior to deposition of Tertiary sediments.

5.4.2.1 Tertiary Clay

The Tertiary unit is comprised of a predominantly clay matrix with intercalation of clay and sand lithologies.

At least seven depositional phases are evident in the Tertiary sediments in the Bowen Basin, generally as truncating, fining upward sequences. Weathering of the sediments is evident in at least three periods of laterisation with associated mottling and concretionary structure (AGE, 2011).

The lithologies can vary from heavily leached, mottled white and maroon clays to sandy clays.

5.4.2.2 Basal Sand and Gravel

A basal sand and gravel sequence has been identified beneath the clay rich matrix in the western limb of the Bowen Basin.

Comprising medium to coarse grained sands and fine gravels, the sequence has a maximum thickness of approximately three metres, and is considered to be locally continuous.

The basal Tertiary unit indicates the presence of a laterally discontinuous paleo-channel system assumed to be related to a proto-Phillips Creek system (JBT, 2014).

5.4.2.3 Tertiary Basalt

Basalt is not mapped within the Saraji Mine and Project site (Figure 5 and Figure 11).

5.4.2.4 Duaringa Formation

Tertiary Duaringa Formation filled the Duaringa Basin, which formed as a result of post Bowen Basin faulting. This Tertiary basin formed concordantly with the Tertiary volcanics, and consists of mudstone, siltstone, sandstone, conglomerate, oil shale, lignite, and basalt.

This unit is not mapped within the Project site.

5.4.3 Permian Strata

The Permian coal bearing strata within the Project area, unconformably overlain by the Tertiary and Quaternary sediments, comprise the FCM and MCM. The MCM hosts the target coal seams of economic value to the Project.

The Permian unit comprises less weathered to fresh overburden which is comprised of sandstone, siltstone, claystone, mudstone, coal, coal parting materials, and sub-coal (under burden) strata.

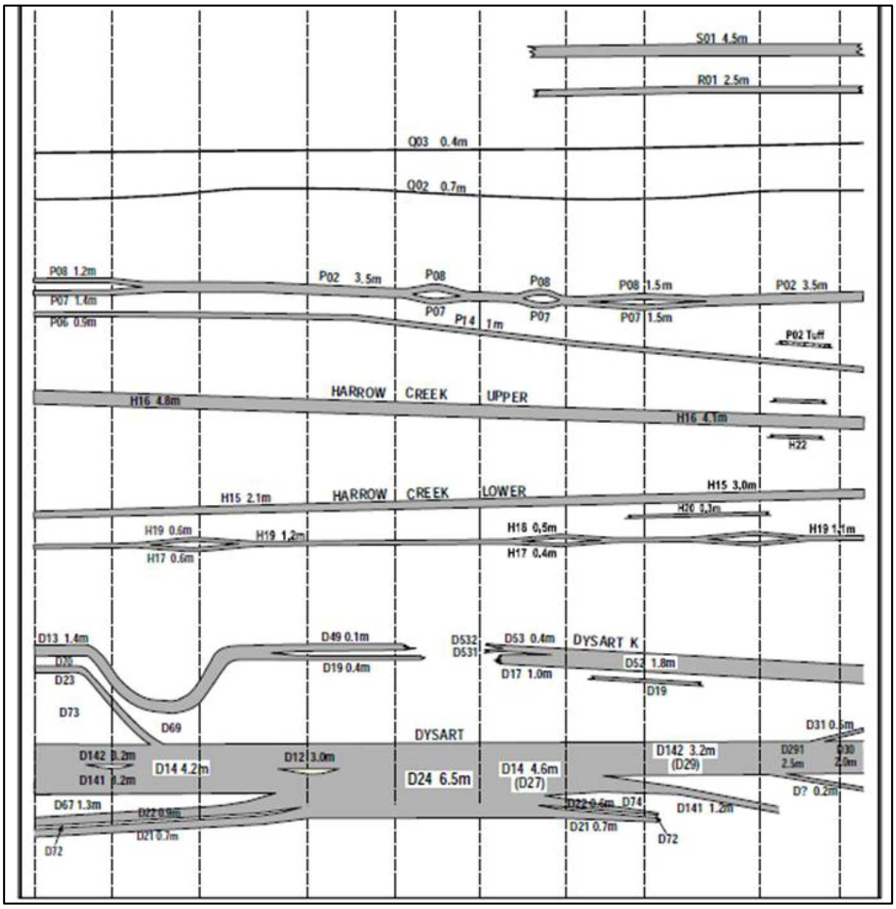
The MCM include the Dysart series, Harrow Creek group, P seams, Q seams and R seam. Of these, the Harrow Creek Upper (H16) and Dysart Lower (D24 and D14) coal seams are the targeted project seams.

A generalised north-south interpretation of the coal seam stratigraphy across the Saraji Mine is depicted in Figure 9.

The Harrow Creek Upper (H16) seam is the uppermost of the two targeted coal seams and subcrops to the west of the Saraji Mine with an easterly dip. The H16 seam is typically around 5 m thick and is considered the most consistent coal seam throughout the deposit. Located 60 to 80 m above the Dysart Lower seam (D24 and D14), and 30 to 50 m above the Dysart Upper (D52) seam, the H16 seam does not split into thinner seams.

The Dysart Lower (D24 and D14) Seam is located 17 to 35 m below the Dysart Upper (D52) Seam. The D24 seam has an average thickness of approximately 7 m; the D24 seam splits into the D14 seam where thicknesses range from 4.5 to 5.8 m.

Figure 9 Coal Seam Stratigraphy



Source: AGE, 2012a.

6.0 Groundwater Resources

An aquifer is defined as a groundwater bearing formation sufficiently permeable to transmit and yield water in useable quantities. It is assessed that there are three aquifer systems which define the hydrogeologic regime within the Project area:

- quaternary alluvial aquifers
- tertiary sedimentary units
- coal seam aquifers.

This section of the report discusses these aquifer systems in terms of groundwater occurrence, recharge and flow, and groundwater quality to present a conceptual groundwater model for the site. The conceptual model was developed from:

- historical and ongoing investigations at the saraji mine
- a review of site geology and data from the lithological logs
- groundwater intersection records and quality
- static groundwater level measurement data
- data from the groundwater monitoring network.

Additionally, the Department of Natural Resources and Mines (DNRM) groundwater bore database was interrogated to identify registered groundwater bores within and adjacent to the Project site and associated data.

6.1 Hydrostratigraphy

The Project is situated in the Bowen Basin. The sediment successions that are relevant to the Project are classified in Table 4 in terms of hydrostratigraphy.

The Back Creek Group comprises sandstone, siltstone, shale, and minor coal and is considered a semi-pervious lower boundary for groundwater flow to the overlying coal measures.

The Triassic and Permian sedimentary successions are overlain by Tertiary and alluvial deposits (Quaternary) along the creeks within the Project area.

Table 4 Hydrostratigraphy of the Project Area

Age	Stratigraphic Unit	Lithology	Aquifer Type
Quaternary	Alluvium	Clay, silts, sand, gravel, floodplain alluvium	Unconfined (aquifer)
Tertiary	Sediments	Clay, silt, sand, gravel, colluvium, fluvial and lacustrine deposits including cross-bedded quartz sandstone, conglomerate, claystone	Aquitard
	Duaringa Formation	Mudstone, sandstone, conglomerate, siltstone, oil shale, lignite and basalt	Aquitard
Late Permian	Fort Cooper Coal Measures (FCCM)	Coal, brown and green sandstone, conglomerate, carbonaceous shale, tuff	Confined aquifer (coal) and confining unit (interburden)
	Moranbah Coal Measures (MCM)	Coal, sandstone, siltstone, mudstone, carbonaceous mudstone	Confined aquifer (coal) and confining unit (interburden)
Middle Permian	Back Creek Group	Sandstone, siltstone, carbonaceous shale, minor coal and sandy coquinite	Confining unit

6.2 Alluvial Aquifers

6.2.1 Occurrence

The Quaternary alluvial sands and gravels adjacent to the Project site are recognised to occur as paleo-channels associated with the present day Phillips Creek system. The alluvial sediment aquifer is unconfined and limited in lateral extent from Phillips Creek with a maximum thickness of 25 m adjacent to the creek.

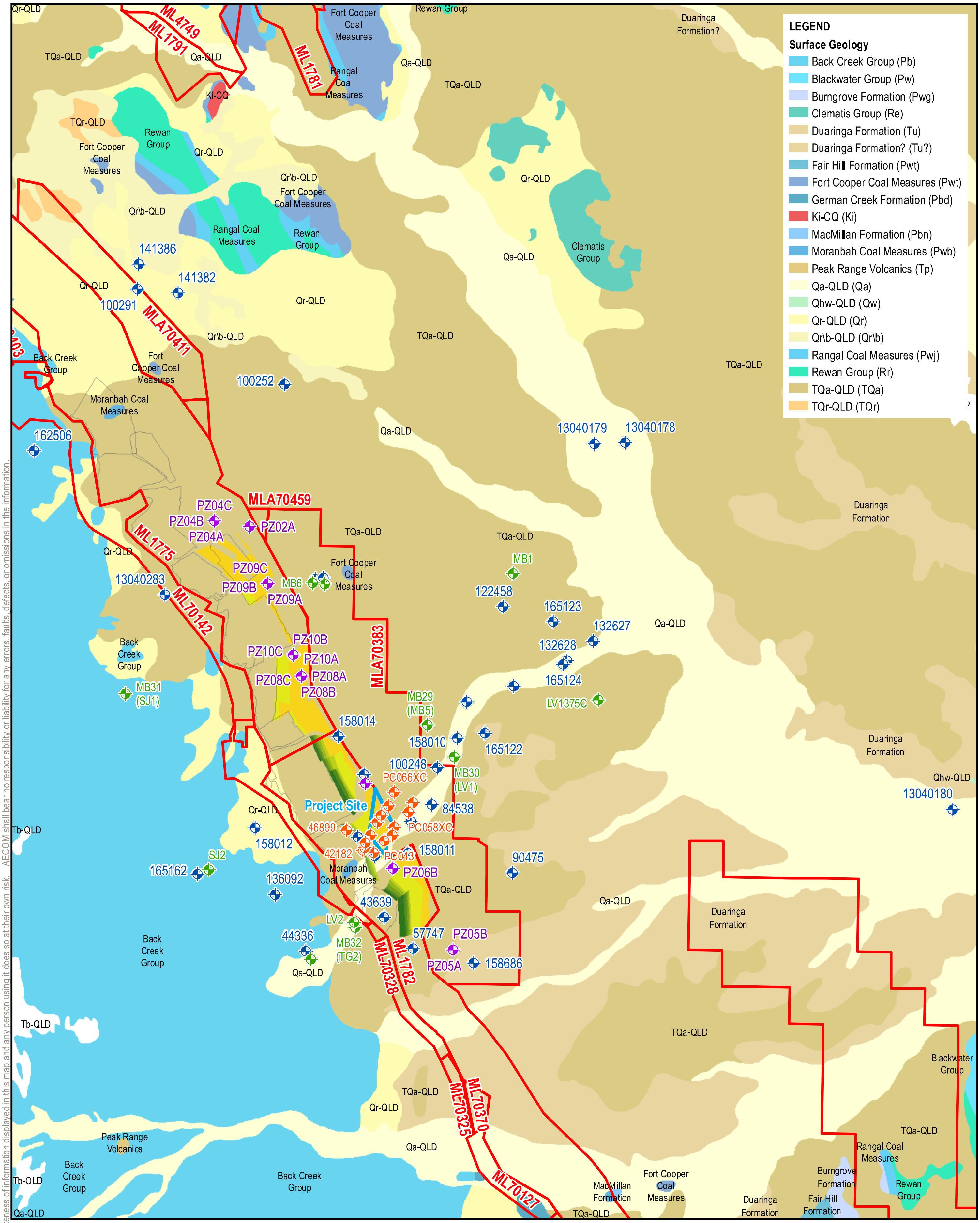
Due to the ephemeral nature of Phillips Creek, it is considered that the alluvial aquifer is not a permanent source of groundwater. A review of DNRM and site data indicates several bores were drilled in close proximity to Phillips Creek. However, only a few of these bores were constructed to intersect the alluvial aquifer; these bores were reported to be drilled dry. The other bores drilled along the creek were constructed in the Tertiary sediments below and adjacent to the alluvial sediments.

The drilling results indicate limited or no sustainable groundwater is associated with the alluvium. Bores drilled through the dry alluvium were further advanced until groundwater was encountered below the alluvial sediments.

Only one bore constructed in the alluvial sediments of Phillips Creek west of the Project, MB32, has been reported to contain water during groundwater monitoring events. This bore is up hydraulic gradient, as Phillips Creek flows from west to east.

The records of dry bores indicate that the alluvial sediments have limited storage (recharged during flow events and by direct rainfall but does not store groundwater) and non-continuous (the coarse grained more permeable sediments are not continuous down the length of the creek).

Figure 5 presents the mapped extent of the Quaternary alluvial sediments. The monitoring bore MB32 is presented on Figure 10.



LEGEND

Project Site

BMA Tenure / Tenement

Groundwater Bore

BMA Core Hole

Census Bore

Registered Bore

Saraji Monitoring Bore

Existing Open-Cut Extent

Conceptual Mine Plan

FY2017

FY2018

FY2019

FY2020

FY2021

FY2022 - FY2026

FY2027 - FY2031

Data sources:

1. Tenements, Bores, Infrastructure © BMA 2016 (RFI)
2. Geology, Bores © State of Queensland (Department of Natural Resources and Mines) 2016

N

Figure 10
Groundwater Monitoring Bores

Saraji Open Cut Extension Project Environmental Assessment Report

0 2 4 8

Kilometres

Scale: 1:250,000 (when printed at A4)

Projection: Map Grid of Australia - Zone 55 (GDA94)

BMA
BHP Billiton Mitsubishi Alliance

DATE: 29/11/2016 VERSION: 1

6.2.2 Groundwater Recharge and Flow

The alluvial aquifers are considered to be strongly linked to surface water features with recharge primarily the result of creek high flow events. As Phillips Creek is ephemeral, recharge of the alluvium is by:

- recharge from surface water flow or flooding
- surface infiltration of direct rainfall and overland flow, where alluvium is exposed and no substantial clay barriers occur in the shallow sub-surface.

Available hydrological data suggests that water infiltrates/drains to the base of the alluvium relatively quickly after rainfall events where more permeable units are at surface. This saturation is sporadic, producing semi-permanent, localised, thin, aquifers.

During periods of creek flow, the alluvial sediments may discharge to sub-cropping coal seams and/or underlying Tertiary sediment aquifers where they exist. Discharge mechanisms of the alluvium are expected to be significant, and include:

- Short duration baseflow from the permeable sands and gravels within the alluvium material.
- Evapotranspiration from vegetation growing in the creek beds and along the banks.
- Infiltration and recharge to the underlying formations where Phillips Creek intersects more permeable areas within these units.
- Discharge to the creek during or after flow events as base flow. Limited effective storage (recognised due to the dry bores in the alluvium) results in the alluvium dewatering under gravity

  A review of the available DNRM bore logs (Section 6.6) indicated that several bores drilled in close proximity of Phillips Creek, were constructed to intersect the units directly below the alluvial sediments and surface water drainage features. This indicates that the alluvium, which are often drilled dry but readily recharge through rainfall and creek flow, can provide recharge to the underlying units.

  Groundwater flow is considered to follow topography and is limited to the areas where the alluvium is present. Seepage from the alluvial aquifer to the underlying stratigraphic units can occur through the base of the alluvium. It is considered the alluvial sediments may provide a source of recharge to the underlying units.

6.2.3 Hydraulic Parameters

As the alluvial aquifer is ephemeral hydraulic parameters have not been determined in the Project area.

More extensive alluvial systems occur outside the Project footprint, associated with ephemeral water courses such as the Isaac River.

No site-specific aquifer data was obtained during the AGE groundwater studies, due to the dry nature of the alluvium. Based on a review of the historic Bowen Basin groundwater studies (Section 4.0), alluvium associated with creeks and main river tributaries indicate that the associated Quaternary alluvium has hydraulic conductivity values of 0.001 m/day, which are typical for silty clay.

6.3 Tertiary Sediment

6.3.1 Occurrence

The Tertiary sediments maintain permanent groundwater particularly within the deeper sequences and the basal unit. The primary groundwater bearing strata of this unit is the basal sand, where it is locally extensive. These basal sands are however considered to be discontinuous.

Observations from open pits at Saraji Mine indicate that groundwater discharges relatively slowly from these sandy horizons within the Tertiary sequence and/or at the unconformity with the underlying Permian strata. Based on these observations, the Tertiary sediments are considered to contain a series of poorly connected aquifers of low to moderate permeability, with drainage from the upper to lower aquifers delayed by lower permeability horizons. Groundwater ingress rates are very low, resulting in damp pit walls. Evaporation rates are higher than the seepage such that this groundwater does not report directly or require management in the pits.

Data indicates that groundwater is typically intersected near the base of the Tertiary sediments in the Project area, between 13 m (PZ05) and 35 m (PZ02) (AGE, 2011). These bores are shown on Figure 10. Based on bore logs reviewed, the sandy lenses and/or basal sand/gravel units are the primary storage for groundwater. The depth and occurrence of the Tertiary aquifer is considered variable and dependant on the extent and location of these porous, sandy layers within the sequence.

Groundwater levels within the Tertiary sediments from monitoring bores near the Project area are reported to be at depths shallower than the recorded water strikes from drilling and installation. This indicates the aquifer is confined to semi-confined as a result of the clayey sediments in the upper sections of the sequence.

Figure 4 depicts the extent of mapped Tertiary sediments.

6.3.2 Groundwater Recharge and Flow

Recharge to the tertiary aquifers is considered to be the result of:

- direct infiltration of rainfall and/or surface water runoff where the sediments subcrop or outcrop
- leakage from overlying alluvium in the instances of creek / stream flow
- inflow from adjacent aquifers which are hydraulically connected, for example, underlying confined units that subcrop at the base of the Tertiary sequence.

Primary discharge mechanisms in the Tertiary sediment aquifers are likely to be:

- through flow into underlying and/or adjacent aquifers, such as subcrop or outcrop coal seams
- evapotranspiration
- groundwater extraction.

Sub-vertical faults zones may provide a pathway for interflow with other units, but only if these faults are sufficiently permeable in the tangential plane.

Direction of groundwater flow within the Tertiary aquifer is expected to reflect topography, from topographically elevated areas in the west towards lower topographic areas of surface drainage, towards the east (Figure 3).

6.3.3 Hydraulic Parameters

As the extent and nature of the Tertiary sediments are highly variable, the porosity and permeability of the aquifer are also considered to be highly variable. As a result, usable yields of groundwater are expected to occur within the high permeability sand and gravel lenses near the base of the sequence.

Aquifer permeability tests were undertaken by AGE in 2011 at groundwater monitoring bores PZ02A, PZ04A and PZ07A using variable head (slug out) tests. To assess the permeability of the Tertiary sediments at each location, groundwater was removed from each bore via airlift techniques; the rate of water level recovery for each well was then measured via automated groundwater level loggers installed in each well. Additionally, manual water level measurements were procured with an electronic water level indicator prior to, and at regular intervals, for each test.

Results of these tests indicated a permeability range of 1×10^{-7} metres per second (m/s) to 2×10^{-8} m/s (0.01 to 0.002 m/day) from bores PZ07A and PZ02A (Figure 10), respectively (AGE, 2011). These results represent a low permeability (clay-rich or consolidated) sedimentary aquifer.

6.4 Permian Overburden and Interburden Aquifers

6.4.1 Occurrence

The Permian (non-coal bearing) units comprise claystone, mudstone, sandstone, siltstone, and shale. These low permeable rock types are not recognised to contain good groundwater potential. They can, however, provide localised supplies of variable, generally low yielding, and poor quality groundwater.

The overburden and interburden rocks in several mines in the northern Bowen Basin (Broadlea Coal Mine, Burton Mine, and Ellensfield Coal Mine) have been described as essentially impervious to groundwater movement (AGE, 2007); however, minor groundwater supplies are contained in porous sandstone layers of the interburden and overburden (AGE, 2007). An exception to these confining properties is the occurrence of overburden that contains significant faults and joints which provides storage for groundwater.

Based on this the Permian strata can be categorised into two hydrogeological units:

- Hydrogeologically “tight” and hence very low yielding to essentially dry sandstone, siltstone, and shales which comprise most of the Permian overburden/interburden.
- Localised open fracture and/or fault systems, which have not been infilled by clay/carbonate deposition, that have a capacity to store and transmit groundwater.

The Permian aged sediments in the Project area include the FCCM and MCM of the Back Creek Group. While the Permian sediments do not outcrop in the Project area, they subcrop under the Tertiary sequence.

Groundwater within the overburden sandstone was intersected in five BMA groundwater monitoring bores (PZ06, PZ07B/C, PZ08 and PZ09B/C) at depth between 25 m and 32 m (Figure 10).

The occurrence and vertical extent of the interburden/overburden aquifer is considered to be highly variable and dependant on factors such as the:

- depth, extent, frequency, and interconnection of fractures on a local scale, and faults on a regional scale
- depth and lateral extent of any more porous sediments.

Figure 11 depicts the extent of mapped Permian sediments.

It is recognised from vibrating wire piezometers (VWPs) constructed in the FCCM (JBT, 2014) that the interburden units which over- and under-lie the coal seams act as effective aquitards. These aquitards have very low vertical hydraulic conductivity resulting in marked differences in piezometeric pressures between the different coal seams and interburden (i.e. a leakier aquitard would result in all bores having the same composite piezometeric levels).

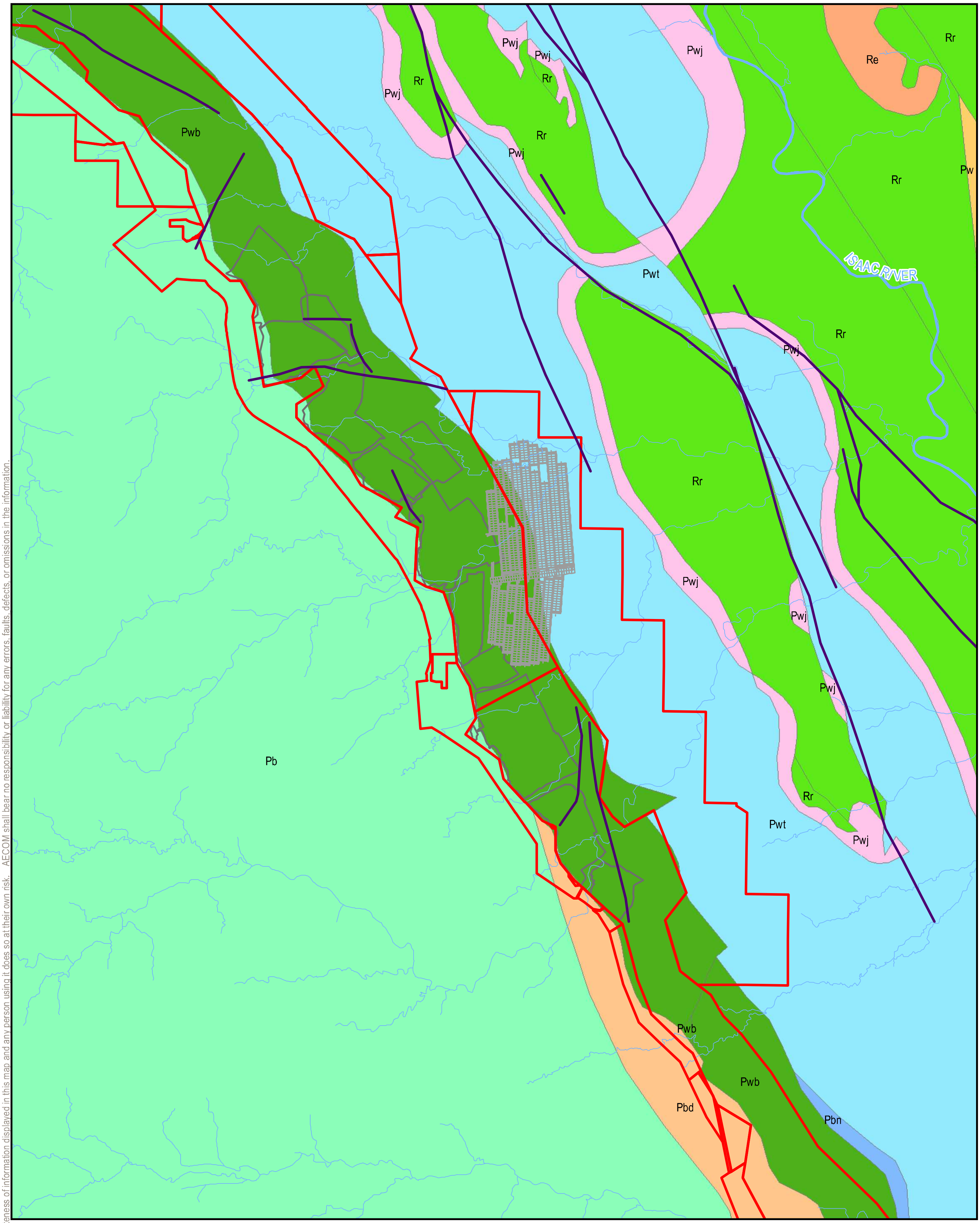
6.4.2 Groundwater Recharge, Discharge and Flow

Two groundwater monitoring wells have been constructed to intersect the Permian overburden, PZ06A and PZ08A, with vibrating wire piezometer (VWP) sensors places at depths of 38.5 and 40 m, respectively. Groundwater levels in these bores range from 18.6 m (PZ06A) to 27.7 m (PZ08A) below ground level (mbgl) which indicates the groundwater in this unit is confined beneath the overlying less permeable sedimentary layers.

Recharge is expected to be the result of:

- direct rainfall infiltration to Permian sediments at subcrop or outcrop
- indirectly from baseflow leakage and/or leakage from overlying Cainozoic sediments after significant rainfall or creek flow events.

Groundwater flow within this unit is expected to generally be down dip; however, flow direction may be modified by structures inclusive of faults.



LEGEND

- Watercourse
- Fault
- Underground Mining Panel
- Existing Open-Cut Extent
- BMA Tenure / Tenement

Bowen Basin Basement Geology

- Pb - Permian Back Creek Group
- Pbd - Permian German Creek Formation
- Pbn - Permian MacMillan Formation
- Pw - Permian Backwater Group
- Pwb - Permian Moranbah Coal Measures
- Pwj - Permian Rangal Coal Measures
- Pwt - Permian Fort Cooper Coal Measures
- Re - Triassic Clematic Group
- Rr - Triassic Rewan Group

Data sources:

1. Existing Infrastructure, Tenements © BMA 2016 (RFI)
2. Geology, Watercourses © State of Queensland (Department of Natural Resources and Mines) 2016

N

Figure 11
Bedrock Geology
(Source: AGE 2012)

Saraji Open Cut Extension Project
Environmental Assessment Report

0 1 2 4
Kilometres

Scale: 1:200,000 (when printed at A4)

Projection: Map Grid of Australia - Zone 55 (GDA94)

BMA
BHP Billiton Mitsubishi Alliance

DATE: 29/11/2016 VERSION: 1

6.4.3 Hydraulic parameters

The characteristics of the consolidated Permian sediments do not allow for a significant aquifer in this unit as the aquifer storage and hydraulic conductivity characteristics are considered to:

- Be primarily a function of secondary porosity features such as fractures, faults and joints. That is, structural features which have developed subsequent to the host rock's emplacement.
- A lesser extent, primary porosity which is the intergranular spaces or pore openings that formed when the sediment was deposited.

Hydraulic testing of the interburden units across the Bowen Basin (Arrow, 2012) indicates highly variable hydraulic conductivity from moderately pervious to highly impervious. This is evidence that the Permian formations are heterogeneous, having discrete zones of higher permeability over short distances and the very low hydraulic conductivity in the majority of the interburden and overburden and isolate more conductive parts associated with the fracture/fault systems.

6.5 Coal Seam Aquifers

6.5.1 Occurrence

Typically throughout the Bowen Basin, the coal seams are considered to be the primary aquifers within the Permian sequences as the adjacent overburden and interburden sediments are considered to generally be aquitards, except where these sediments are fractured or faulted.

The target coal seams within the Project area are the Harrow Creek Upper Seam and the Dysart Lower Seams of the MCM of the Back Creek Group and are confined aquifers. These seams are laterally extensive along the western and eastern margins of the Bowen Basin and within the Project area but with varying degrees of thickness.

The coal seams generally are considered dual-porosity strata where primary-porosity is provided by the matrix and a secondary porosity is the result of the presence of fractures (joints and cleats). Natural fractures within the coal seams are likely the dominant space for groundwater storage; the main pathway for groundwater movement is dependent on fracture interconnectivity.

The coal seam aquifers are confined above and below by very low permeability inter- and over-burden. Groundwater movement through the aquifer (transmissivity) is considered to be through the more permeable coal (cleats) rather than through the confining inter- and over-burden units.

The inter- and over-burden confining units generally have very low vertical hydraulic conductivity (leakage), based on the piezometeric pressure differences in the coal seams. Such low vertical conductivity limits vertical movement and recharge to the coal seam aquifers.

6.5.2 Groundwater Recharge, Discharge, and Flow

Groundwater recharge to the coal seam aquifers occurs from:

- direct infiltration from overland flow and rainfall in areas where the unit outcrop and subcrop
- downward seepage and/or through flow from adjacent or overlying Cainozoic sediments in places where no substantial clay unit is present
- leakage between aquifers from faults and other structural features in interburden / overburden sediments.

Discharge mechanisms of the Permian coal seam aquifers are likely to be:

- through flow into adjacent (outcropping or sub-cropping coal seams) or seepage into underlying aquifers (via structural discontinuities)
- downgradient Permian strata outcrop areas
- groundwater extraction from regional / local mine dewatering activities.

Historically, groundwater flow direction in the coal seam aquifers across the Bowen Basin is considered to have been from the north and western recharge areas of the coal subcrops/outcrops then flows down hydraulic gradient towards the Isaac River sub-catchment.

Current groundwater flow patterns of the coal seam aquifers across the Bowen Basin have been locally influenced which has altered groundwater flow toward existing mine pits and underground workings due to mine dewatering and depressurisation.

Groundwater modelling (AGE, 2011) and groundwater level measurements at various mines within the northern Bowen Basin indicate that groundwater levels are affected by mining induced drawdown within 3 km of working mines.

6.5.3 Hydraulic Parameters

The coal seam aquifers within the Project area generally exhibit low transmissivity and low to moderately permeability. Groundwater storage and movement occurs primarily within the cleats of the coal seams and fissures within open fractures that intersect the seams. The permeability and storage properties of the coal seam aquifers are likely to be variable and dependent on depth due to variation of aquifer thickness, extent, and interconnectivity of fractures and cleats within the coal.

Aquifer permeability tests were undertaken by AGE in 2011 at groundwater monitoring bores PZ02B/C, PZ04B/C, PZ07B, PZ09B, and PZ10B/C via rising head (slug out) test methodology, as described in (Section 6.3.3). The outcomes of the tests indicated permeability values for the coal seam aquifers in the Project area range from 0.03 to 0.006 m/day for the Harrow Creek Upper Seam.

Results for the Dysart Lower Seam were 0.003 to 0.005 m/day. These values indicate the coal seam aquifers in the Project area have low to very low permeability; the deeper Dysart Lower Seam is less permeable than the Harrow Creek Upper Seam.

Packer tests were also undertaken by Mining One at eight geotechnical boreholes in 2011 to assess the permeability of the roof, floor, and coal seams of the Dysart and Harrow Creek Upper seams as well as the interburden between these coals. Average and maximum permeability values were presented for each part of the section tested. The results indicate the permeability of the coal declined with depth for both the Dysart and the Harrow Creek coal seams. Table 5 below presents a summary of the results.

Table 5 Permeability Test Results

Geological Unit	Test Method	Hydraulic Conductivity (m/sec)		
		Minimum	Maximum	Average
Harrow Creek	Slug	5×10^{-10}	3×10^{-7}	8.1×10^{-8}
	Packer	NR	1.1×10^{-6}	1.9×10^{-7}
	Stress & perm	6.8×10^{-10}	3.8×10^{-6}	4.5×10^{-7}
Dysart	Slug	5×10^{-10}	5.3×10^{-8}	2.7×10^{-8}
	Packer	NR	1.1×10^{-4}	1.1×10^{-7}
	Stress & perm	6.7×10^{-9}	1.2×10^{-6}	1.4×10^{-7}
Permian Interburden	Slug	-	-	-
	Packer	NR	5.8×10^{-6}	1.9×10^{-6}
	Stress & perm	-	-	-
Tertiary	Slug	2×10^{-8}	3×10^{-7}	1.1×10^{-7}

Notes: NR – No result, "-" not tested

Source: AGE, 2012a.

The hydraulic conductivity data, determined during the field tests, indicates a reducing hydraulic conductivity of the coal with depth. Exponential equations for the coal seams were derived:

- Harrow Creek Horizontal Hydraulic Conductivity (K) = $0.045919 \times e^{-0.016 \times depth}$
- Dysart Horizontal Hydraulic Conductivity (K) = $0.006499 \times e^{-0.0104 \times depth}$

6.6 Groundwater Data

A review of groundwater monitoring bores, DNRM registered bores, and previous bore census studies was conducted to develop a database of groundwater bores within the area containing the Project site.

A summary of these bores is presented in Table 6. These bores are included on Figure 10.

Table 6 Groundwater Bore Database

Registration Number	Easting	Northing	Depth (m)	Geology	Water Level (mbgl)	Yield litres per second (L/s)	Type / Name
Registered Bores							
100291	626431	7542882					
141386	626507	7544152	52	Coal	17.97 (198.99 mAHD)		DNRM
141382	628490	7542693	52	Shale	18.36 (196.2 mAHD)	0.02	DNRM
100252	633893	7538053					
162506	621205	7534682	42	Sandstone	5	1.89	
13040283	627834	7527375	68.5	Coal	40.56 (178.29 mAHD)		DNRM
132631	635440	7528179	328	Back Creek sandstone	31 (156.88 mAHD)	15?	
136689	635868	7528234		Duaringa Fm	157.13 mAHD		
13040179	649627	7535053	14.32	Alluvial sand			
13040178	651167	7535107	10.05				
122458	644983	7526770	50.5	Permian overburden	26 (149.11 mAHD)		
165123	647515	7526007	136	Rangal Coal Measures			VWP
158014	636640	7520199	37.5	Moranbah Coal Measures	21.28 (172.83 mAHD)	0.08	MB33
158013	637926	7518269	107	Moranbah Coal Measures	23.10 (172.51 mAHD)	0.05	MB34
158012	632389	7515571	41.4	Back Creek Group	12.80 (221.86 mAHD)	0.02	MB37
165162	629499	7513228	100	No data			
136092	633416	7512196	22	Back Creek Group	12	1.1	
44336	634975	7509310	54.86	No data	36.6	2.5	
43639	638939	7511033	43.9	Tertiary to	29.49	0.75	Lost

Registration Number	Easting	Northing	Depth (m)	Geology	Water Level (mbgl)	Yield litres per second (L/s)	Type / Name
				22 m, coal, sandstone			
57747	640392	7509441	126.5	Back Creek Group Basalt		4.42	
158686	643499	7508708	210	MCM	60 (141.15 mAHD)	0.13	MW9P
90475	645463	7513291	76.2	Blackwater Group		0.01	abandoned
165323	637620	7515091	15	Alluvial sand			Piezometer
165324	638481	7514161	15	Alluvial clay			Piezometer
158011	640150	7514283	32	Fair Hill Fm	17.96 (178.97 mAHD)	0.09	MB36
165326	640296	7515897	35	Quaternary sand and clay			Abandoned
165325	640296	7515897	18.5	Quaternary			Piezometer
84538	641354	7516737	109.7	No strata data	18.3	0.07	
100248	641645	7518640		No data			
158010	642646	7520110	34.5	Fair Hill Fm	18.41 (166.87 mAHD)		MB35
165122	644067	7520357	40	Rangal Coal Measures	VWP4 144.6 mAHD		LV2183 VWP
			61		VWP3 155.4 mAHD		
			71		VWP2 135.6 mAHD		
			83		VWP1 144.1 mAHD		
158485	643131	7521947	22	Quaternary clay	Dry		LV2371W
158481	643132	7521949	38	Rangal Coal Measures	VWP4 162.5 mAHD		LV2226 VWP
			56		VWP3 157.9 mAHD		
			74		VWP2 154.5 mAHD		

Registration Number	Easting	Northing	Depth (m)	Geology	Water Level (mbgl)	Yield litres per second (L/s)	Type / Name
			94		VWP1 153.6 mAHD		
158482	645525	7522752	65	Rangal Coal Measures	VWP4 152.1 mAHD		LV2218 VWP
			86		VWP3 149.0 mAHD		
			116		VWP2 147.1 mAHD		
			137		VWP1 146.8 mAHD		
158483	645524	7522752	20	Quaternary	Dry		LV2369W
158480	649801	7522051	94	Tertiary to 56 m then Rangal Coal Measures			LV1235C
158484	648037	7523878	19	Quaternary	157.7 mAHD		LV2370W
132628	648220	7524052	120	Duaringa Fm	77 (95.61 mAHD)	0.8	
165124	648038	7523864	82	Rangal Coal Measures			LV2375W VWP
132627	649564	7525028	70	Duaringa Fm	30 (141.29 mAHD)	0.95	
13040180	667759	7516513	32	Isaac River Alluvium	17.2 (140.71 mAHD)		DNRM
Census Bores							
-	625828	7522379	44.23	Coal	7.85 (217.19 mAHD)		MB31 (SJ1)
-	637481	7510535	19.52	Alluvium	10.4 (197.73 mAHD)		MB32 (TG2)
-	641146	7520794		Unknown			MB29 (MB5)
-	642503	7519162	>100	Coal	23.77		MB30 (LV1)
-	645485	7528479	79.4		20.63		MB1
-	635932	7527937	60.94		22.86		MB2
-	635938	7527942	50		23.82		MB3
-	635928	7527934	27.1		23.53		MB4

Registration Number	Easting	Northing	Depth (m)	Geology	Water Level (mbgl)	Yield litres per second (L/s)	Type / Name
-	635335	7527993					MB6
-	637431	7510772					LV2
-	630049	7513461					SJ2
-	635215	7508903	15.06		9.42		TG1
-	649799	7522054	58	Rangal Coal Measures	VWP 4 141.45 mAHD		LV1375C
			72		VWP3 134.3 mAHD		
			90		VWP2 132.9 mAHD		
			107		VWP1 132,05 mAHD		
Saraji Monitoring Bores							
PZ02A	632019	7530675	26	Regolith			MB
PZ02B	632019	7530675	170	Sandstone			MB
PZ02C	632019	7530675	278	Dysart D24			MB
PZ04A	630242	7530952	30	Regolith			MB
PZ04B	630242	7530952	66	Harrow Creek H16			MB
PZ04C	630242	7530952	180	Coal D47			MB
PZ07A	637885	7517636	14	Claystone			MB
PZ07B	637885	7517636	198	Sandstone			MB
PZ07C	637885	7517636	303	Harrow Creek H16			MB
PZ09A	632912	7527779		Clay			MB
PZ09B	632912	7527779	75	Harrow Creek H16			MB
PZ09C	632912	7527779	195	Dysart D24			MB
PZ10A	634236	7524164		Regolith			MB
PZ10B	634236	7524164	70	Harrow Creek H16			MB
PZ10C	634236	7524164	184	Dysart D24			MB
PZ05A	642327	7509221	203	Harrow Creek H16	168.8 mAHD		VWP
PZ05B	642327	7509221	239	Coal D52	166.3 mAHD		VWP
PZ06A	639272	7513326	40.5	Sandstone	185.9 mAHD		VWP

Registration Number	Easting	Northing	Depth (m)	Geology	Water Level (mbgl)	Yield litres per second (L/s)	Type / Name
PZ06B	639272	7513326	78.5	Harrow Creek H16	179.6 mAHD		VWP
PZ06C	639272	7513326	167	Coal D142	183.4 mAHD		VWP
PZ08A	634647	7523069	38.5	Coal P07	177.6 mAHD		VWP
PZ08B	634647	7523069	65	Harrow Creek H16	173.6 mAHD		VWP
PZ08C	634647	7523069	180	Dysart D24			VWP
BMA Core Holes							
-	638471	7515690	50.08				6557
-	638285	7514125	214.01		21.9		32924
-	638124.8	7515001	238				42178
-	637746	7514257	200		27		42182
-	636931.8	7515269	127		41.5		46899
-	637834.7	7514392	216.37		38.362		49995
-	637879.3	7514635	222.32		30.59		49997
-	639333.4	7515433	318		66.777		PC039HC
-	639258	7515023	290				PC041HC
-	638840	7514721	301				PC043
-	638667.8	7516023	300.8				PC046XC
-	640288.3	7516655	400		17		PC056
-	640054.7	7516179	279.49		18		PC058XC
-	639328.9	7517206	360		36.359		PC066XC
-	639041.7	7516493	330				PC081XC

Notes: VWP – Vibrating Wire Piezometer MB – Monitoring Bore Fm - Formation

6.7 Groundwater Levels

Groundwater level data was compiled from the various bores identified during the EA Amendment study, as included in Table 6 as well as transient groundwater level measurements recorded by DNRM in their regional monitoring bores and the Saraji Mine monitoring bores.

6.7.1 Quaternary Groundwater Levels

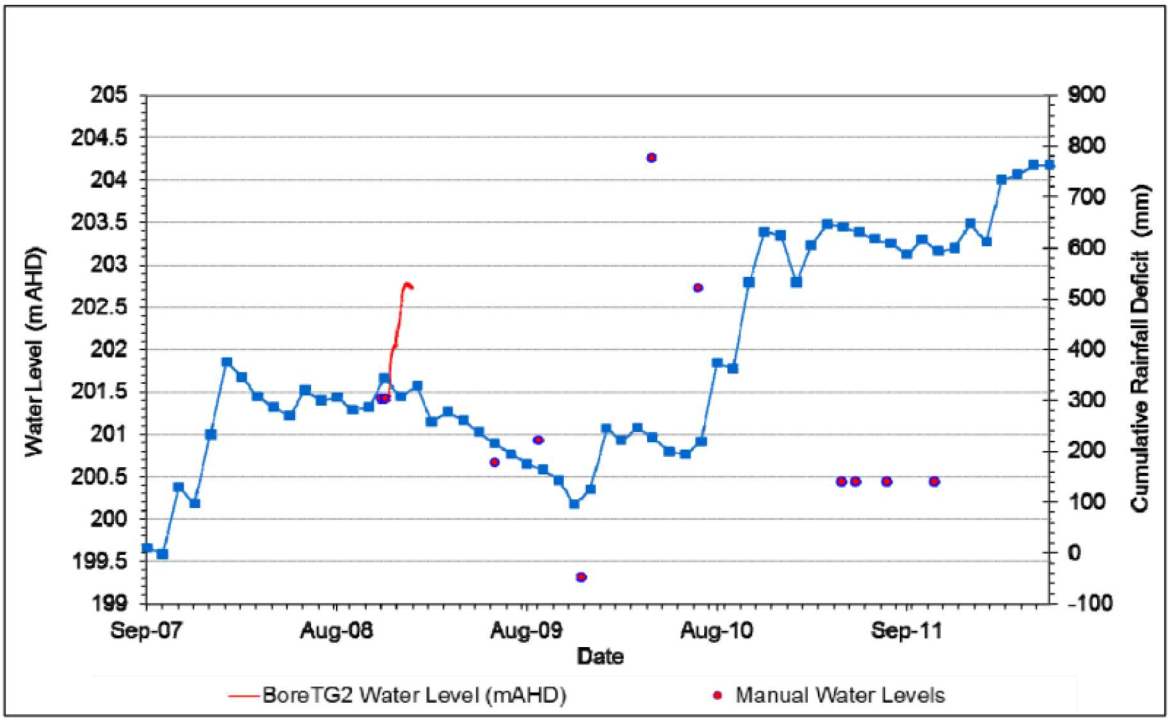
Ten (10) bores were reported to intersect Quaternary sediments, including alluvium and Isaac River alluvium. Groundwater level data for this unit includes:

- five bores with no water level data
- two bores which were drilled dry
- one bore with a single recorded water level measurement
- two bores with transient water level data.

Bore MB32 (TG2) is a historic stock watering bore identified during a bore census. This bore is located upstream of the Saraji Mine on Phillips Creek (Figure 10).

The bore was fitted with a groundwater level logger between December 2008 and January 2009. Manual readings were collected regularly until October 2011. Figure 12 presents the data captured from this bore (Gauge, 2015).

Figure 12 MB32 (TG2) Hydrograph and CRD

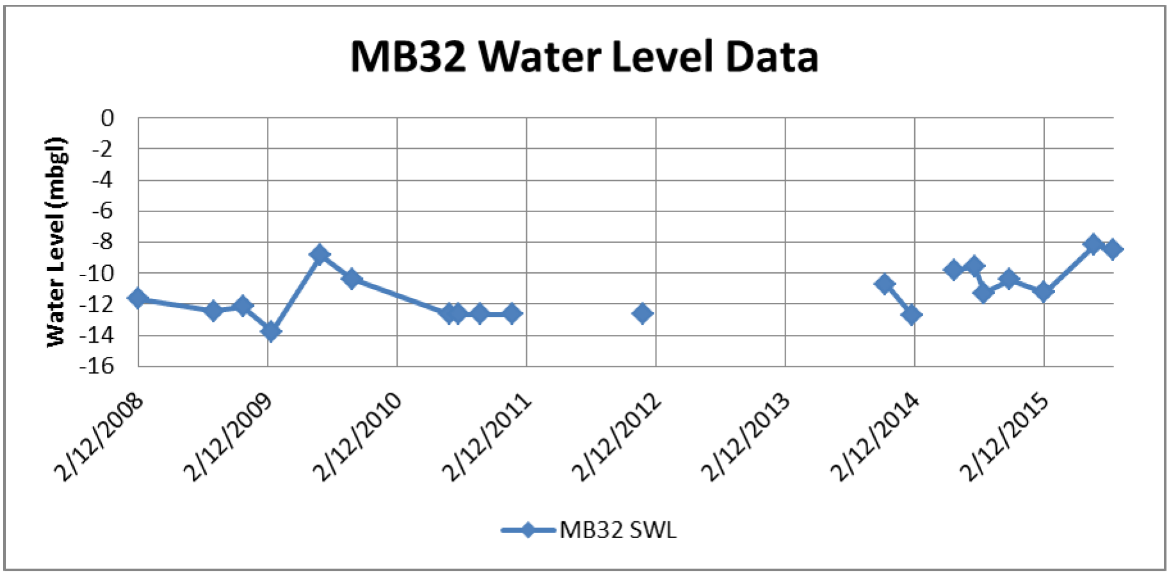


Groundwater levels within the alluvium are recognised to fluctuate over a 5 m range, which does not correlate to the CRD (Section 3.4.1) indicating possible semi-confining conditions (not unconfined at this location), alteration due to limited effective storage (drainage under gravity), and possible abstraction (AGE, 2012a).

The groundwater level in this bore is some 10 m from surface in a 19.5 m deep bore,

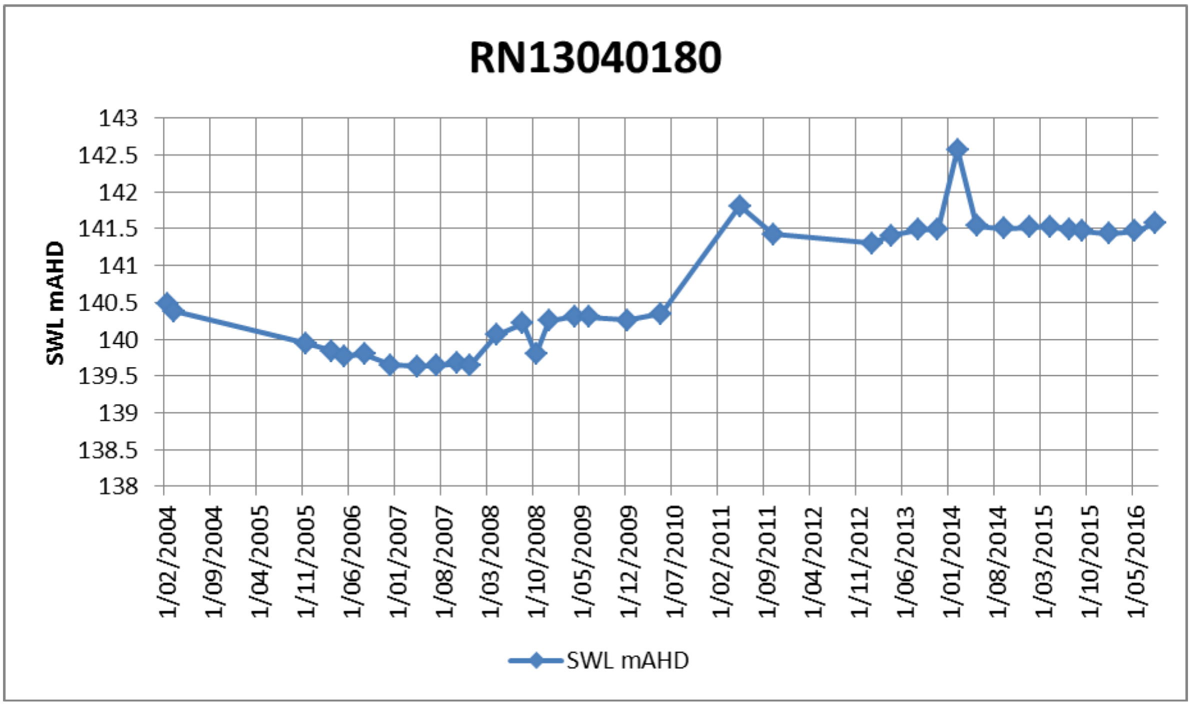
Additional groundwater level data from this bore, which forms part of the Saraji Mine groundwater monitoring network, has been collected manually on a regular basis. Figure 13 presents all available groundwater level data for MB32.

Figure 13 MB32 Groundwater Level Data



DNRM monitoring bore RN13040180 provides an indication of groundwater level fluctuations in the saturated Isaac River alluvium to the south east of the Project (Figure 10). The alluvium data (Figure 14) shows less groundwater fluctuation (some 3 m) compared to Phillips Creek alluvium.

Figure 14 RN13040180 Groundwater Level Data



Groundwater levels in MB32 (TG2) are around 198 mAHD while groundwater elevations in RN13040180 are around 140 mAHD. This indicates the general groundwater flow in the alluvium mimics topography from east to west (ignoring the dry alluvium bores).

6.7.2 Tertiary Groundwater Levels

BMA drilled several bores into the Tertiary sediments as part of their groundwater monitoring program; bores PZ02A, PZ04A and PZ07A were constructed as standpipe monitoring bores within the Tertiary sediments. PZ09A and PZ10A were drilled to intersect Tertiary sediments but both were drilled dry (greater than 20 m).

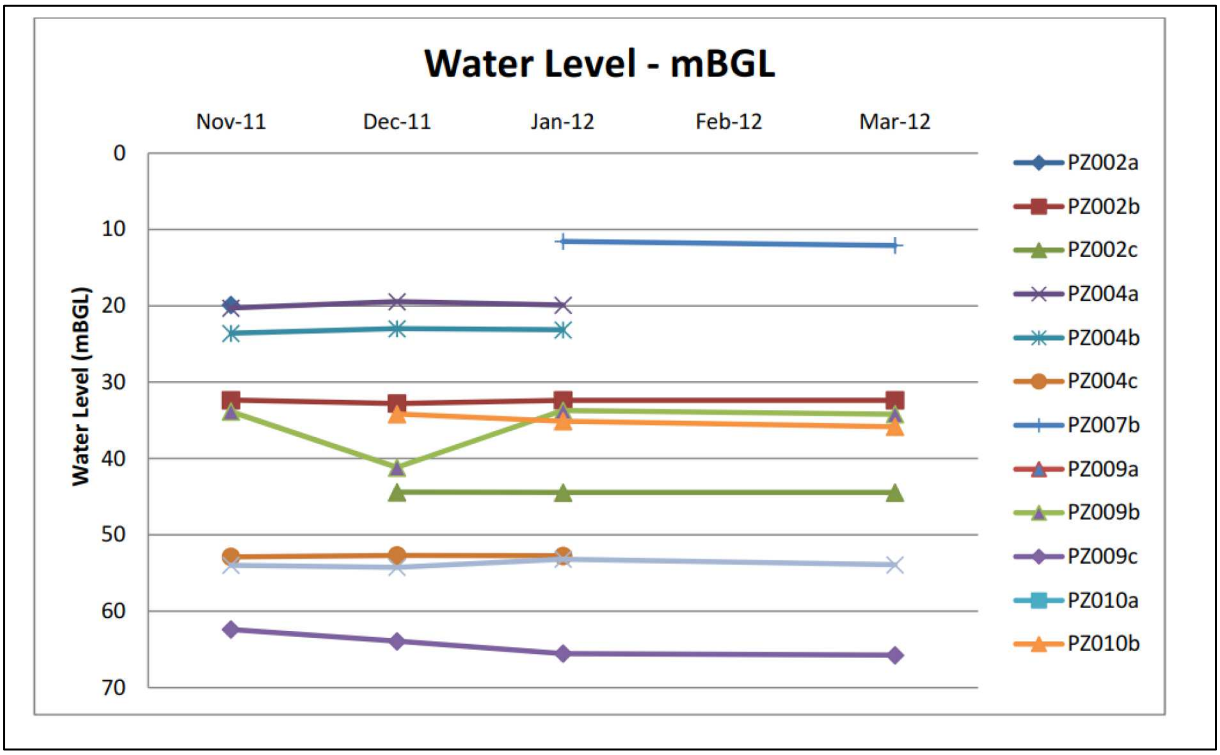
Tertiary sand and gravel (basal sand) was located in several of these bores, indicating this groundwater resource is lensoidal and discontinuous across the Project area. Observations in the Saraji Mine open pits indicates very slow groundwater ingress due to these more permeable sediments having been dewatered (groundwater removed from storage during initial open cut mining), limited recharge from above, and reduced through flow due to being discontinuous and contained within low permeable clay.

Groundwater levels within these sediments, measured in monitoring bores PZ02A, PZ04A, and PZ07A, are between 13 m and 22 m below surface. These groundwater levels are higher than were the groundwater was intersected (some 35 m below surface in PZ02A) indicating confined aquifer conditions. Recharge to these more permeable sediments is thus considered to be limited (i.e. limited vertical hydraulic conductivity in the overlying sediments).

Groundwater level measurements, compiled during 2011 and 2012, indicate variable groundwater levels both across the study area and over time (AGE, 2012b). Tertiary monitoring bores generally became dry during the monitoring period as a result of sampling, indicating limited sustainable yields of the coarse-grained more permeable basal sands due their discontinuous nature and containment within clay.

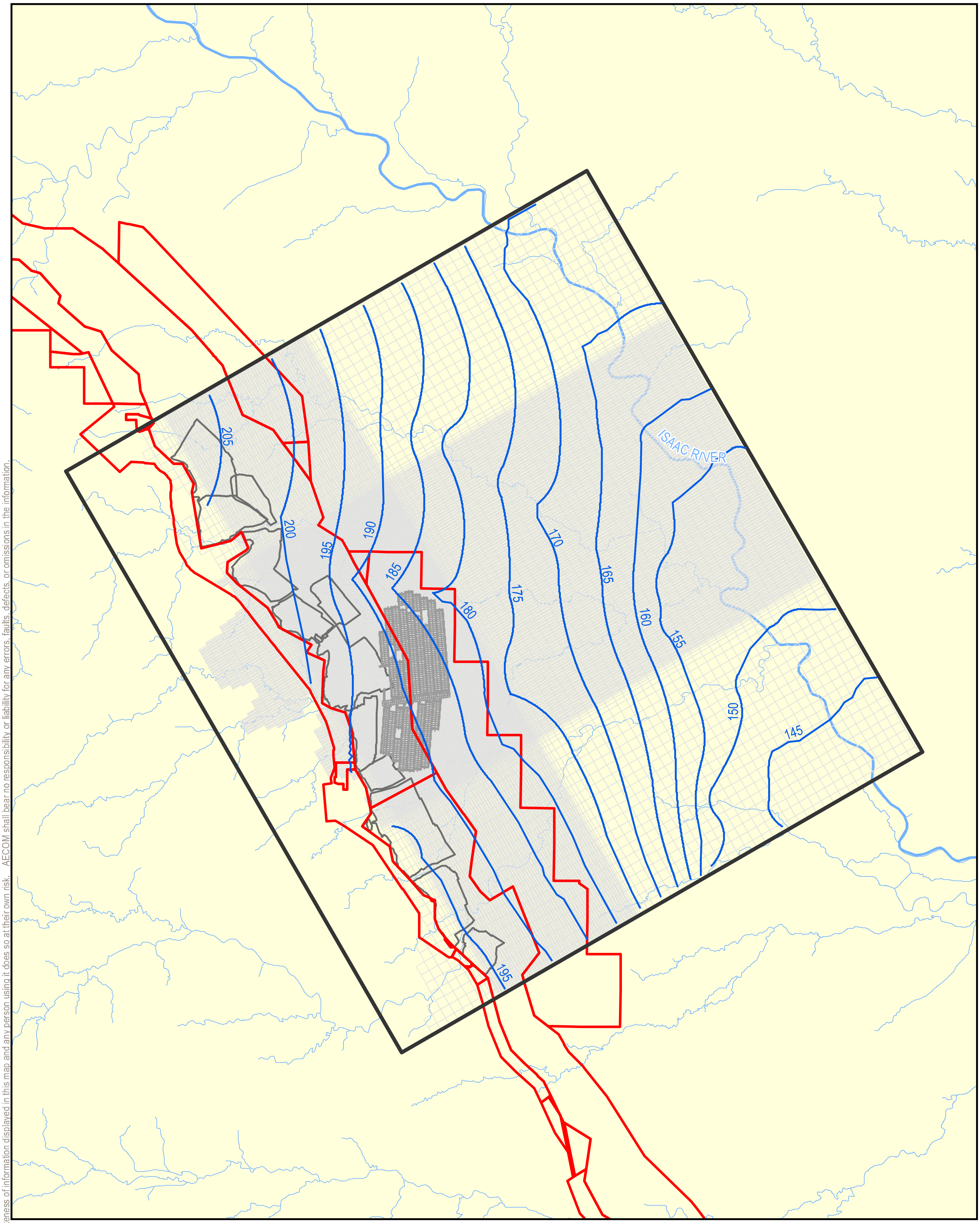
Stabilised Tertiary groundwater levels, measured in PZ02A and PZ04A (IESA, 2012), indicate groundwater levels some 20 m below surface (Figure 15).

Figure 15 Tertiary Groundwater Level Data



Groundwater contours were generated during the initial groundwater model for the upper Tertiary and Quaternary sediments, these groundwater contours indicate approximate groundwater levels (generated for pre-mining) with no influence of the open cut mining.

Groundwater levels, some 20 m below surface, mimic topography and illustrate groundwater flow from west to east towards the Isaac River (Figure 16).



LEGEND

- Watercourse
- Underground Mining Panel
- 5m Potentiometric Surface Contour
- Model Boundary
- Model Mesh
- Existing Open-Cut Extent
- BMA Tenure / Tenement

Data sources:

1. Infrastructure, Tenements © BMA 2016 (RFI)
2. Watercourses © State of Queensland (Department of Natural Resources and Mines) 2016
3. Contours, Model Boundary from AGE 2012

N

Figure 16
Pre-mining Groundwater Contours (Source: AGE 2012a)

Saraji Open Cut Extension Project
Environmental Assessment Report

0 1 2 4
Kilometres

Scale: 1:250,000 (when printed at A4)

Projection: Map Grid of Australia - Zone 55 (GDA94)

BMA
BHP Billiton Mitsubishi Alliance

DATE: 29/11/2016 VERSION: 1

Filename: \\aubne1fp003\Projects\605X\60507031\4. Tech Work Area\4.99 GIS\02_MXDs\04 Saraji OC Environmental Assessment Report\00 Technical Report\Groundwater\60507031_G051_v1_A4P.mxd

6.7.3 Permian Groundwater Levels

Groundwater monitoring bores and VWPs have been constructed within the MCM Harrow Creek (H16) and Dysart (D14 and D24) coal seams. These bores include:

- Harrow Creek – PZ02B, PZ04B, PZ05A, PZ06B, PZ07C, PZ08B, PZ09B and PZ10B
- Dysart – PZ02C, PZ04C, PZ05B, PZ06C, PZ07B, PZ08C, PZ09C and PZ10C.

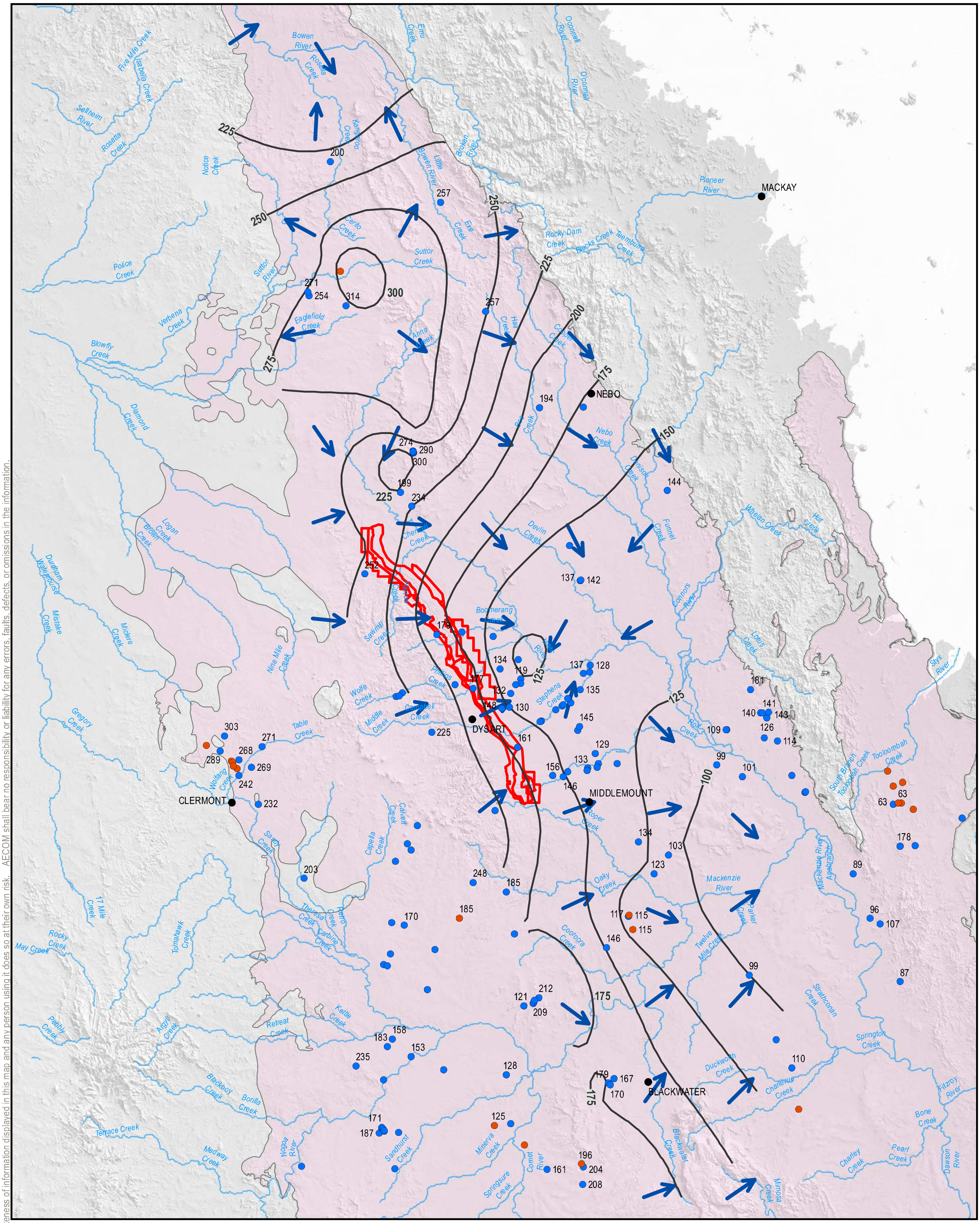
The coal seams are confined and generally exhibit low transmissivity and recharge rates due to low permeability. Groundwater storage and movement occurs within the coal seam cleats and fractures.

Groundwater levels measured in the monitoring bores range from 27 (PZ02B) to 64.5 (PZ07C) m below ground level for the Harrow Creek H16 seam and from 20.8 (PZ06C) to 65.2 (PZ09C) m below ground for the Dysart Lower Seam (D14 and D24).

The potentiometric surface of the Permian sequences indicates a gradient from around 185 mAHD in the northwest to around 170 mAHD in the south east. This is similar to the regional groundwater contours generated for the Permian coal seams across the Bowen Basin, Figure 17 (Arrow, 2012).

The regional groundwater flow pattern across the study area, near Phillips Creek, indicates flow from north-west to south-east. There is a groundwater low indicated on the regional groundwater flow pattern in this area. It is considered that this low could be as a result of abstraction or faulting.

Groundwater levels for the coal seam bores is include in Figure 15. These groundwater levels indicate no seasonal fluctuation (response to dry and wet seasons) and no influence of mining (even though the mining at Saraji Mine has been operating since 1974).



LEGEND

- Locality
- Coal Seam Bores (mAHD)
- Permian Bores (mAHD)
- Major Watercourse
- Groundwater Contour (mAHD)
- Approximate Groundwater Flow Direction
- BMA Tenure / Tenement
- Bowen Basin

Data sources:

1. Tenements © BMA 2016 (RFI)
2. Watercourses © BOM 2012
3. Bores © State of Queensland (Department of Natural Resources and Water) 2008
4. Contours, Direction from Arrow Energy 2012

N

Figure 17
Average Groundwater Level Contours Across the Bowen Basin (Source: Arrow, 2012a)

Saraji Open Cut Extension Project Environmental Assessment Report

0 5 10 20
Kilometres

Scale: 1:1,500,000 (when printed at A4)

Projection: Map Grid of Australia - Zone 55 (GDA94)

BMA
BHP Billiton Mitsubishi Alliance

DATE: 29/11/2016 VERSION: 1

Filename: \\aubne1fp003\Projects\605X\60507031\4. Tech Work Area\4.99 GIS\02_MXDs\04 Saraji OC Environmental Assessment Report\00 Technical Report\Groundwater\60507031_G052_v1_A4P.mxd

6.7.4 Groundwater Flow Patterns from Model

The initial starting groundwater levels, used in the refined predictive model calibration, allowed for the generation of groundwater contours in the unconfined upper sediments (model layer 1) and the Harrow Creek (H16) coal seam (model layer 6), see Section 9.4.3.

Figure 18 and Figure 19 present the pre-Project groundwater levels for the Tertiary and alluvium sediments and H16 coal seam, respectively.

Figure 18 Pre-Project Groundwater Contours in the Tertiary and Alluvium

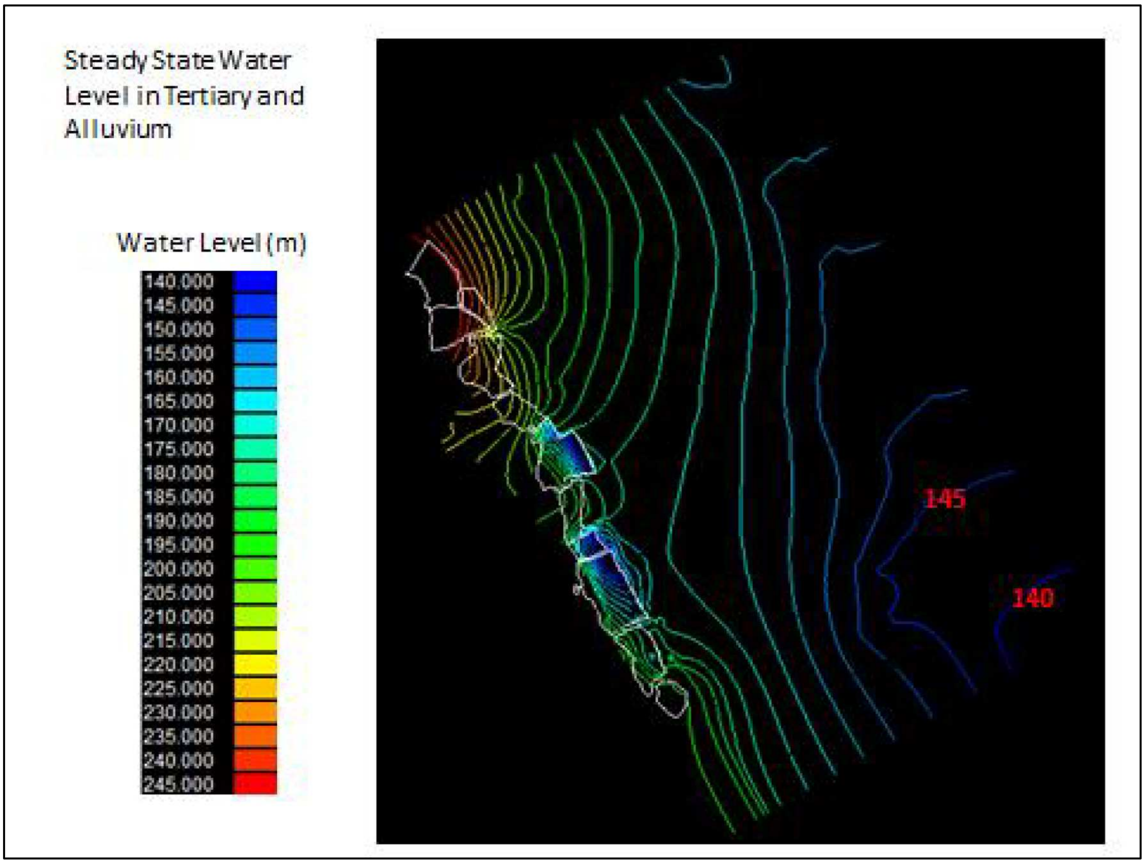
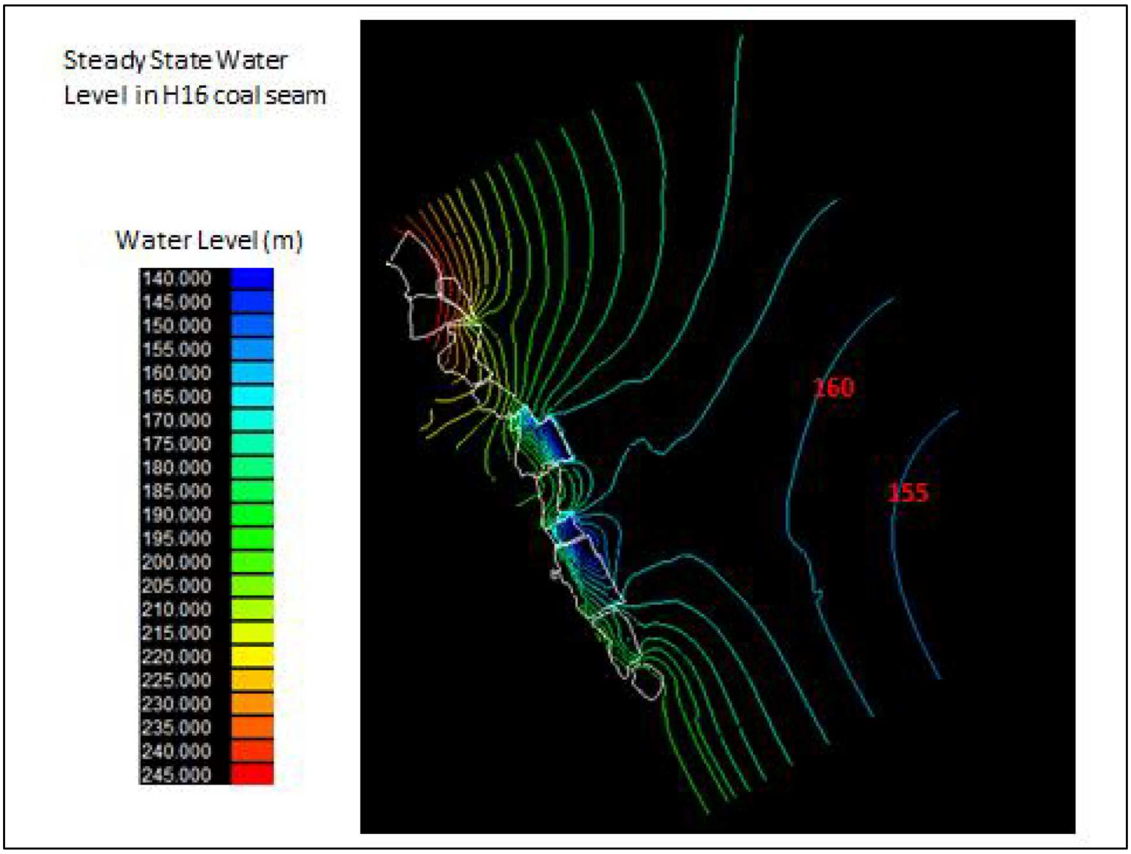


Figure 19 Pre-Project Groundwater Contours in H16 Coal Seam



These groundwater contours flow patterns are recognised to correlate well with the AGE data (Figure 16) and the Arrow regional groundwater flow in the Permian (Figure 17).

6.7.5 Vertical Gradients

Groundwater levels measured in the nested bores PZ02, PZ04, PZ07, PZ09, PZ10 and VWPs PZ05, PZ06, and PZ08 were assessed to determine vertical groundwater gradients across the study area. Representative groundwater data and bested bore details are included in Table 7.

Table 7 Vertical Groundwater Level Assessment (Aug /Sept 2011 Groundwater Monitoring Data)

Bore	Monitoring Point	Depth (mbgl)	Unit	Water Level (mAHD)	Comment
PZ02	PZ02A	26	Tertiary	181.78	Downwards gradient Marked water level separation indicating aquitards
	PZ02B	170	Permian interburden	173.78	
	PZ02C	279	Dysart D24	170.78	
PZ04	PZ04A	30	Tertiary	187.92	Downwards gradient Marked water level separation between coal seams
	PZ04B	66	H16	186.81	
	PZ04C	180	Dysart (D47)	166.81	
PZ05	PZ05A	203	H16	168.43	Downwards gradient 3 m water level separation between coal seams
	PZ05B	239	Dysart (D52)	166.43	
PZ06	PZ06A	40.5	Permian overburden	184.39	Two separate water levels

Bore	Monitoring Point	Depth (mbgl)	Unit	Water Level (mAHD)	Comment
	PZ06B	78.5	H16	179.08	High potentiometric pressure in lower D142 seam, upward gradient
	PZ06C	167	Dysart (D142)	182.62	
PZ08	PZ08A	38.5	P07 coal	177.70	Downward gradient
	PZ08B	65	H16	173.25	
	PZ08C	180	Dysart (D24)	No Data	
PZ09	PZ09A		Tertiary	Dry	Downward gradient
	PZ09B	75	H16	165.69	
	PZ09C	195	Dysart (D24)	133.02	
PZ10	PZ10A		Tertiary	Dry	Downward gradient
	PZ10B	70	H16	177.52	
	PZ10C	184	Dysart (D24)	159.33	

Source: AGE, 2012a.

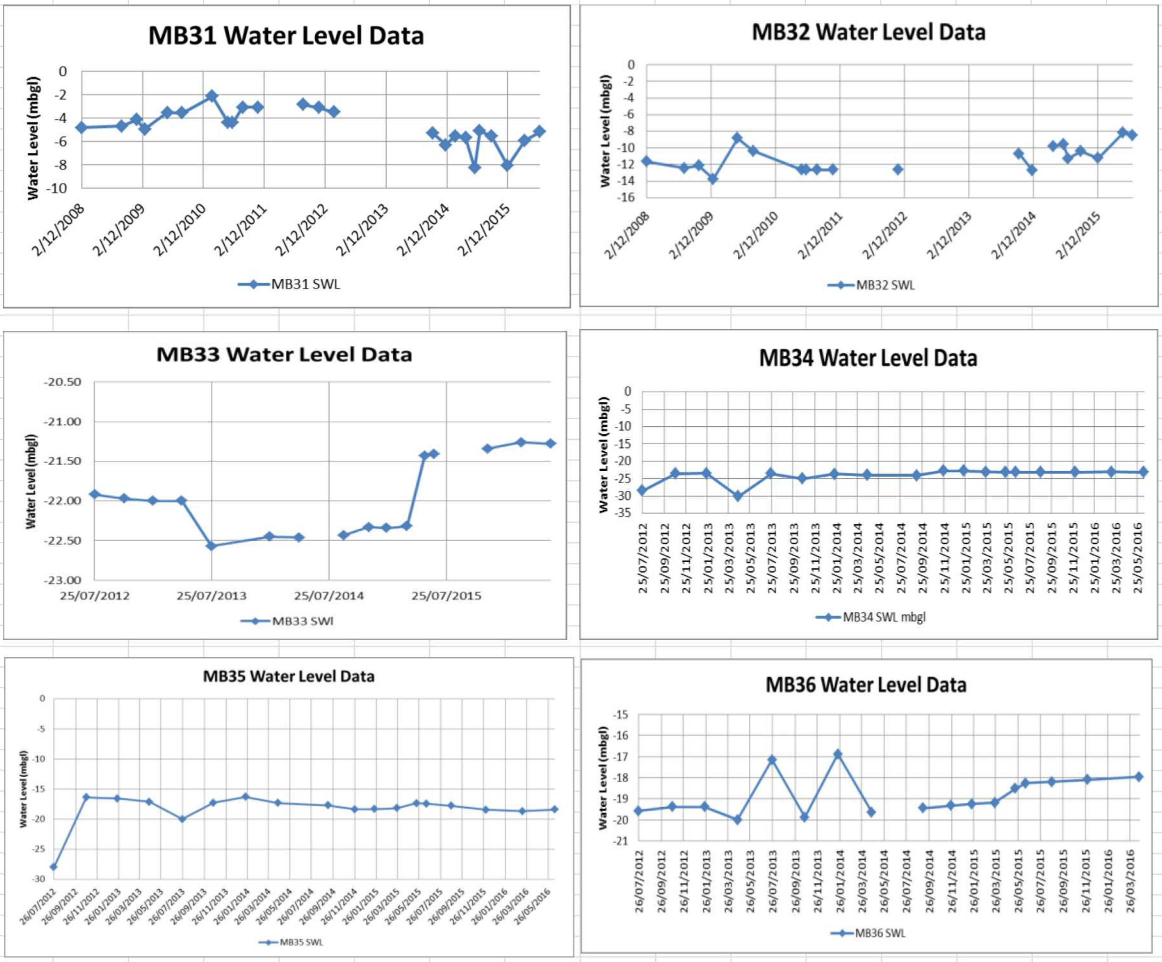
Groundwater level data indicate two distinct groundwater levels, one associated with the Tertiary, and one with the Permian. This is adopted in the groundwater conceptualisation (Section 9.1).

Vertical groundwater gradient is generally downwards with the highest potentiometric pressures in the Tertiary and upper coal seams. Potentiometric pressure decreases with the depth of coal seam.

6.7.6 Dewatering as a Result of Existing Mining

Groundwater levels in the alluvium (MB2), Tertiary (PZ02A and PZ04A) and Permian (MB31, MB33 to MB37) strata, measured over time, do not indicate any impacts of mine dewatering even though coal mining at Saraji Mine has been undertaken since 1974 (Figure 20). Figure 15 shows the trends for the PZ bores.

Figure 20 Monitoring Bore Water Level Trends



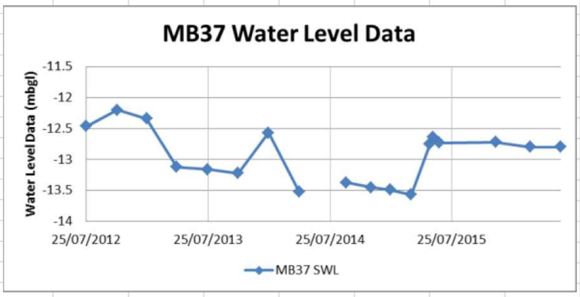


Table 4: SARAJI MINE MONITORING BORE DETAILS

Bore Name	Property	Easting	Northing	Diameter mm	Total Depth (mbgl)	Surface Elevation (mRL)	Screened Interval From	Screened Interval To	Screened Lithology	Use	Status
MB29 (MB5)	Meadowbrook	641146	7520794	150	-	184.0	-	-	Unknown	Stock	UE
MB30 (LV1A)	Lake Vermont	642503	7519162	150	25.42	186.6	-	-	Tertiary and Permian coal measures	Stock	SP
MB31 (SJ1)	Saraji Station	625828	7522379	150	44.23	221.9	-	-	Permian coal measures	Stock	UE
MB32 (TG2)	Tay Glen	637481	7510535	150	19.52	208.0	-	-	Alluvium (Phillips Creek)	Stock	SP
MB33	Saraji Mine	636640	7520199	50	37.5	194.8	30	36	Weathered sandstone interburden	Monitoring	MB
MB34	Saraji Mine	637926	7518269	50	107	195.9	99.5	105.5	Fresh siltstone interburden	Monitoring	MB
MB35	Lake Vermont	642646	7520110	50	34.5	184.6	27	33	Weathered shale and fresh siltstone overburden	Monitoring	MB
MB36	Lake Vermont	640150	7514283	50	32	197.8	24.5	30.5	Weathered siltstone & sandstone overburden	Monitoring	MB
MB37	Saraji Mine	632389	7515571	50	42.5	234.8	1.7	42.5	Weathered & fresh sandstone overburden	Monitoring	MB

Notes: *Coordinates are in AMG 84, Zone 55*
Surface Elevation derived from 1 arc second DEM-S (smoothed digital elevation model – 1 second SRTM derived) – elevation accuracy ± 3 m
mbgl – metres below ground level
Screened Interval in metres below ground level
SP – equipped with a submersible pump
UE – currently unequipped
MB – monitoring bore

The bores are located within 600 (MB2) to 1,500 m (MB33 and MB34) of the existing Saraji Mine open cut pits. This indicates the zone of influence (as measured in groundwater level drawdown) is restricted to immediately adjacent to the mine workings.

The zone of influence is restricted due to low permeability, groundwater head differences (particularly in the Tertiary), water storage in pits (Section 9.5.1 and Table 14**)**, and no active dewatering schemes on the mine (i.e. little or no groundwater ingress on seepage occurs within the mine workings).

It is considered that the long term mine activities do not markedly impact on regional groundwater resources.

6.8 Groundwater Quality

6.8.1 Quaternary Deposits

Groundwater quality of the alluvium associated with creeks and river systems within the Isaac-Connors sub-catchment is considered moderately to highly variable, ranges from fresh to very saline, and is typically slightly saline (URS, 2012).

The Phillips Creek drainage feature, which is located adjacent to the Project area, houses the mapped Quaternary alluvial sediments associated with the Project area. It is considered that the alluvial aquifer is recharged by seepage from Phillips Creek (Section 6.2.1), which is located in the Isaac Connors groundwater management area (GMA).

Raymond and McNeil (2011) were unable to map the quality of the groundwater in the area between Phillips Creek and Sawmill Creek due to a paucity of field data. However groundwater in this portion of the Project area is likely to be saline-sodic like the 'Isaac Dawson' given that the upstream catchment to this area is comparatively small, flat and semi-arid.

Site specific data

The groundwater monitoring bores across the site, reported to be screened through the alluvium are reportedly dry, except for bore MB32. Available hydrochemical data for MB32 was compiled (Gauge, 2015), these data are presented in Table 8 and provide an indication of the groundwater quality associated with saturated alluvium adjacent to the Project site.

Ignoring the sample dated 20/06/2012, the groundwater associated with the alluvium is variable with time, brackish and slightly alkaline. The groundwater is sodium- chloride dominant with calcium and magnesium.

Total Dissolved Solids concentrations indicate it is not suitable for drinking but can be used for livestock watering.

Table 8 Alluvium Groundwater Quality - MB32

Date	pH	EC	TDS	CO_3	HCO_3	SO_4	Cl	Ca	Mg	Na	K	Al	Sb	As	Hg	NO_3	P	C_6-C_9	C_{10}-C_{36}
Units	units	µS/cm	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	µg/L	µg/L	µg/L	µg/L	mg/L	mg/L	µg/L	µg/L
14/12/09	6.98	1.440	649	< 1	422	21	51	73	74	47	< 1			< 1				< 20	< 50
29/4/10	7.34	996	552	< 1	423	26	40	80	65	41	< 1			1				< 20	< 50
27/7/10	7.06	1,098	637	< 1	497	24	55	71	78	61	< 1			< 1		< 0.01	0.06	< 20	< 50
29/4/11	7.28	1,080	606	< 1	471	21	42	87	64	38	1			< 1		< 0.01	0.37	< 20	< 50
25/5/11	7.28	1,080	606	< 1	471	21	42	87	64	38	1			< 1		< 0.01	0.06	< 20	< 50
25/7/11	7.48	867	606	< 1	471	21	42	87	64	38	1					< 0.01		< 20	< 50
24/10/11	6.95	997	609	< 1	517	23	50	83	70	48	< 1			< 1		< 0.01	0.05	< 20	< 50
20/6/12	7.67	773	3000?	< 5	940	500	780	69	89	910	51			1		< 0.005	4.4	< 20	< 50
25/7/12	6.80	1,690	690	< 5	500	32	83	95	82	56	1.1			< 1		< 0.005	0.44	< 20	< 50
24/10/12	7.57	1,401	790	< 5	540	32	91	80	72	53	1			< 1		< 0.005	0.067	< 20	< 50
22/1/13	7.15	2,276	860	< 5	650	59	140	86	94	90	1			< 1		< 0.005	0.065	< 20	< 50
24/7/13	6.65	2,437	1,100	< 5	560	42	140	110	97	77	1.3			< 1		< 0.005	0.24	< 20	< 50
22/10/13	7.37	1.713	930	< 1	488	67	202	105	111	75	1	50	< 1	< 1	< 1			< 20	< 50
21/1/14	8.18	1,672	1,100	29	436	82	219	79	113	107	1	100	< 1	< 1	< 0.1			< 20	< 50
22/4/14		1,622	940	< 1	586	91	218	117	111	106	1	70	< 1	< 1	< 0.1			< 20	< 50
29/7/14			856	< 1	563	62	182	91	102	94	1	150	< 1	< 1	< 0.1			< 20	< 50
10/9/14	7.5	1,562	797	18	485	52	193	104	104	83	2	< 10		< 1	< 0.1			< 20	< 50
25/11/14	7.5	1,611	882	< 1	646	59	172	98	106	108	2	30		< 1	< 0.1			< 20	< 50
24/3/15	7.5	1,695	961	< 1	611	91	212	110	101	119	1	90		< 1	< 0.1			< 20	< 50

Where: EC – Electrical Conductivity, TDS – Total Dissolved Solids, CO_3 – Carbonate, HCO_3 – Bicarbonate, SO_4 – Sulphate, Cl – Chloride, Ca – Calcium, Mg – Magnesium, Na –Sodium, K – Potassium, Al – Dissolved Aluminium, Sb – Antimony, As – Arsenic, Hg – Mercury, NO_3 – Nitrate, P – Reactive phosphorous, C_x – Hydrocarbon fractions

6.8.2 Tertiary Sediments

Tertiary groundwater quality was determined from Saraji Mine monitoring bores PZ02A and PZ04A. A representative sample could not be collected from bore PZ07A, constructed to target the Tertiary sediments, due to bentonite invading the screened zone in that bore.

Table 9 summarises the groundwater quality of samples from the Tertiary aquifer as collected from bores PZ02A and PZ04A.

Table 9 Tertiary Groundwater Quality (Oct/Nov 2011 data)

Parameter	Unit	LOR	PZ02A	PZ04A	Livestock Guidelines (2000)
pH	pH unit	0.01	6.7	8.1	-
EC	µS/cm	1	22,000	9,000	
TDS	mg/L	5	18,000	6,300	4,000
T. Alkalinity	mg/L	1	490	81	-
Sulphate	mg/L SO_4	1	1,700	44	1,000 – 2,000
Chloride	mg/L Cl	1	8,800	3,700	-
Fluoride	mg/L F	0.1	0.44	0.12	1,000
Calcium	mg/L Ca	0.5	370	230	-
Magnesium	mg/L Mg	0.5	730	110	-
Sodium	mg/L Na	0.5	5,100	1,600	-
Potassium	mg/L K	0.5	110	19	-
Diss. Aluminium	mg/L Al	0.01	0.15	0.11	5
Antimony	mg/L Sb	0.001	0.001	0.002	-
Arsenic	mg/L As	0.001	0.002	0.001	0.5
Molybdenum	mg/L Mo	0.001	0.002	0.006	0.15
Selenium	mg/L Se	0.001	< 0.001	< 0.001	0.02
Silver	mg/L Ag	0.001	< 0.001	< 0.001	-
Iron	mg/L Fe	0.01	2.56	1.0	-
Mercury	mg/L Hg	0.0001	< 0.0001	< 0.0001	0.002
Nitrite	mg/L NO_2	0.01	< 0.01	< 0.01	30
Nitrate	mg/L NO_3	0.1	< 0.1	< 0.1	400
Nitrate + Nitrite	mg/L	-	< 0.1	< 0.1	-
Orthophosphate	mg/L PO_4	0.005	0.01	< 0.005	-
$C_6 – C_9$	µg/L	10	< 10	< 10	-
$C_{10} – C_{14}$	µg/L	50	< 50	140	-
$C_{15} – C_{28}$	µg/L	100	< 100	890	-
$C_{29} – C_{36}$	µg/L	100	< 100	180	-
BTEX	µg/L	1 - 2	< LOR	< LOR	1 - 25

LOR – Limit of Reporting
Source: AGE, 2012a)

The analyses indicate that the Tertiary groundwater ranges from slightly acidic to slightly alkaline and is dominated by sodium and chloride with total dissolved solids (TDS) in excess of 6,000 mg/L. This means the water is brackish to saline and exceeds the recommended level for cattle. A relatively high sulphate level was recorded in PZ02A; however, this was still within the range for livestock.
Metal concentrations for all parameters analysed were either below the laboratory detection limit or below relevant guideline levels.

Total petroleum hydrocarbon concentrations were below the laboratory detection limits in PZ02A, but reported detectable levels between 140 micrograms per litre (µg/L) and 890 µg/L for the C_{10} – C_{36} fractions analysed. It is possible that the source for these hydrocarbon fractions might be oil based lubricant used whilst drilling the borehole and not hydrocarbon contamination from within the aquifer. Interference from naturally occurring organic matter is also a potential source of the hydrocarbons detected in the water samples. Aromatic (BTEX) hydrocarbons were all below the laboratory detection limits in both monitoring bores.

Additional sampling events have reported that these two Tertiary monitoring bores contain insufficient groundwater to collect additional samples.

6.8.3 Coal Seam Aquifers

Representative samples of the Permian coal seam aquifers were collected from bores PZ02B, PZ04B, and PZ09B for the Harrow Creek Upper Coal Seam and from PZ04C, PZ09C, and PZ10C for the Dysart Lower Coal Seam (Figure 10). Table 10 and Table 11 provide summaries of the water quality results.

The analyses indicate that the Permian coal seam groundwater ranges from slightly acidic to alkaline and is dominated by sodium and chloride with TDS levels ranging from 3,300 mg/L to 20,000 mg/L. The coal seam water is brackish to saline and typically not suitable for stock watering.

Metal concentrations for all parameters analysed were either below the laboratory detection limit or below the relevant guideline level. Total petroleum hydrocarbon concentrations were mostly below the laboratory detection limits, but reported detectable levels between 25 µg/L and 1,100 µg/L for the C_6 – C_{35} fractions analysed in bores PZ09B and PZ10C. It is possible that the source for these hydrocarbon fractions is oil based lubricant used whilst drilling the borehole and not hydrocarbon contamination from within the aquifer. Similarly, aromatic (BTEX) hydrocarbons were mostly below the laboratory detection limits in both monitoring bores, except for detectable levels reported for toluene between 2 µg/L and 4 µg/L for toluene in bores PZ09B and PZ10C. Interference from naturally occurring organic matter is also a potential source of the hydrocarbons detected in the water samples.

Table 10 Harrow Coal Seam Groundwater Quality

Table 7: SUMMARY OF HARROW CREEK SEAM WATER QUALITY						
Analyte	Unit	LOR	PZ02B (31/10/11)	PZ04B (18/11/11)	PZ09B (1/11/11)	Livestock Guidelines (2000)
pH Value	pH Unit	0.01	7.6	6.7	8.1	-
Electrical Conductivity	µS/cm	1	14,000	27,000	20,000	-
Total Dissolved Solids	mg/L	5	***9,600***	***20,000***	***15,000***	4,000
Major Ions						
Total Alkalinity	mg/L	1	35	590	420	-
Sulphate	mg/L	1	49	1,900	1,500	1,000-2,000
Chloride	mg/L	1	4,900	9,100	6,700	-
Fluoride	mg/L	0.1	0.14	0.44	0.2	1,000
Calcium	mg/L	0.5	310	400	320	
Magnesium	mg/L	0.5	120	740	500	-
Sodium	mg/L	0.5	2,900	5,200	4,700	-
Potassium	mg/L	0.5	9.1	130	17	-
Trace Metals						
Aluminium	mg/L	0.01	0.013/0.08	0.05/0.15	<0.01/0.038	5
Antimony	mg/L	0.001	<0.001/<0.001	0.001/<0.001	<0.001/<0.001	-
Arsenic	mg/L	0.001	0.004/0.004	0.003/0.003	<0.001/<0.001	0.5
Molybdenum	mg/L	0.001	0.008/0.009	0.002/0.002	<0.001/0.002	0.15
Selenium	mg/L	0.001	<0.001/<0.001	<0.001/<0.001	<0.001/<0.001	0.02
Silver	mg/L	0.001	<0.001/<0.001	<0.001/<0.001	<0.001/<0.001	-
Iron	mg/L	0.01	0.75/1.1	1.7/2.5	0.028/0.29	-
Mercury	mg/L	0.0001	<0.0001/<0.0001	<0.0001/<0.0001	<0.0001/<0.0001	0.002
Nutrients						
Nitrite	mg/L	0.01	<0.01	<0.01	<0.01	30
Nitrate	mg/L	0.1	<0.005	<0.1	<0.005	400
Nitrate + Nitrite	mg/L	-	<0.005	<0.1	<0.005	-
Reactive Phosphorous	mg/L	0.005	<0.005	<0.005	<0.005	-
Total Petroleum Hydrocarbons						
C_6 - C_9 Fraction	µg/L	10	<10	<10	28	-
C_{10} - C_{14} Fraction	µg/L	50	<50	<50	<50	-
C_{15} - C_{28} Fraction	µg/L	100	<100	<100	<100	-
C_{29} - C_{36} Fraction	µg/L	100	<100	<100	<100	-
BTEX[1]	µg/L	1-2	<LOR	<LOR	4 (Toluene)	1-25

Notes:
TDS guideline is for beef cattle
LOR – laboratory limit of reporting
" – " No guideline level established
[1] – In the absence of guidelines derived specifically for livestock, the *Australian Drinking Water Guidelines* (NHMRC & ARMCANZ, 2011) have been adopted for BTEX.
Source: AGE, 2012a.

Table 11 Dysart Coal Seam Groundwater Quality

Analyte	Unit	LOR	PZ04C (18/11/11)	PZ09C (1/11/11)	PZ10C (1/11/11)	Livestock Guidelines (2000)
pH Value	pH Unit	0.01	7.6	8.25	9.0	-
Electrical Conductivity	µS/cm	1	23,000	8,122	5,500	-
Total Dissolved Solids	mg/L	5	***18,000***	3,420	3,300	4,000
Major Ions						
Total Alkalinity	mg/L	1	270	201	220	-
Sulphate	mg/L	1	1,200	52	60	1,000-2,000
Chloride	mg/L	1	7,900	1,880	1,600	-
Fluoride	mg/L	0.1	0.18	0.44	0.4	1,000
Calcium	mg/L	0.5	350	32	29	
Magnesium	mg/L	0.5	520	27	25	-
Sodium	mg/L	0.5	4,400	0.45	1,200	-
Potassium	mg/L	0.5	92	8.9	9.8	-
Trace Metals						
Aluminium	mg/L	0.01	0.048/0.12	0.022/0.57	0.026/0.59	5
Antimony	mg/L	0.001	<0.001/<0.001	<0.001/<0.001	<0.001/<0.001	-
Arsenic	mg/L	0.001	<0.001/<0.001	<0.001/0.001	<0.001/0.001	0.5
Molybdenum	mg/L	0.001	<0.001/<0.001	0.034/0.040	0.038/0.040	0.15
Selenium	mg/L	0.001	<0.001/<0.001	<0.001/<0.001	<0.001/<0.001	0.02
Silver	mg/L	0.001	<0.001/<0.001	<0.001/<0.001	<0.001/<0.001	-
Iron	mg/L	0.01	0.4/0.65	0.13/1.9	0.012/2.0	-
Mercury	mg/L	0.0001	<0.0001/<0.0001	<0.0001/<0.0001	<0.0001/<0.0001	0.002
Nutrients						
Nitrite	mg/L	0.01	<0.01	<0.025	<0.025	30
Nitrate	mg/L	0.1	<0.1	<0.025	<0.025	400
Nitrate + Nitrite	mg/L	-	<0.1	<0.025	<0.025	-
Reactive Phosphorous	mg/L	0.005	0.007	0.01	0.01	-
Total Petroleum Hydrocarbons						
C_6 - C_9 Fraction	µg/L	10	<10	-	25	-
C_{10} - C_{14} Fraction	µg/L	50	<50	-	<50	-
C_{15} - C_{28} Fraction	µg/L	100	<100	-	1,100	-
C_{29} - C_{36} Fraction	µg/L	100	<100	-	490	-
BTEX[1]	µg/L	1-2	<LOR	-	2 (Toluene)	1-25

Notes:
TDS guideline is for beef cattle
LOR – laboratory limit of reporting
" – " No guideline level established
[1] – In the absence of guidelines derived specifically for livestock, the *Australian Drinking Water Guidelines* (NHMRC & ARMCANZ, 2011) have been adopted for BTEX.
Source: AGE, 2012a.

Ongoing Monitoring

Seven monitoring bores, MB31 to MB37, form part of the Saraji Mine groundwater monitoring network. All these bores, except MB32 (alluvium), provide ongoing hydrochemistry data for the Permian strata across and adjacent to the Saraji Mine.

The latest annual groundwater monitoring report (Gauge, 2015) indicates the following:

- Groundwater quality parameters monitored include; pH, Electrical Conductivity (EC), Total Dissolved Solids (TDS), Calcium (Ca), Magnesium (Mg), Potassium (K), Chlorine (Cl), Sulfate (SO_4), Carbonate (CO_3), Bicarbonate (HCO_3), Phosphate (PO_4), Nitrate (NO_3), Iron (Fe), Arsenic (As), Mercury (Hg), Serbium (Sb), and petroleum hydrocarbons.
- Bores MB33 and MB34 have the highest salinities, 20,000 to 30,000 µS/cm associated with deeper Permian interburden, Permian sub-crop bore MB37 has salinity concentrations of 14,000 to 15,000 µS/cm indicating increased salinity with depth due to slow movement and interaction with Permian sediments.
- The lowest salinities occur within the Phillips Creek bores MB2 (alluvium) and MB35 (Fairhill Formation directly below alluvium), Electrical Conductivity (EC) concentrations are less than 2,500 µS/cm.
- All bores have salinity concentrations greater than 600 mg/L TDS, the drinking water guideline.
- All Permian groundwater samples have high sulphate concentrations (280 to 2,580 mg/L) except for MB35 (which is considered to be a blend with alluvium water). SO_4 concentrations in MB31, MB33, and MB37 are greater than the beef stock watering guideline (1,000 mg/L SO_4).
- Total metals in groundwater samples are less than the ANZECC stock water guidelines.
- Concentrations of nitrate are well below guideline values.
- Orthophosphate (reactive phosphate) concentrations are highest in MB31, a bore located within farming land up gradient of Saraji Mine.
- Low levels of hydrocarbons are still being measured in MB34, considered to have been contaminated during construction.

These ongoing groundwater monitoring results are comparable with the initial baseline data indicate little or no alteration due to mine operations.

6.8.4 Summary

The groundwater quality data across the site, strata, and depth is variable and ranges from brackish to saline. Although the groundwater is generally within the guidelines for livestock, Section 4.3.3.5 of the ANZECC guidelines (2000) states that loss of production and a decline in animal health occurs If stock are exposed to high salinity water for prolonged periods. For beef cattle, this limit is in range the range of 5,000 mg/L to 10,000 mg/L.

Given the variable salinity levels for groundwater hosted in the Tertiary and Permian aquifers are within this range and there are some cases of salinity greater than 10,000 mg/L, the regional groundwater would generally not be considered suitable for livestock.

6.9 Groundwater Dependent Ecosystems

GDEs are those ecosystems that require access to groundwater on a permanent or intermittent basis to meet all or some of their water requirements. GDEs can be categorised into three difference groups including:

- ecosystems reliant on surface expression of groundwater
- ecosystems reliant on groundwater within the root zone
- stygofauna.

A desktop assessment of the Project site, for *The Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) listed GDEs (spring ecosystems), was undertaken. This assessment did not identify the potential occurrence of any GDEs listed under the EPBC Act. The terrestrial ecology field survey confirmed this finding, with no EPBC Act listed GDEs recorded.

To determine the likelihood of terrestrial GDEs occurring, a review of the geological and groundwater data was undertaken. This review identified that GDEs are most likely to occur in areas where groundwater levels are shallow (less than 9 m), including alluvial deposits. Review of groundwater levels surrounding the Project site identified that groundwater was typically recorded at levels deeper than 10 m and likely to be outside of the accessible reach of Eucalypt vegetation (Zolfaghar et al. 2014).

Further to the above, the assessment of alluvial deposits along Phillips Creek identified that given the ephemeral nature of Phillips Creek, it is considered that the alluvial aquifer is not a permanent source of groundwater. Additionally, it was identified that the alluvial sediments within the Project site have limited storage (recharged during flow events and by direct rainfall but does not store groundwater) and are non-continuous (the coarse grained more permeable sediments are not continuous down the length of the creek).

It is considered that terrestrial GDEs are unlikely to occur within Project site, given the depth of groundwater and limited storage capacity of alluvial sediments.

6.9.1 Stygofauna

4T Consultants conducted a desktop study to assess the potential for stygofauna in the Bowen Basin based on an assessment of suitable stygofauna habitat (4T, 2012). The assessment considered:

- aquifer type
- groundwater flow into and out of the aquifer (hydraulic conductivity)
- groundwater quality characteristics
- depth to groundwater
- food supply
- water extraction and use.

Considering the deep saline groundwater associated with the Tertiary and Permian aquifers, these units are unlikely to contain habitat suitable for stygofauna.

Portions of the alluvium, which have higher porosity, suitable hydraulic conductivity, and interconnectivity, are likely to contain habitat suitable for stygofauna. However, as the alluvium in and adjacent to the Project site is ephemeral, discontinuous, and can be saline it is considered that this groundwater resource does not contain sufficient permanent suitable groundwater to support stygofauna populations.

7.0 Groundwater Use and Environmental Values

7.1 Groundwater Use

In Queensland, a number of areas have been declared as sub-artesian areas under the Water Act. The proposed Project is located within the Highlands Declared Sub-artesian Area and under this legislation all water supply bores drilled in the area must be approved and licensed by DNRM.

DNRM maintains a database of all registered groundwater bores in Queensland and a search of the groundwater database covering an area that could potentially be impacted by the mine was undertaken.

The database indicates that there are 64 registered bores existing within a 30 km radius of the proposed mine, of which only four bores (RN86538, RN100248, RN132631 and RN132689) were located proximal to Saraji Mine.

A bore census was undertaken by AGE in 2007 which identified 12 bores surrounding to Saraji Mine which do not correlate with the registered bore data and as such were considered to be unregistered bores. Table 12 presents a summary of information available for each bore.

Table 12 2007 Bore Census Data

Bore ID	Property	Location (AGD84)		Standing Water Level (m)	Bore Depth (m)	Water Quality		Status
		Easting	*Northing*			*pH*	*EC*	
MB1	Meadowbrook	645485	7528479	20.63	79.4	7.62	2760	Pump removed
MB2	Meadowbrook	635932	7527937	22.86	60.94	-	-	Not equipped
MB3	Meadowbrook	635938	7527942	23.82	50	6.67	6990	Not equipped
MB4	Meadowbrook	635928	7527934	23.53	27.1	-	-	Not equipped
MB5	Meadowbrook	641146	7520794	-	-	7.11	7270	Equipped
MB6	Meadowbrook	635335	7527993	-	-	8.23	5880	Equipped
LV1	Lake Vermont	642503	7519162	23.77	>100	7.32	916	New unequipped bore
LV2	Lake Vermont	637431	7510772	-	-	7.87	758	Equipped
SJ1	Saraji Station	625828	7522379	7.85	-	7.74	8250	Equipped
SJ2	Saraji Station	630049	7513461	-	-	-	-	Equipped - not operational
TG1	Tay Glen	635215	7508903	9.42	15.06	8.23	1940	Not equipped
TG2	Tay Glen	637481	7510535	-	-	7.88	754	Equipped

Source: AGE, 2007.

Of these, four bores (MB2 to MB4, and MB6) were identified adjacent to the two registered bores RN132631 and RN136689. The location of all registered and non-registered bores are shown on Figure 10 and the registered bore details are summarised in Table 6**.**

Groundwater bores:

- Bores MB2 to MB4 are between 27 m and 60 m deep and not equipped with any pumps
- Bore MB6 is equipped but its depth is unknown. Given the reported water quality (EC value of 6,000 µS/cm), it can be assumed this bore is less than 60m depth.
- There is no water quality data for the two registered bores (RN132631 and RN136689), however construction details indicate both bores are screened between 315 m and 325 m depth indicating they access groundwater hosted in one of the deeper coal seams.

In 2011 BMA commissioned SKM to conduct an assessment of groundwater permits within 20 km of the Saraji Mine. As part of this assessment, a review of the DNRM database indicated that there were six permits to abstract groundwater issued within the search area. All the permits are located approximately 16 km to the east of the proposed Project and are all from bores at depths less than 70m. These bores are most likely to be abstracting groundwater from Tertiary or Quaternary aquifers.

These bores, being located within overlying units, separated by regional faults (Section 5.3), and located approximately 16 km away from the Project (where drawdown associated with mining activities is recognised to be limited (Section 6.7.6), are therefore not considered to be impacted by the proposed mine workings.

7.2 Groundwater Environmental Values

This section identifies and describes groundwater related environmental values in the Project area. Sensitivity of these environmental values to disturbance and the anticipated Project related impacts on environmental values are included in Section 11.0.

The enhancement of Groundwater Environmental Values and the protection groundwater are required in the EPP (Water) (Section 2.0). The EPP (Water) provides a framework for identifying the environmental values, and establishing water quality guidelines and objectives to enhance or protect Queensland waters. For the purposes of this assessment the 'values', as defined in the EPP (Water), are those attributes of the groundwater systems within the potential impact area (and Project area) that are sufficiently important to be protected or enhanced.

The majority of the proposed Project area is within the Isaac River sub-basin of the Fitzroy Basin as described in Schedule 1 of the EPP (Water). The scheduled environmental values for groundwater to be enhanced or protected in the area are the following qualities:

- aquatic ecosystem environmental values
- human use environmental values
- for waters that may be used for recreation or aesthetic purposes
- for waters that may be used for drinking water
- for waters that may be used for industrial purposes
- cultural and spiritual values.

An assessment was made of the groundwater quality in terms of the relevant environmental values in the terms used in the Environmental Protection (Water) Policy 2011.

7.2.1 Aquatic Ecosystems

Aquatic or specifically GDEs are defined as "*those parts of the environment the species composition and natural ecological process of which are determined by the permanent or temporary presence or influence of groundwater*" (DEH, 2001).

The fauna and flora assessment for the Project indicates that no GDEs have been identified or are known to exist within the Project area (Section 6.7).

The deep (greater than 20 m) depth to permanent groundwater (Section 6.0) in the Tertiary and Permian aquifers plus the saline nature of the groundwater quality, are not considered to be suitable for use for GDEs.

7.2.2 Agricultural Use

The review of DNRM registered bores and the bore census data indicate that groundwater in the area is used for stock watering.

The groundwater quality information (Section 6.6) is recognised to be variable and ranges from brackish to saline. Although the groundwater is generally within the guidelines for livestock, Section 4.3.3.5 of the ANZEEC guidelines (2000) states that loss of production and a decline in animal health occurs If stock are exposed to high salinity water for prolonged periods. For beef cattle, this limit is in range the range of 5,000 mg/L to 10,000 mg/L.

Given the variable salinity levels for groundwater hosted in the Tertiary and Permian aquifers are within this range and there are some cases of salinity greater than 10,000 mg/L, the regional groundwater would generally not be considered suitable for livestock.

7.2.3 Recreational Use

This category of environmental value is considered not applicable to groundwater in-situ. There are also no registered groundwater springs in the Project area that could be considered for recreational use. Groundwater seepage from the alluvium and/or Tertiary units into water courses can provide short duration baseflow into rivers and creeks immediately after heavy rains or flooding, however, after larger flood events suitability of these waters for recreation may be limited by other factors.

This value is more common for surface water features that are accessible for recreational use and visual interaction; however, there is currently no evidence to suggest that groundwater is directly used for recreational or aesthetic purposes in the study area.

7.2.4 Drinking Water Suitability

The suitability of water for human consumption is defined in the Australian Drinking Water Guidelines (NHMRC and NRMMC, 2011). The groundwater quality data, as presented in Section 6.6, indicates that in general, the groundwater is unsuitable for human consumption before treatment due to elevated levels of salinity.

The hydrochemistry data for the Permian coal seams (Table 10 and Table 11) has elevated concentrations of sodium above the EPP (Water) drinking water guideline of 30 mg/L for sodium.

Groundwater resources within the Project area are, therefore, considered to require significant treatment before utilisation for drinking.

The availability of rain water tank supplies and the generally low sustainable yield and poor quality of the groundwater bores in the area, are also factors that preclude the usage and potential for usage of the groundwater as a drinking water source.

7.2.5 Industrial Use

The nearest industry to the Project is the Saraji Mine which is located adjacently west of the Project area. It is understood the Saraji Mine does not utilise groundwater for its operations. There are no other industrial users of groundwater within the project area.

7.2.6 Cultural and Spiritual Values

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

7.2.7 Summary

In summary, the evaluation of groundwater environmental values in the area enveloping the Project indicates that aquifers associated with the Tertiary, Permian, and coal seam sequences are of limited value for most uses. Groundwater associated with the alluvium is sporadic and seasonal and is not considered to provide sufficient (sustainable supply) in the Project area to allow for evaluation.

The recognised values include:

- Used for agricultural for limited stock watering
- Industrial purposes including coal mine operations.

To the limited extent that agriculture (grazing) use is occurring, the application of Part 3, Section 6 of the EPP (Water) the environmental values for suitability of groundwater within the Project area would mean that those agricultural uses would need to be enhanced or protected.

8.0 Proposed Mine Expansion

To allow for the assessment of potential groundwater impacts as a result of the Project, an assessment of the proposed mining activities were conducted.

8.1 Proposed Mine Plan

In order to identify potential impacts the proposed mining activities detailed in Section 1.1 and the conceptual mine plan, allowing for the extension of the Grevillea pit, were assessed.

The proposed mining plan was utilised in the predictive modelling to allow for an assessment of potential impacts. This is detailed in Section 11.0.

8.2 Potential Impacts

A summary of potential impacts of mining activities on the groundwater resources has been compiled based on the proposed mining activities.

8.2.1 Construction Phase

As the proposed mining activities are the extension of existing open cut operations, no construction phase activities or impacts are recognised.

It is envisaged that, on approval, the ongoing mining including prestripping and truck and excavator open-cast extraction methods will continue uninterrupted (i.e. move directly into the operations phase of mining), where mining strips are excavated in a perpendicular fashion to the dip of the coal thus maintaining a consistent coal/waste stripping ratio.

8.2.2 Operational Phase

The principal activities during the operational phase of the open-cut extension, which may impact groundwater resources, include:

- Dewatering of open cut pits.
- Overburden/interburden will be backfilled into the void where practicable or placed onto dumps and rehabilitated as part of the broader Saraji Mine strategy. There is currently one out-of-pit overburden dump west of Jacaranda Pit
- The management of the ephemeral Phillips Creek, through the extension of levees along the southern boundary of the Project site (which could result in alteration in surface water flow and possible increase or decrease of groundwater recharge).

Mine Dewatering

Dewatering may be required (dependent on strata permeability, influence of existing mine dewatering, and model predictions) to lower groundwater levels to the base of the proposed workings for safe and efficient operation of the open cut extension. As a result, groundwater levels will be drawn down during the operational phase.

Dewatering has the potential to reduce groundwater levels in existing groundwater bores that fall within the cone of influence of the proposed mine and hence has the potential to impact on existing groundwater supplies.

The dewatering impacts, outside the Project site, have been considered.

Indirect Impacts

The extension of the open cut mining may have some indirect dewatering impacts through induced flow, which include:

- Drawdown in the near-surface Tertiary and Quaternary-age units which are present adjacent to the open cut extension.
- Additional leakage from the overlying Permian units to the dewatered and depressurised target coal seams.

Creek Flow Impacts

Mine dewatering can result in drawdown of the coal seam potentiometric surface, which can extend beneath the Phillips Creek. Seasonal surface water flows and remanent pools in the creek may decline as a result of possible induced flow from the surface water to the groundwater, in response to the reduction in groundwater levels below the creek.

As a result this impact could potentially increase the period of no flow in the creek.

8.2.3 Post Closure

It is considered that on completion of the proposed open cut extension, the approved Saraji Mine workings will continue.

For the Project assessment the post closure phase considers the potential impacts on groundwater resources related to the partial backfilling of the open cut pits and the long-term impacts from final voids. Principally the reduced groundwater levels and alterations to the groundwater regime due to ongoing evaporation from final void areas.

Final voids can gradually fill with water once dewatering operations have ceased, potential evaporation losses from the voids are considered to exceed predicted groundwater inflow and hence the voids are expected to remain mainly dry, except following prolonged heavy rainfall events. In this case, ongoing evaporation from these voids will essentially act as long-term groundwater extractions from within the mine area, with the potential to permanently reduce groundwater levels to the base of proposed final voids.

9.0 Groundwater Modelling

A numerical groundwater model was constructed and partially calibrated during 2012 for BMA to assess the then proposed underground mining on the broader Saraji East mining lease application area. This 2012 model was the starting point for AECOM's modelling efforts as detailed in this report. AECOM has made refinements to the 2011 model in order to assess the potential impacts of the proposed open cut extension on the groundwater resources.

The modelling objectives were:

- asses the additional impacts of the proposed open cut extension considering the ongoing approved open cut mining
- determine drawdown of groundwater levels as a result of the proposed open cut mining
- predict groundwater ingress into the proposed open cut extension
- assess groundwater recovery and long term impacts occurring after cessation of the open cut mining.

9.1 Conceptual Model

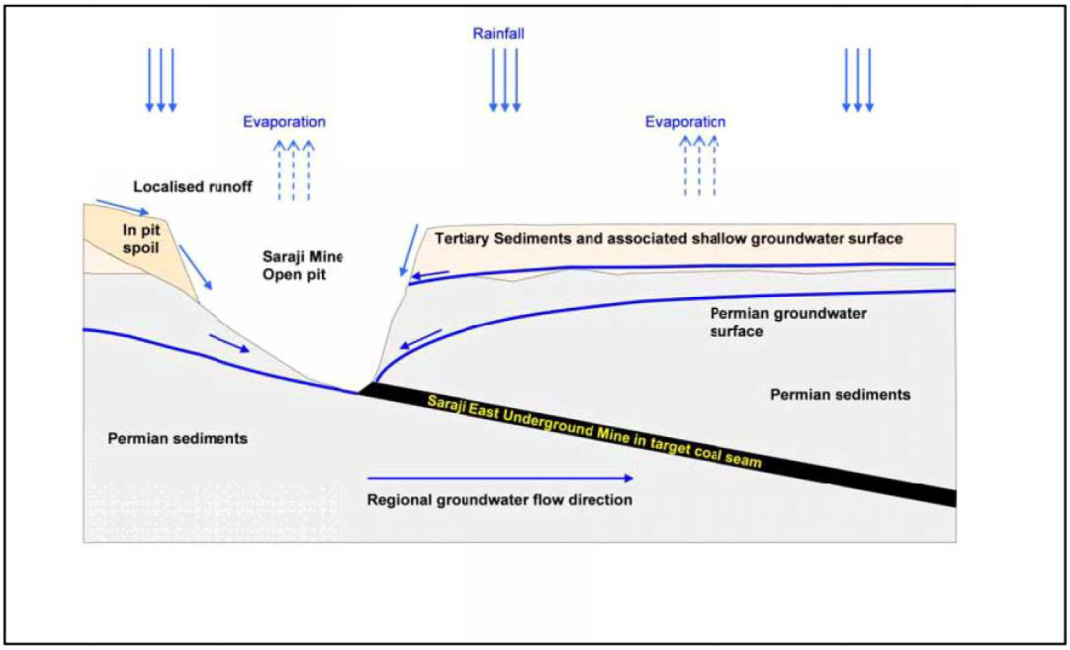
A conceptual groundwater model, which formed the basis of the numerical groundwater model, was compiled based on available hydrogeological data (AGE, 2012a).

The existing information and field data, as discussed in the sections above, were used to develop a conceptual understanding of the groundwater regime at the Project. The data used to develop the conceptualisation indicates two separate groundwater systems in the Project area, these include:

- localised basal sand and gravel at the base of the Tertiary sediments
- deeper Permian coal seam aquifers.

Figure 21 shows the hydrogeological conceptualisation at the Project site.

Figure 21 Conceptual Groundwater Model



Note: the coal in the Project site area is now proposed to be mined using open cut method not underground as was planned in 2012 across the Saraji East Mining Lease area

Source: AGE, 2012a.

The conceptualisation shows groundwater occurs:

- Locally at the base of the Tertiary sediments where more permeable sediments occur within the basal sands
- The piezometeric heads of the deeper saline coal seam aquifers hosted within the Moranbah Coal Measures, which include the target Harrow Creek and Dysart coal seams

Differences in groundwater levels measured in the Tertiary and deeper Permian aquifers indicate that there is limited hydraulic connection between these groundwater systems.

Recharge occurs from infiltration from the rainfall and creek flow into the Tertiary and Permian aquifer sub-crop areas. Minor leakage from overlying aquifers may occur but is not evident based on groundwater level data.

The regional groundwater levels are a subdued reflection of the surface topography except immediately adjacent to the open pit mine area where localised discharge / seepage into the pits results in the steeper gradients around the pits.

Regionally groundwater discharge within the deeper aquifers is complex based on the horst and graben structures within the Bowen Basin. Groundwater flow is considered to flow down dip from sub-crop to the east. Groundwater level data indicate lower groundwater levels to the east even though the permeability decreases with depth (Section 6.4.3) and the coal is truncated by faults. It is considered that faulting facilitates more complex groundwater movement to the east of the Project.

The development of the numerical model was based on the conceptual model (AGE, 2012).

9.2 Model Code

Numerical simulation of groundwater flow in the aquifers was undertaken using the MODFLOW SURFACT code Version 4 (Hydrogeologic Inc.), hereafter referred to as SURFACT. A commercial derivative of the standard MODFLOW code, SURFACT has some distinct advantages that are critical for the simulation of groundwater flow at the Project.

SURFACT is capable of simulating unsaturated conditions, which is critical for the requirements of the proposed mine where the coal seams are progressively dewatered during mining. SURFACT also supplies more robust numerical solution schemes to handle the more complex numerical problems resulting from the unsaturated flow formulation.

The MODFLOW pre- and post-processor PMWIN was utilised to generate some of the input files for the SURFACT model (AGE, 2012a).

9.3 Modelling Strategy

Modelling was undertaken in a number of stages as follows:

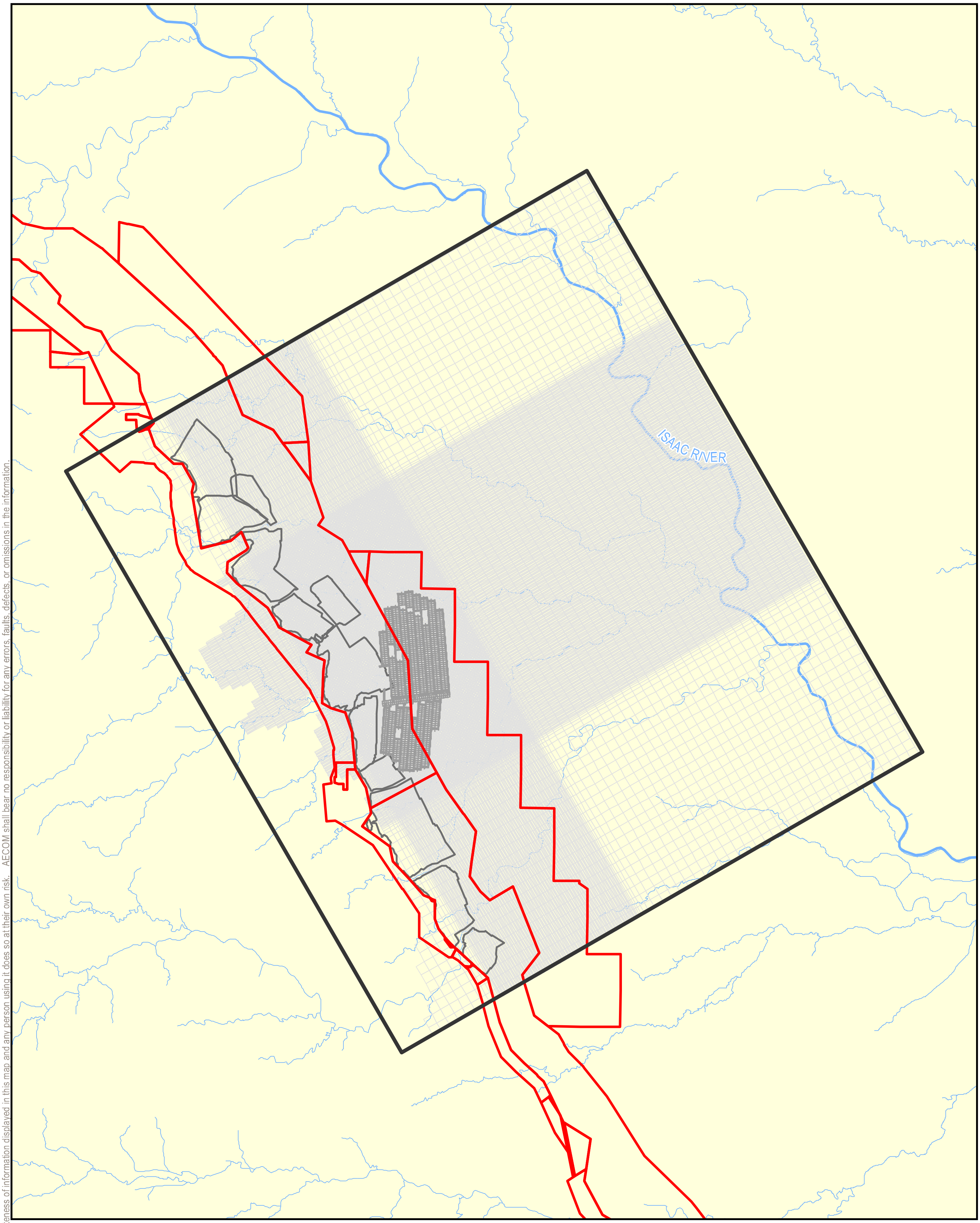
- review the existing SURFACT model
- assess existing data compiled since the model was constructed and calibrated in 2012, including additional mining, DNRM bore data, and groundwater monitoring
- revise the existing mining areas, pit depths, and backfill areas (from 2012 to 2016)
- include representative groundwater level data, identify corresponding model layers, and recalibrate the model (previous model root mean square error was 27%)
- revise the coal permeability with depth exponential formula to better represent the groundwater / piezometeric heads in the coal
- increase the model extent as the southern boundary was too close to the Saraji Mine open cuts to be mined 2017 to 2031 (two iterations as drawdown extends south due to deep pits)
- revise the model grid to reduce the cell sizes over the Project site (coarse grid size 500 m x 500 m in existing model)
- modelling predictions for the proposed open-cut extension, including:

- predicting groundwater drawdown with and without the Project after mining ceases in 2031
- estimate groundwater ingress into the open cut extension
- determine long-term groundwater levels and impacts post-mining
- consider cumulative impact of the Project and the existing approved Saraji Mine mining.

9.4 Model and Refinement

9.4.1 Model Geometry

The extent of the existing groundwater model is presented in Figure 22. The model domain comprised 73,698 cells aligned in 346 rows and 213 columns, ranging in size from 50 m x 50 m up to 500 m x 500 m.



LEGEND

- Watercourse
- Underground Mining Panel
- Model Boundary
- Model Mesh
- Existing Open-Cut Extent
- BMA Tenure / Tenement

Data sources:

1. Infrastructure, Tenements © BMA 2016 (RFI)
2. Watercourses © State of Queensland (Department of Natural Resources and Mines) 2016
3. Model Boundary from AGE 2012

N

Figure 22
AGE Model Boundary and Mesh (Source: AGE, 2012a)

Saraji Open Cut Extension Project
Environmental Assessment Report

0 1 2 4
Kilometres

Scale: 1:250,000 (when printed at A4)

Projection: Map Grid of Australia - Zone 55 (GDA94)

BHP Billiton Mitsubishi Alliance

DATE: 24/11/2016 VERSION: 0

Filename: \\aubne1fp003\Projects\605X\60507031\4. Tech Work Area\4.99 GIS\02_MXDs\04 Saraji OC Environmental Assessment Report\00 Technical Report\Groundwater\60507031_G049_v0_A4P.mxd

The model extent was 31 km x 34 km, covering an area of approximately 1,037 km^2.

The proposed mine plan (Section 8.0), which includes the approved mining at Saraji Mine, was recognised to extend to close to the southern model boundary (Figure 23), which could influence model predictions. AECOM extended the model domain a further 5 km to the south, resulting in the edge of the mine being 7 km from the original 2012 model boundary (Figure 24).

Figure 23 Existing Model Boundary and Saraji Mine Open Cut Workings to 2031

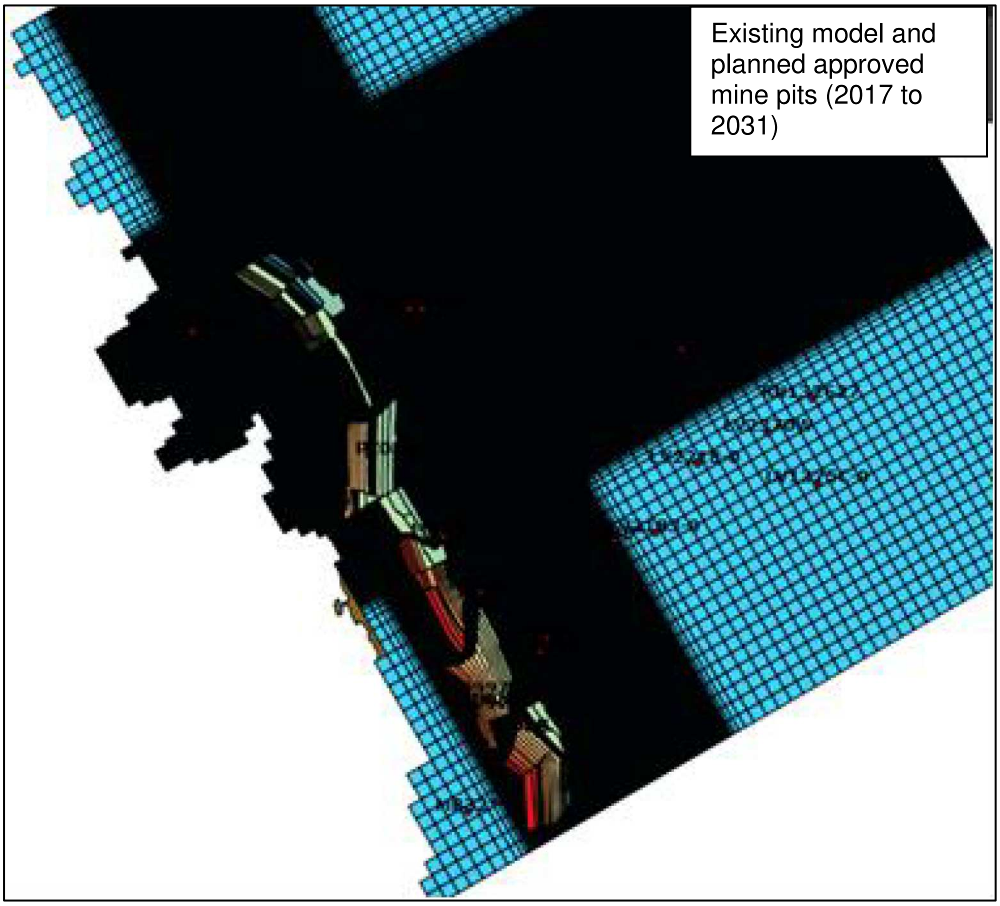
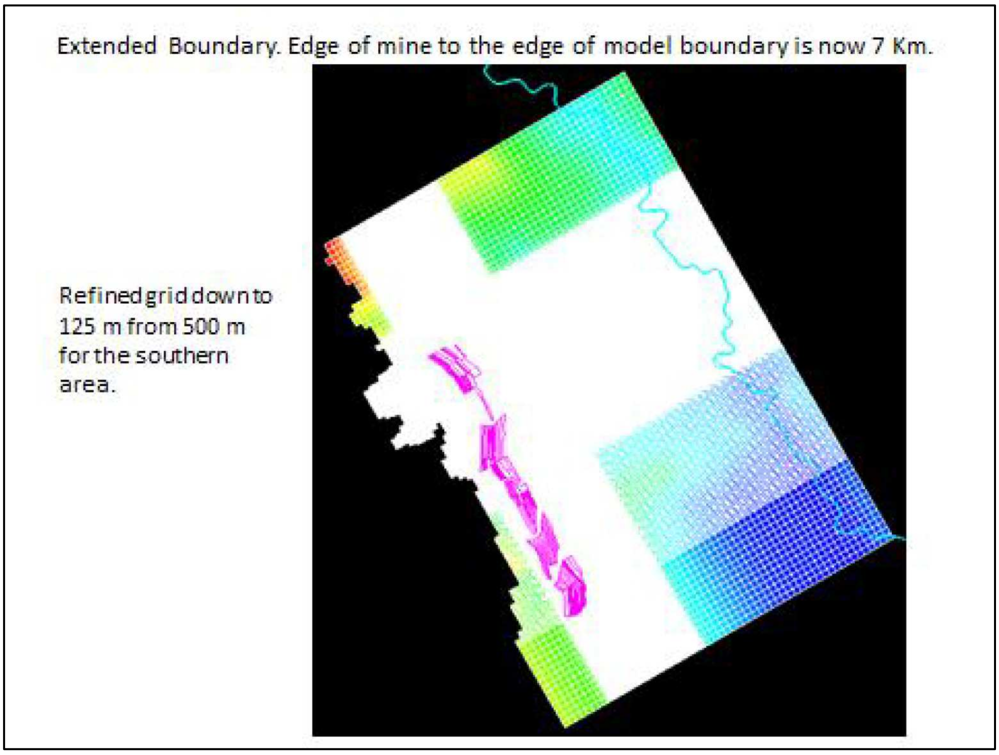


Figure 24 Revised Model Domain Extent



The model cells were recognised to be coarse (500 m x 500 m) in the Project area as the existing model aimed at assessing the proposed Saraji East underground workings and not the open cut extension to the south. The grid cells were reduced to 125 m in the southern area (Figure 24).

9.4.2 Model Boundaries

The eastern model boundary is roughly coincident with the Isaac River alignment. The Isaac (thrust) Fault alignment is located east of the Project (and west of the Isaac River), beyond which the model layers are abruptly disconnected as a result of the thrust fault displacement.

The western boundary is represented by the sub-crop alignment of the Back Creek Group, as defined by the regional geological mapping for the area. Cells located (west) outside this boundary have been excluded from the simulations as they are not representative of the geology in hydraulic connection with the mine site.

The major surface drainage alignment in the model area is the Isaac River which runs in a south-southeast direction close to the model's eastern boundary. Constant head boundaries were defined where the river enters and exits the model. This boundary condition assumes a fixed groundwater level for the entire period of simulation, allowing water to pass into and out of the model domain depending on the direction of flow defined by the relative groundwater levels in the adjoining portion of the model.

The north and south boundaries have been selected sufficient far from the approved and planned open-cut mining so as not to markedly influence model predictions.

Only the model boundary to the south has been altered in the refined model, as detailed in Section 9.4.1.

With the exception of the constant head boundaries, the numerical model domain has an inactive or "no flow" boundary at the active model extent and at the base of Layer 11 in the model (Section 9.4.3).

9.4.3 Model Layers

The structure of the coal seams within the Project comprises a Permian sequence overlain by a surficial covering of Tertiary and Alluvium (in places) sediments. The Permian rocks form a regular layered sedimentary sequence which was simplified for the numerical model by merging several formations / strata into model layers. This is most evident when considering the overlying Permian coal measures, where coal seam aquifers and interburden aquitards are considered as one hydrogeological model layer. This is a conservative approach allowing for higher vertical hydraulic conductivity than can be expected associated with the interburden aquitards.

The target coal seams are included preserving the measured thickness to ensure the transmissivity of these seams.

The thickness and extent of the model layers within the model domain were interpreted from geological surfaces provided by BMA. The refined model extended the model layers into the extended model domain to the south.

A minimum value of 1 m was applied to the layers that subcrop beneath the Tertiary sediments (Layer 1). This minimum thickness then extends westwards to the model's western boundary to ensure continuity of the respective layer within the model domain for modelling purposes.

The model consists of 11 layers as summarised in Table 13.

Table 13 Model Layers

Model Layer	Hydro-stratigraphic unit	Model Layer Thickness	
1	Tertiary sediments	Variable	1 to 35 m
2	FCCM overburden	Variable	1 to 240 m
3	MCM overburden	Variable	1 to 760 m
4	P02 coal seam	Uniform	3.5 m
5	MCM interburden	Variable	1 to 10 m
6	Harrow Creek (H16) coal seam	Variable	1 to 10 m
7	MCM interburden	Variable	1 to 90 m
8	Harrow Creek (H15, H19) coal seam	Uniform	3.3 m
9	MCM interburden	Variable	1 to 86 m
10	Dysart Lower (D14, D24) coal seam	Variable	1 to 15 m
11	Back Creek Group	Uniform	20 m

It is noted that alluvium is not laterally or vertically extensive across the model domain; as such it was included within Layer 1 as a separate zone but not as a separate layer.

No refinement of the model layers or thicknesses was necessary in the refined model.

9.4.4 Hydraulic Parameters

Field permeability testing was adopted as a starting point for the calibration of the existing groundwater model. Where little or no site specific hydraulic parameter data was available, for the alluvium and Tertiary sequences, parameters were adopted from previous experience within the Bowen Basin.

The reducing hydraulic conductivity of the coal seams with depth (Section 6.4.3) was used for the Harrow Creek and Dysart coal seams.

The model layer parameters were refined during the AGE calibration process. These model layer parameters were further refined during the AECOM model calibration (Section 9.5.3).

9.4.5 Recharge and Discharge

The recharge rate was varied across the model, determined during the model calibration, where a rate of recharge was calibrated at 1.43 mm/year for the Quaternary alluvium (0.2% of the mean annual rainfall) and 0.89 mm/year for the rest of the model domain (0.13% of mean annual rainfall).

The rainfall recharge was refined during the calibration of the refined model (Section 9.5).

Surface discharge of groundwater was included in the existing model using the SURFACT river (RIV) package in model Layer 1. The RIV package compares the water level in the aquifer against a reference river depth level, whereby if the aquifer water level is above the reference level then water is removed at a rate specified by the river bed conductance. The river elevations (reference levels) were set to between 1 and 5 m below the ground surface elevations.

Groundwater inflow to the mine workings was modelled using the SURFACT Drain (DRN) package by setting open pit drain cells at the base of the pit for all layers within the pit.

9.5 Model Calibration

The existing groundwater model was calibrated to 25 water level measurements determine to be representative of water levels prior to mining (i.e. pre-1974). The model calibration considered the relatively low rainfall and high evaporation and tried to obtain a representative simulation of observed versus simulated (modelled) steady-state groundwater levels.

The resultant statistics of the calibration, looking at the error between the modelled and observed (measured) water levels, indicated a root mean square error 25.7 m, a scaled root mean square error (SRMS) of 27%.

This SRMS error was recognised as high and AECOM conducted additional calibration, using additional registered bore water levels and groundwater monitoring data compiled since the existing model was constructed and calibrated.

9.5.1 Model Changes

Prior to model calibration AECOM had to revise the existing model to represent 2016 conditions, which included extending the backfill areas from the areas covered in the 2012 existing model to match the current extent of mining at Saraji Mine, including updating the extent of backfilling.

In addition, the depths of the existing pits had to be increased from their locations in the 2012 model to 2016 depths. This was estimated based on 2020 landform data obtained from BMA and the 2012 model mine details. Pit depths and locations were estimated and included in the refined model.

Water levels in the pits (Table 14) were included in the model to aid with simulating current 2016 groundwater conditions on site during the calibration process.

Table 14 Saraji Mine Pit Water Storages (02/11/2016)

Saraji Water Storages	Easting	Northing	Current Level (mAHD)	Pit Floor (mAHD)	Current Depth (m)
Ramp 17	631642	7529400	161.26	102.60	58.66
Ramp 0	629717	7529060	160.11	114.90	45.21
Ramp 1	630610	7528380	160.11	109.10	51.01
Ramp 1A	631668	7527290	117.26	96.50	20.76
Ramp 6	633315	7523320	184.20	138.00	46.20
Ramp 8N	633296	7521600	180.47	121.40	59.07
Ramp 8S	634202	7520710	93.50	75.10	18.40

9.5.2 Calibration Statistics

Representative groundwater level data[4] were compiled across the area containing the Project. These water levels were assigned to the relevant model layers, based on bore depths and model elevations. The bores, observed (measured) water levels, simulated waters and model layers are included in Table 15.

The bore locations are included in Figure 10.

[4] Groundwater levels collected from correctly constructed bores, screened across one known aquifer

Table 15 Refined Model Groundwater Level Data

Well	Easting	Northing	Observed Water Level (mAHD)	Layer	Calibrated Water Level (mAHD)
MB32*	637481	7510535	197.73	1	197.7798
MB33*	636640	7520199	172.83	2	170.2456
MB34*	637926	7518269	172.51	3	168.12
MB35*	642646	7520110	166.87	2	165.1977
MB36*	640150	7514283	178.97	2	176.0876
PZ06A	639272	7513326	185.90	2	182.7568
PZ06B	639272	7513326	179.60	3	182.7553
PZ06C	639272	7513326	183.40	7	183.2552
PZ08A	634647	7523069	177.60	4	178.0589
PZ08B	634647	7523069.	173.60	5	176.2955
RN132627	649564	7525028	141.29	2	152.7143
RN122458	644983	7526770	149.11	2	160.9717
RN132631	635440	7528179	156.88	9	165.7325
LV2370W	648037	7523878	157.70	1	155.7693
32924	638285	7514125	182.10	7	177.2417
42182	637746.01	7514257.15	182.07	7	175.9728
49997	637879.32	7514634.56	176.36	2	182.1012
PC056	640288.25	7516655.39	174.00	3	169.1632
PC058XC	640054.66	7516179.31	173.98	3	170.3148

The refined model calibration indicates that a SRMS error of 9.5%, which is considered sufficient fit for purpose. In addition, the mean error is only -0.42, which is close to 0 indicating minimal bias in the model.

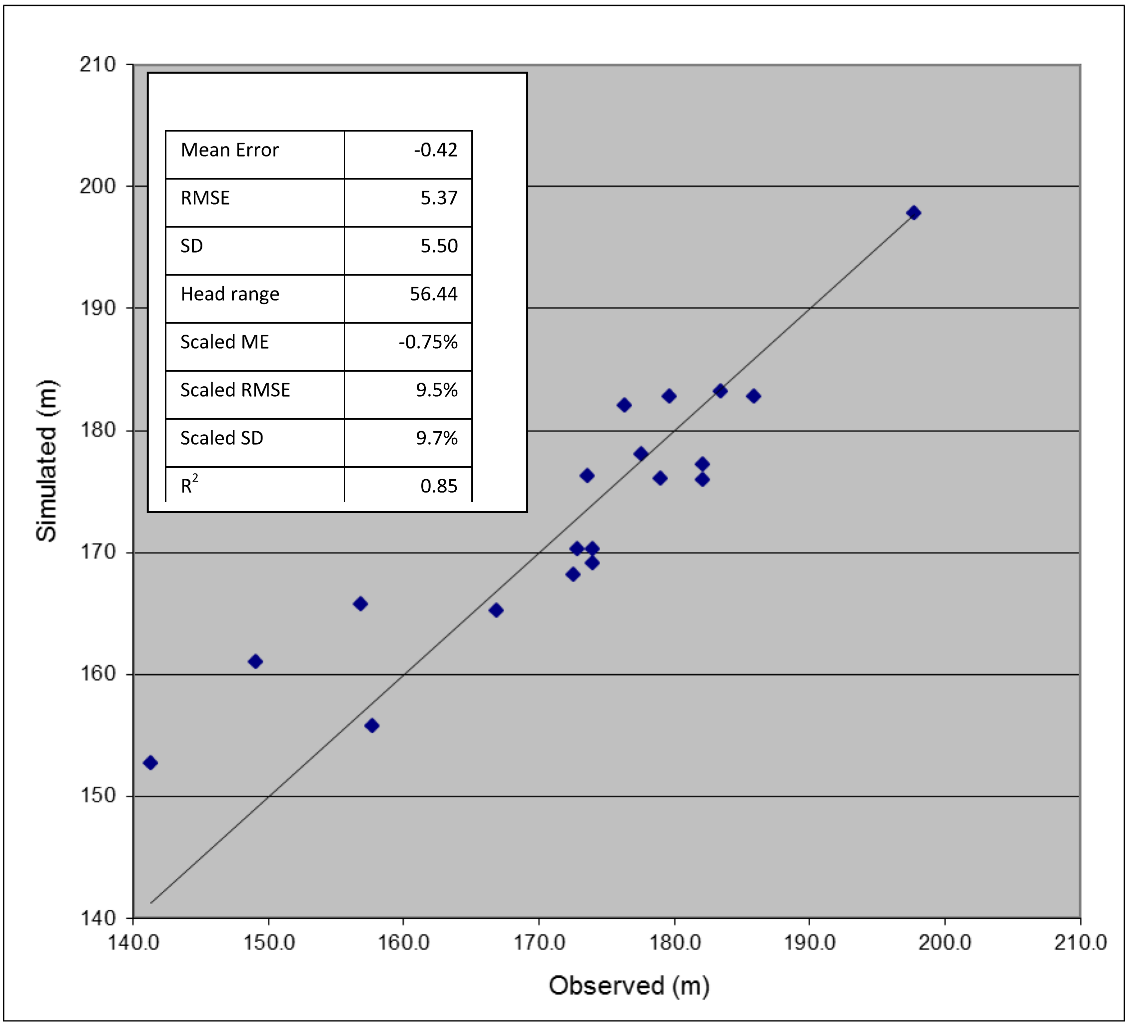
The groundwater flow model is considered a Class 2 model (Barnett et al, 2012) based on the model confidence level classification presented in the Australian Groundwater Modelling Guidelines. The calibration statistics are reasonable and the model is considered suitable for predicting impacts on medium value aquifers, providing estimates of dewatering requirements and associated impacts.

Figure 25 provides the graph of observed versus modelled groundwater levels and the calibration statistics.

The difficulty with achieving more accurate calibration includes:

- long term mining (since 1974) in the area
- complex heterogeneity and simplified representation of strata and permeability
- representativeness of the “snap-shot” water levels selected for calibration
- poor bore logs possibly resulting in incorrect model layer assignment
- possible compartmentalisation due to faulting.

Figure 25 Refined Model Statistics



9.5.3 Hydraulic Conductivity

The model calibration allowed for the refinement of hydraulic conductivity values in each model layer and spatially across the model domain.

The backfill areas, extended from 2012 to 2016, have a uniform hydraulic conductivity of 0.1 m/day in each model layer except the basement model layer, Layer 11.

The hydraulic conductivity values for Layer 1 (Figure 26**)**, which includes high permeability associated with the **I**saac River alluvium.

Layer 2, the Fort Cooper Coal Measures is represented as a single thick layer with a uniform hydraulic conductivity of 0.025 m/day (Figure 27).

The hydraulic conductivity distribution in the MCM non-coal bearing overburden, above the target coals (model layers 3 and 5) were calibrated to be low, 0.001 m/day (Figure 28).

Figure 26 Hydraulic Conductivity (k) Distributions in Layer 1

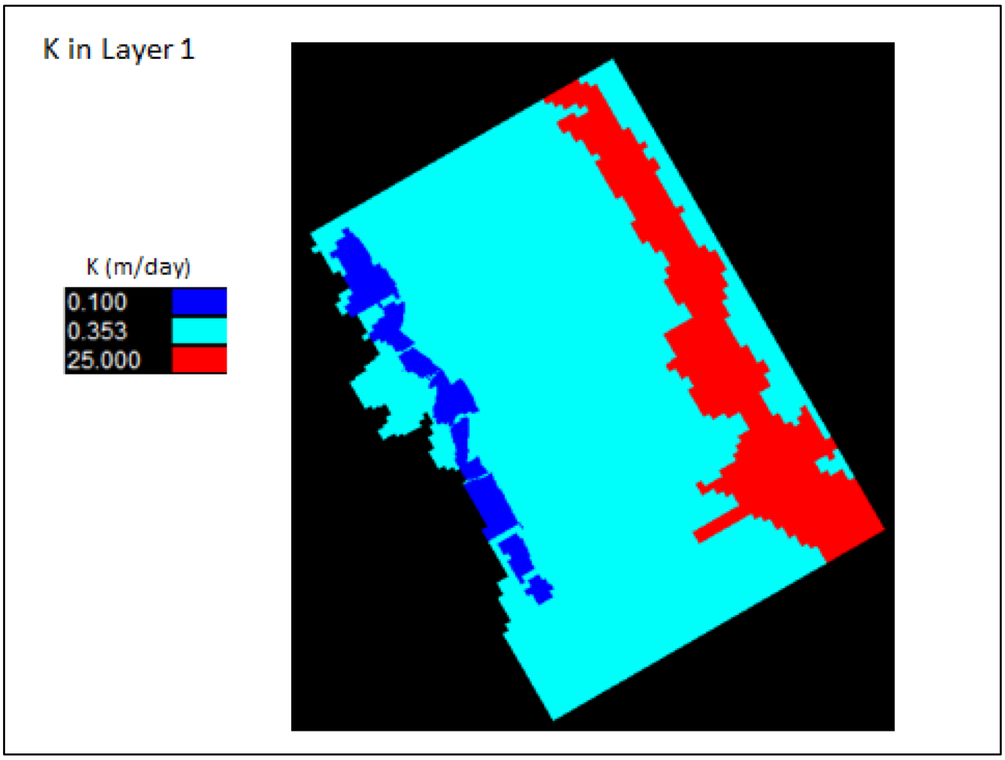


Figure 27 Hydraulic Conductivity (k) Distributions in Layer 2

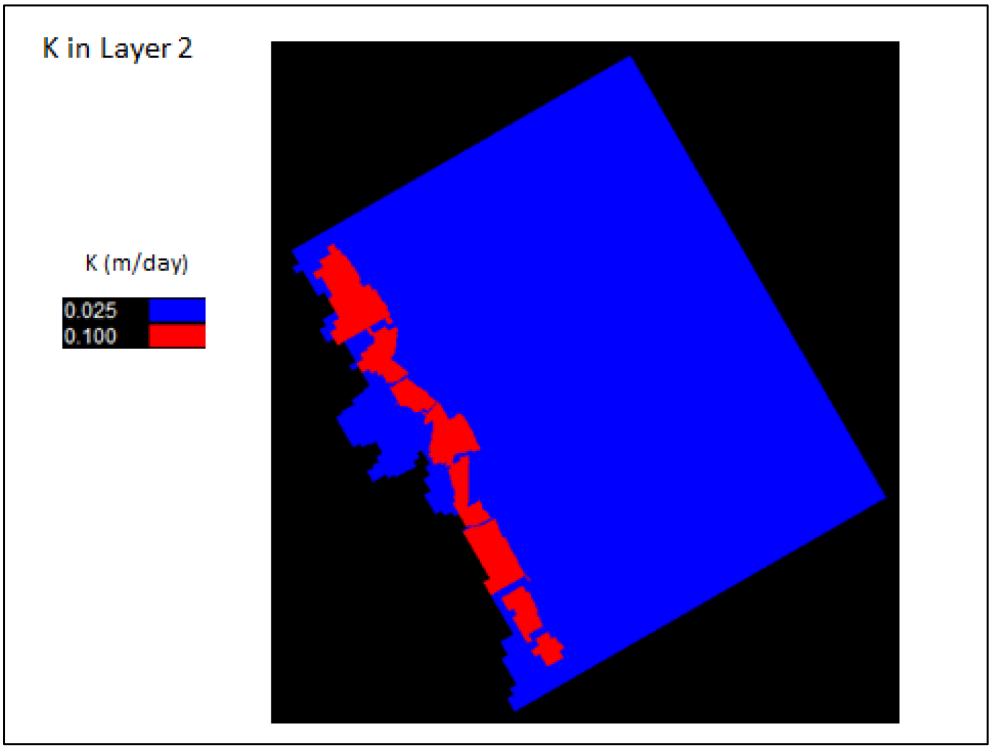
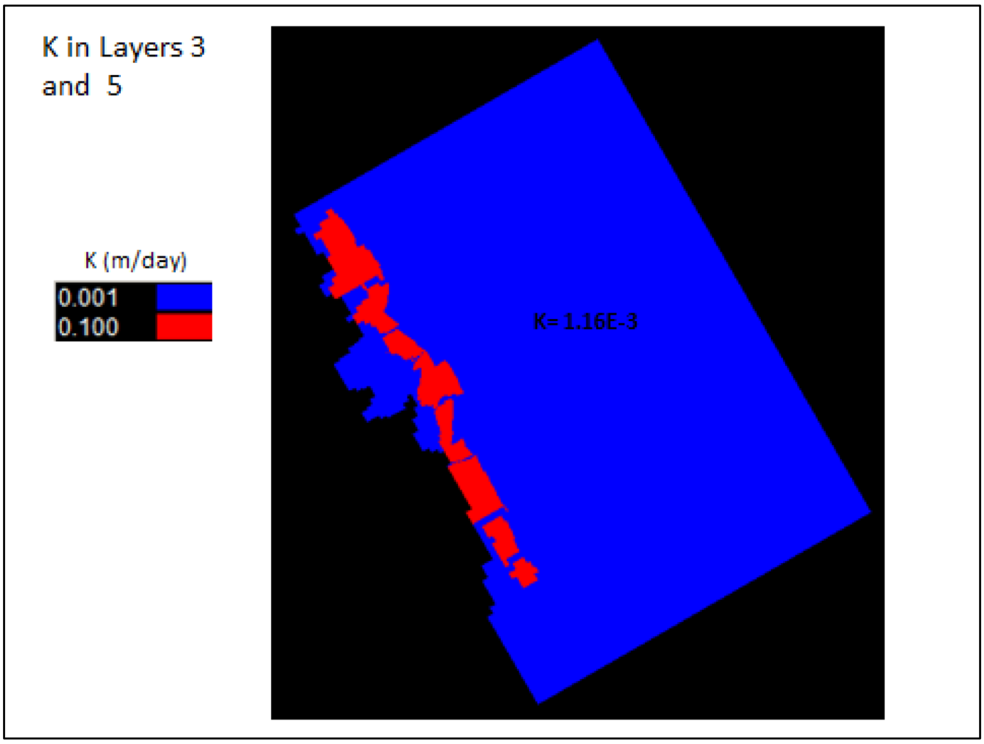


Figure 28 Hydraulic Conductivity (k) Distributions in Layer 3 and 5



The calibration process, using the automatic calibration software package Parameter External Software Tool (PEST) (Doherty et al, 1994), included the revision of the exponential equations related to reducing hydraulic conductivity of the coal seams with depth. Modelling included developing and including algorithms to allow for the variation of hydraulic conductivity within the coal seams.

The exponential equation, used for coal layers 4 (P02 coal), 6 (H16 coal), and 8 (H15, H19 coal) in the existing model, was:

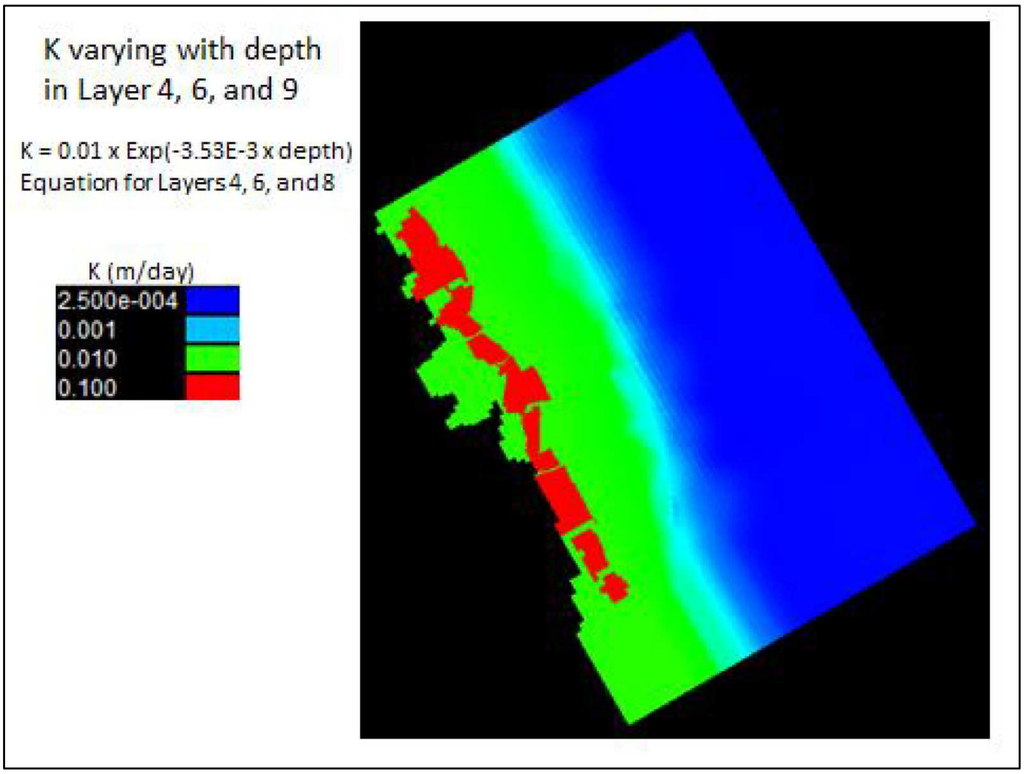
- Harrow Creek Horizontal Hydraulic Conductivity (k) = 0.045919 x $e^{-0.016 \text{ x depth}}$

The refined model included a revised exponential equation for layers 4, 6, and 8. The equation is:

- Harrow Creek Horizontal Hydraulic Conductivity (k) = 0.01 x $e^{-3.53E-3 \text{ x depth}}$

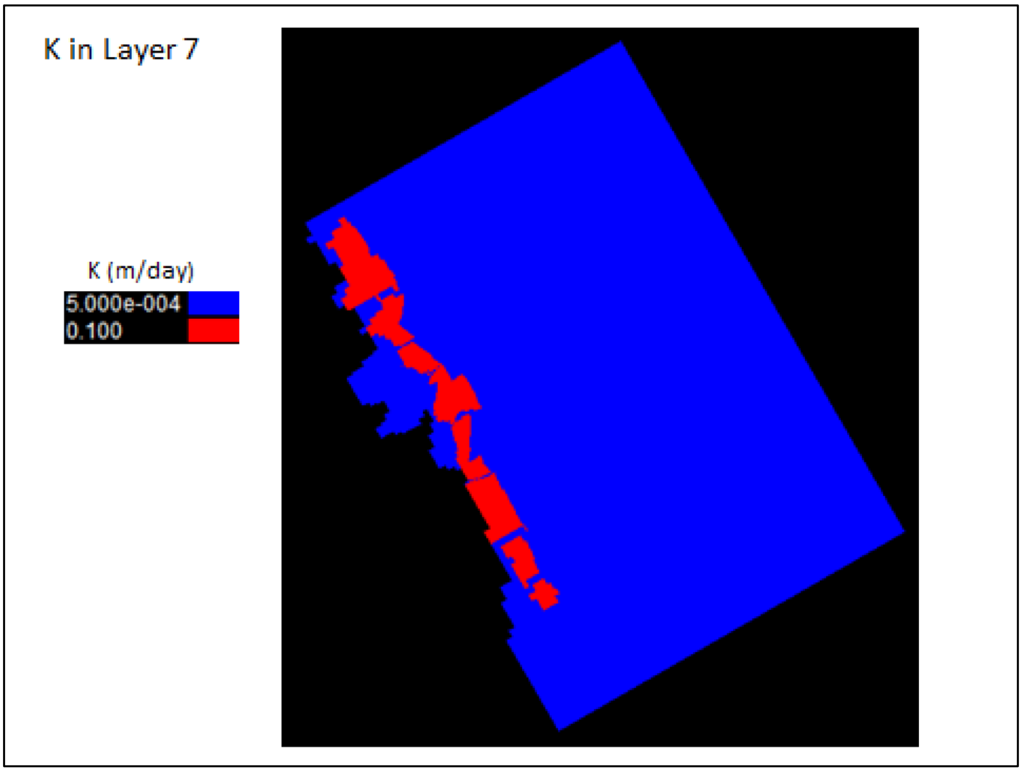
The resultant distribution of horizontal hydraulic conductivity across layers 4, 6, and 8, is presented in Figure 29.

Figure 29 Hydraulic Conductivity (k) Distributions in Layer 4, 6, and 8



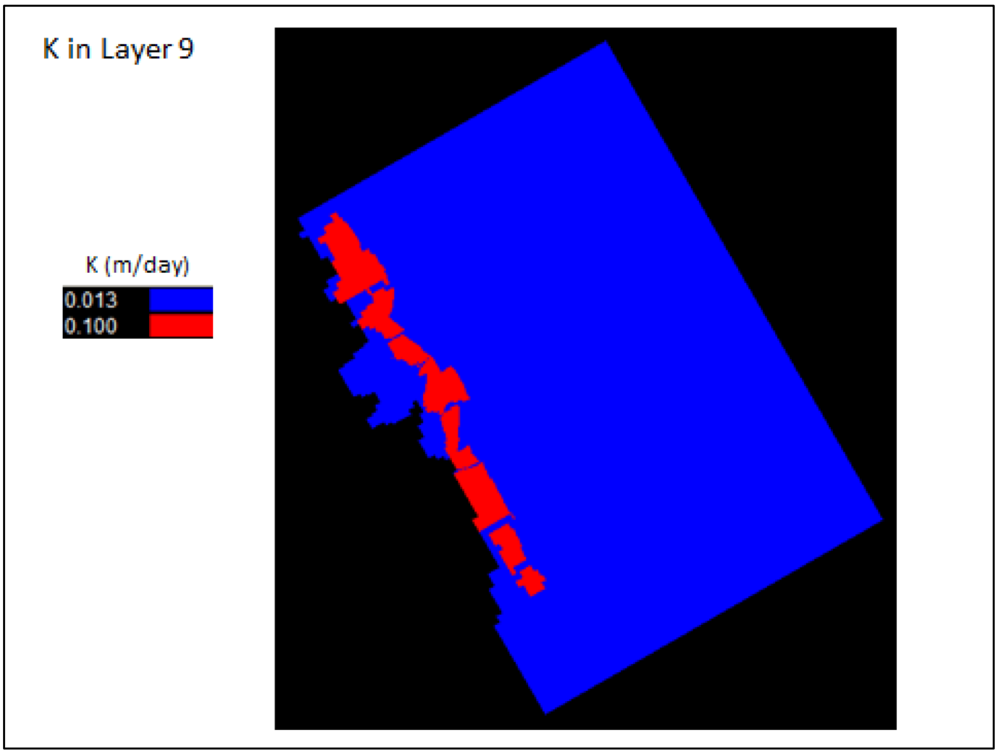
The hydraulic distribution for model Layer 7, as determined through the calibration process is presented in Figure 30.

Figure 30 Hydraulic Conductivity (k) Distribution in Layer 7



The hydraulic distribution for model Layer 9, MCM interburden above the Dysart coal, as determined through the calibration process is presented in Figure 31.

Figure 31 Hydraulic Conductivity (k) Distribution in Layer 9



The exponential equation, used for Layer 10 (the Dysart coal seam) in the existing model, was:

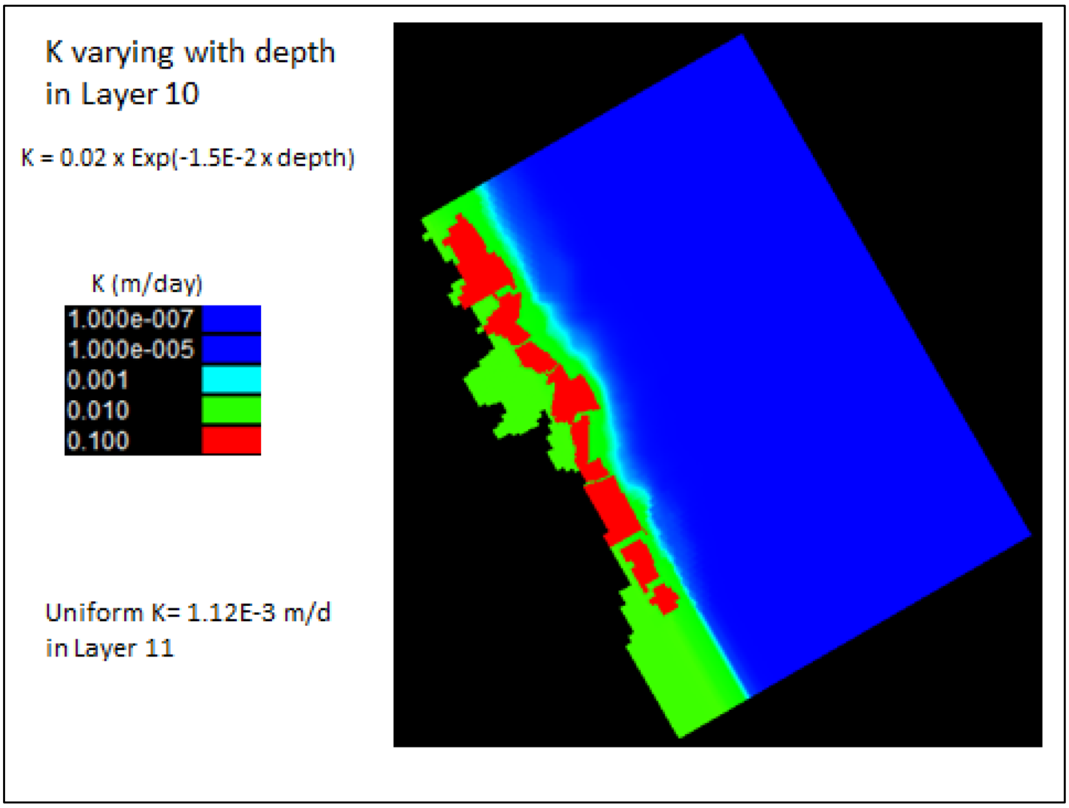
- Dysart Horizontal Hydraulic Conductivity (k) = 0.006499 x $e^{-0.0104 \times depth}$

The calibration of the refined model includes the revision of this exponential equation, which was:

- Dysart Horizontal Hydraulic Conductivity (k) = 0.02 x $e^{-1.5E-2 \times depth}$

The resultant hydraulic conductivity distribution for Layer 10 is presented in Figure 32.

Figure 32 Hydraulic Conductivity (k) Distributions in Layer 10

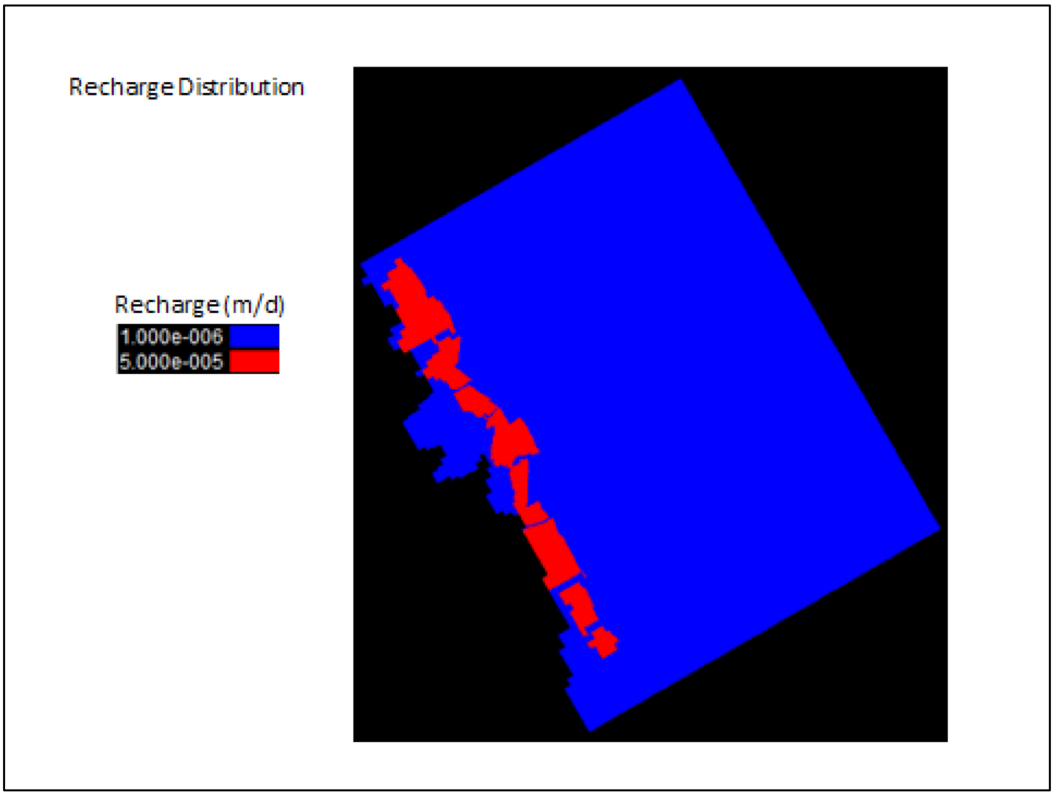


Uniform hydraulic conductivity of 0.001 m/day was adopted for the basement (Back Creek Group) model layer, Layer 11.

9.5.4 Recharge

During the steady-state calibration hydraulic conductivity and recharge parameters in the model were varied, within site specific ranges. The calibrated refined model included two zones of recharge, one associated with the backfill and the other a uniform recharge across Layer 1 (Figure 33).

Figure 33 Recharge Distribution



9.5.5 Calibrated Model Parameters

Table 16 presents the model layer parameters after steady state calibration of the refined groundwater model.

Table 16 Model Parameters

Layer	Unit	Kx	Calibrated	Min	Max	Kz	Calibrated
1	Alluvium	K1x	2.50E+01	1.00E+00	3.50E+01	K1z	2.50E-01
	Tertiary/Quaternary deposits	K2x	3.53E-01	1.00E-01	5.00E-01	K2z	3.53E-02
	Backfill	K3x	1.00E-01	1.00E-02	1.00E+00	K3z	1.00E-02
2	Overburden	K2ax	2.49E-02	1.00E-04	1.00E-01	K2az	2.49E-03
	Backfill	K3x	1.00E-01	1.00E-02	1.00E+00	K3z	1.00E-02
3,5	Interburden	K4x	1.16E-03	1.00E-04	1.00E-02	K4z	1.16E-05
	Backfill	K3x	1.00E-01	1.00E-02	1.00E+00	K3z	1.00E-02
4,6,8	Coal seam (K varying with depth)		K= 0.01*Exp(-3.53E-3*depth)				Kz/Kx=0.02
	Backfill	K3x	1.00E-01	1.00E-02	1.00E+00	K3z	1.00E-02
7	Interburden		5.00E-04	1.00E-05	5.00E-02		5.00E-06
	Backfill	K3x	1.00E-01	1.00E-02	1.00E+00	K3z	1.00E-02
9	Interburden	K9x	1.28E-02	1.00E-04	5.00E-02	K9z	1.28E-04
	Backfill	K3x	1.00E-01	1.00E-02	1.00E+00	K3z	1.00E-02
10	Coal seam (K varying with depth)		K= 0.02*Exp(-0.015*depth)				Kz/Kx=0.02
	Backfill	K3x	1.00E-01	1.00E-02	1.00E+00	K3z	1.00E-02
11	Interburden	K4x	1.16E-03	1.00E-04	1.00E-02	K4z	1.16E-05
	Recharge on Backfilled area	Rch1	1.00E-06	1.00E-06	6.00E-05		
	Recharge ouside Backfilled area	Rch2	5.00E-05	1.00E-06	1.82E-05		
	Drain conductance for pits (Steady State)		1.05E-02	1.00E-03	5.00E+02		

Where: K_x = Horizontal hydraulic conductivity and K_z is the vertical hydraulic conductivity

For the prediction modelling storage values for Specific Yield (S_y) and Storativity (S_c) were included in the model, as presented in Table 17.

Table 17 Storage Coefficients

Layer	Unit	Sc	Sy
1	Alluvium	1.00E-03	0.1
	Tertiary/Quaternary deposits	2.00E-04	4.00E-03
	Backfill	1.00E-03	0.1
2	Overburden	2.00E-04	4.00E-03
	Backfill		
3,5,7,9	Interburden	2.00E-04	4.00E-03
	Backfill		
4,6,8	Coal seam (K varying with depth)	5.00E-05	2.00E-03
	Backfill		
10	Coal seam (K varying with depth)	5.00E-05	2.00E-03
	Backfill		
11	Interburden	2.00E-04	4.00E-03

Note: These base case parameters were used to provide an assessment of the most probably groundwater impacts, related to groundwater ingress and drawdown cone extent.

9.6 Model Water Budget

The model water budget for the refined groundwater model was assessed to:

- ensure the converged solution was adequately conserving mass during the simulation
- to assess water movements in and out of the model domain

The mass balance error, which is the difference between the calculated model inflows and outflows at the completion of the calibration, was 0%. This indicates an accurate numerical solution and overall stability of the model and is below the Class 2 model indicator of 1% error (Barnett et al, 2012).

Table 18 presents the model water balance for the steady state simulation.

Table 18 Calibrated Steady State Refined Model Water Budget

Component	Rate for Simulation (m^3/day)
IN	
Constant Head	0.067
Drains	0.00
Recharge	3,982.41
River Leakage	0.00
TOTAL IN	**3,982.48**
OUT	
Constant Head	1,084.99
Drains	1,916.14
Recharge	0.00
River Leakage	983.63
TOTAL OUT	**3,984.76**
IN - OUT	-2.28
Percent Discrepancy	0.0%

10.0 Predictive Simulations

The refined and calibrated predictive groundwater model was utilised to assess potential impacts of the proposed Project on groundwater resources. The model predictive simulations included:

- An evaluation of groundwater level drawdown, in the target coal seams and overlying Tertiary and Quaternary sediment, as a result of the proposed open cut mining. The modelling included the prediction of groundwater levels after mining operations at the end of 2031 for the approved Saraji Mine operations with and without the Project (the extension of the open cut mining at Grevillea pit).
- The prediction of groundwater ingress into the approved Saraji Mine operations with and without the Project, allowing for the estimate of groundwater ingress into the extension of the open cut.
- The prediction of groundwater level recovery and long term groundwater contours after cessation of the open cut mining, with and without the Project.

10.1 Groundwater Level Drawdown

The initial (2016) groundwater levels included in the groundwater model and used in the model calibration, are included in Figure 18 and Figure 19. These groundwater levels provide data for model Layer 1 (Tertiary and Quaternary cover) and Layer 6 (H16 coal seam), respectively.

The groundwater model was used to simulate the changes in these initial groundwater levels in response to the proposed mine plan. The mine plan was divided into 3 month intervals to allow for 60 time steps over the 15 year life of Project. Backfilling of the open pits occurs after one year, allowing for the change in model layer parameters, as detailed in Table 16.

Including Project Scenario

Groundwater contours, based on meter drawdown from initial groundwater levels, were generated for the end of 2031 for model Layer 1, Layer 6, and Layer 10 (Dysart Lower (D14, D24) coal seam). The drawdown contours, backfill areas, and mine plan for the approved Saraji Mine and the proposed Project are included in Figure 34 (Layer 1), Figure 35 (Layer 6), and Figure 36 (Layer 10). The drawdown figures include the mine plan layout for reference.

Figure 34 Predicted Groundwater Drawdown in Layer 1 in 2031 (approved and proposed mining)

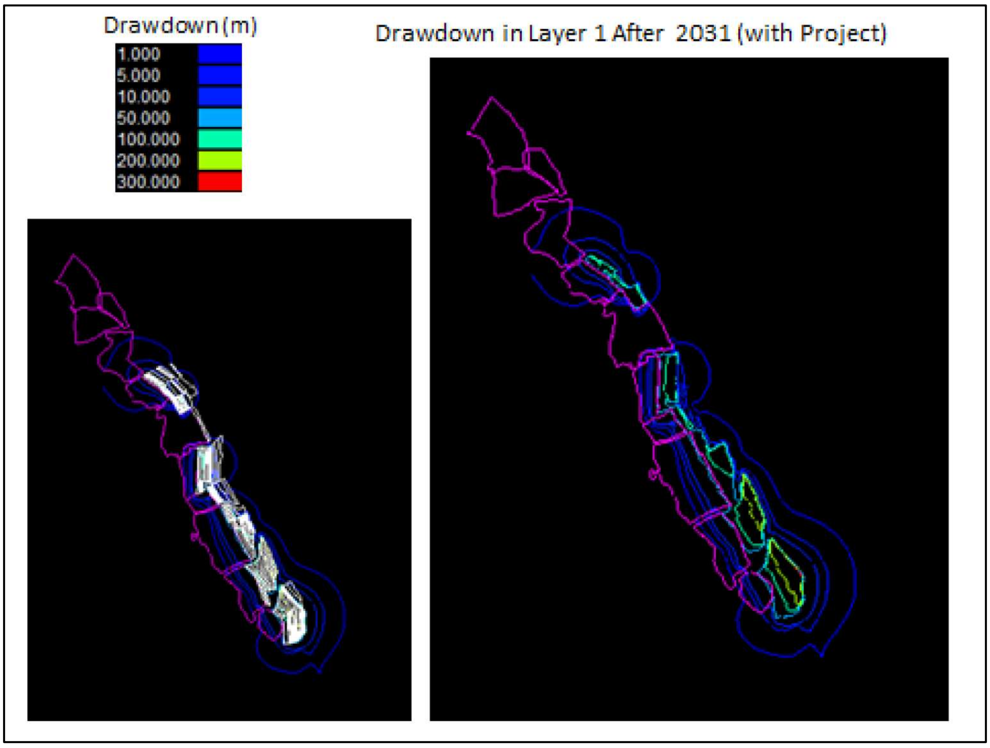


Figure 35 Predicted Groundwater Drawdown in Layer 6 in 2031 (approved and proposed mining)

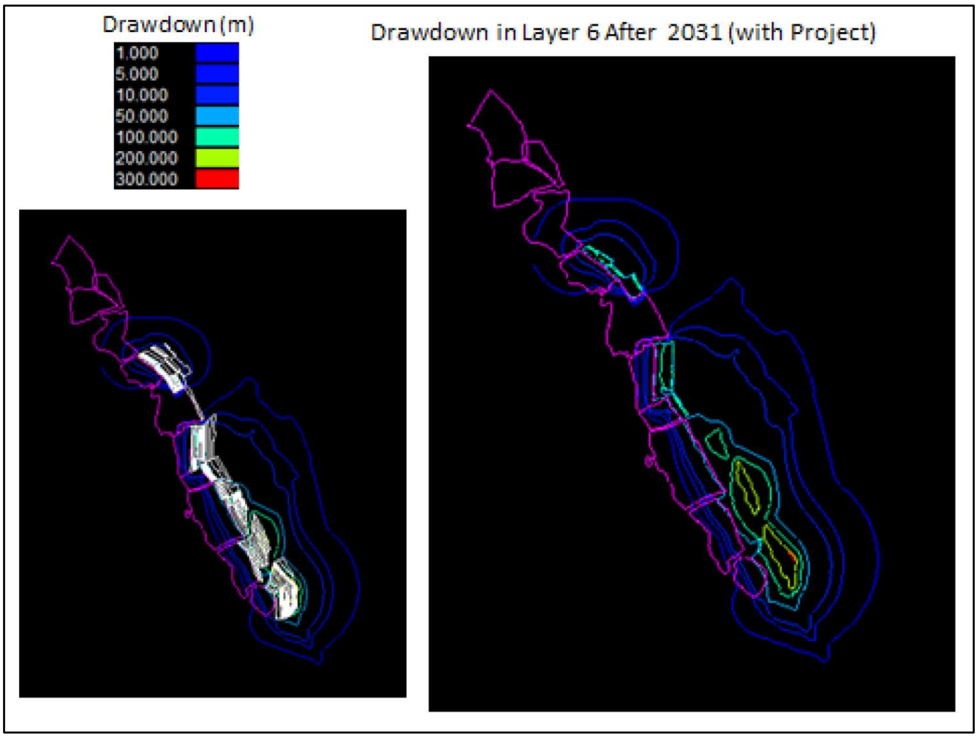
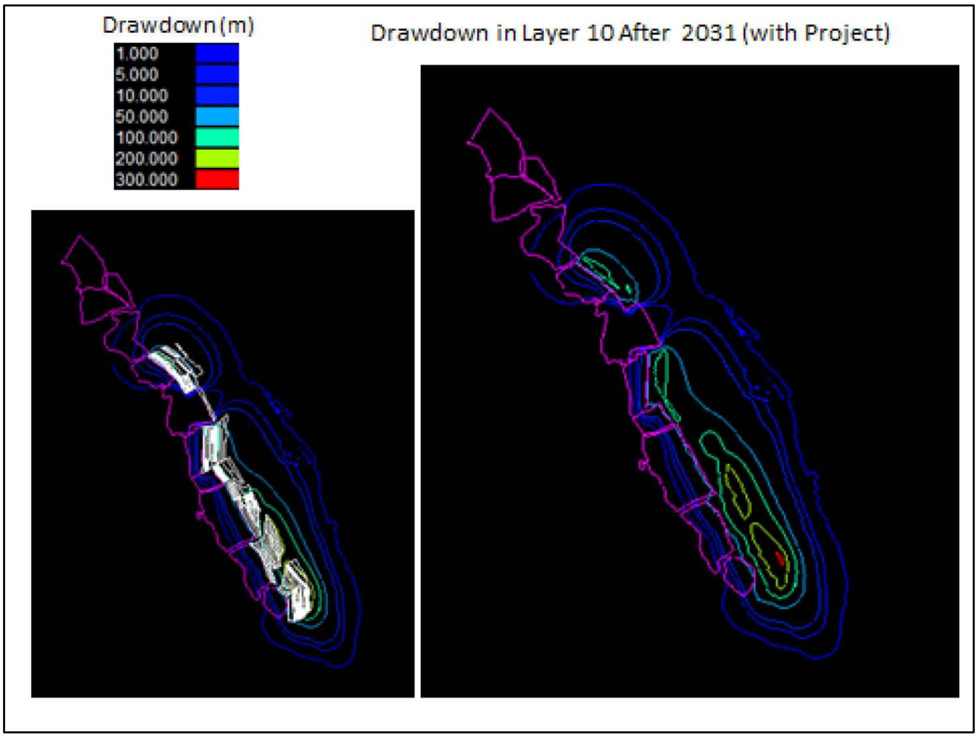


Figure 36 Predicted Groundwater Drawdown in Layer 10 in 2031 (approved and proposed mining)



The largest cumulative groundwater drawdown (in the Dysart target coal seams), based on the predicted 1 m change in groundwater levels, is predicted to extend as follows at the end of 2031:

- approximately 3,900 m to the east opposite the Project site
- approximately 29,400 m north south (a continuous 1m drawdown contour).

The predicted cumulative groundwater drawdown (1 m change), Saraji Mine and the Project, for the target H16 coal seam at the end of 2031 is estimated to include:

- approximately 4,500 m to the east opposite the Project site
- approximately 7,000 m north south (associated with the northern pits)
- aproximately 19,000 m north south (associated with the southern pits)

It is noted that the drawdown cones associated with the H16 seam do not overlap due to low permeability in the strata.

The cumulative drawdown (1 m variation from initial heads) predicted in the overlying Tertiary sediments (Layer 1) include:

- approximately 1,100 m to the east opposite the Project site
- approximately 7,000 m north south (associated with the northern pits)
- approximately 19,000 m north south (associated with the southern pits).

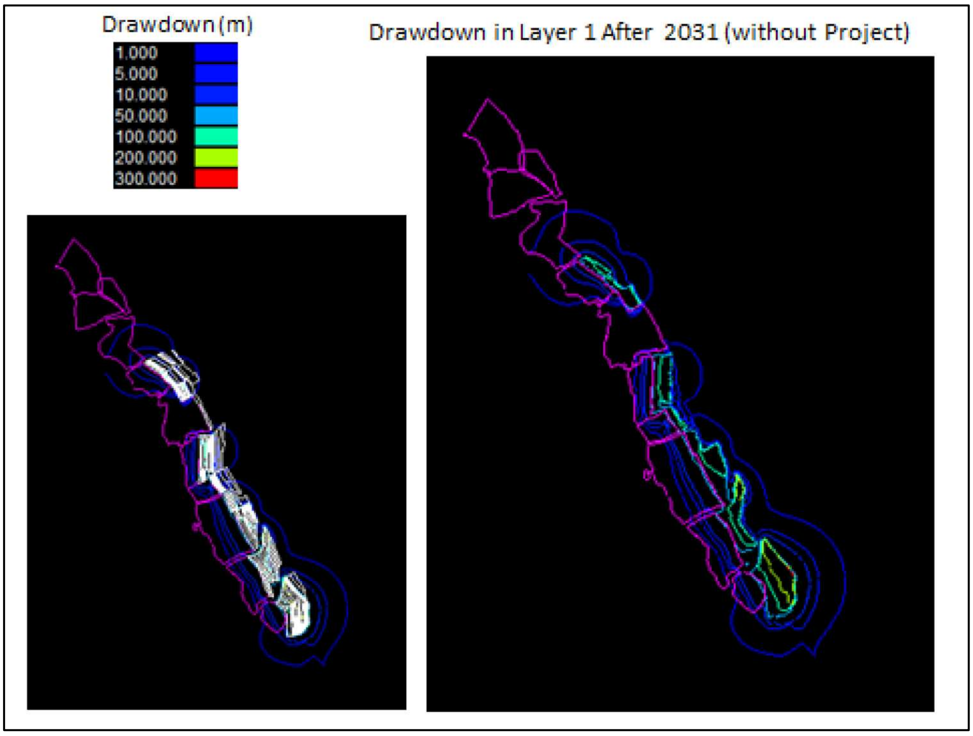
The drawdown in the Tertiary is also recognised to occur as two separate drawdown cones.

Without Project Scenario

Groundwater contours, based one metre drawdown from initial groundwater levels, were generated for the end of 2031 for model Layer 1, Layer 6, and Layer 10 for the approved Saraji Mine excluding the Project

Figure 37 (Layer 1), Figure 38 (Layer 6), and Figure 39 (Layer 10) provide the predicted drawdown contours for this modelling scenario.

Figure 37 Predicted Groundwater Drawdown in Layer 1 in 2031 (approved mining only)

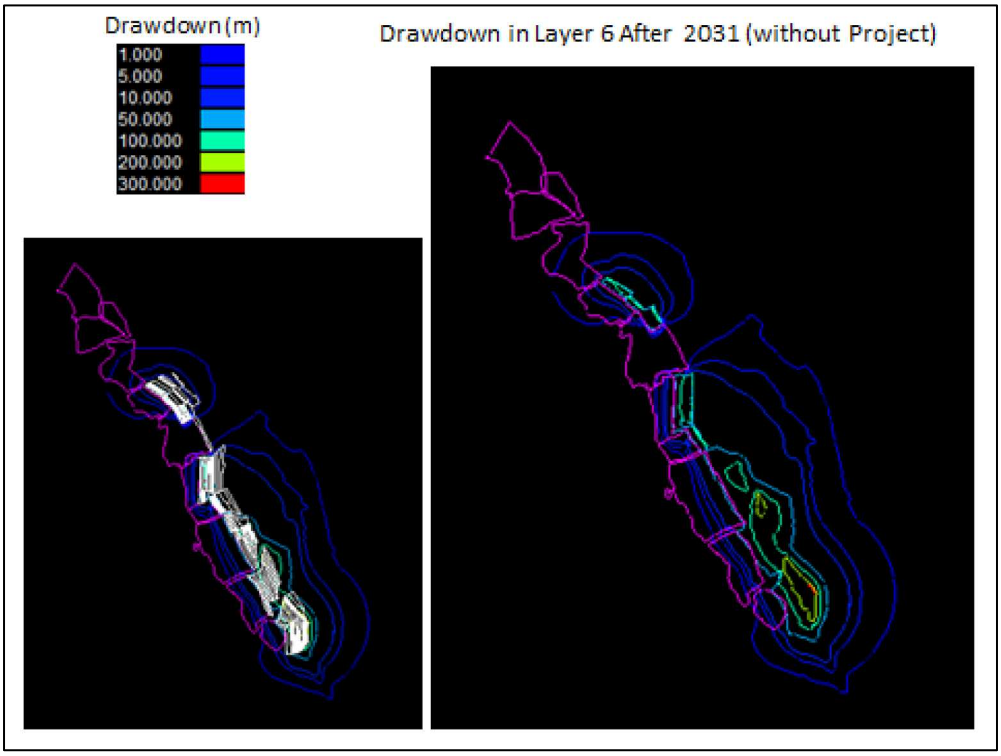


The predicted groundwater drawdown, considering the 1 m drawdown contour, for the approved mining (excluding the Project) includes:

- approximately 560 m to the east opposite the Project site
- approximately 7,000 m north south (associated with the northern pits)
- approximately 19,000 m north south (associated with the southern pits).

A decrease in the one metre drawdown to the west in the Tertiary sediments is predicted.

Figure 38 Predicted Groundwater Drawdown in Layer 6 in 2031 (approved mining only)



The predicted drawdown for the approved mining of H16 coal seam indicates two separate drawdown cones at the end of 2031, associated with the northern pits and the southern pits. The drawdown is predicted to extend:

- approximately 4,200 m to the east opposite the Project site
- approximately 7,000 m north south (associated with the northern pits)
- approximately 19,000 m north south (associated with the southern pits).

A reduced 1 m drawdown cone in the H16 coal is predicted to the west of the Project site. The extent of the 200 m drawdown (change in groundwater level from initial heads) is recognised to have reduced extent without the Project.

The predicted drawdown associated with the approved mining of the Dysart seams is presented in Figure 39. The 1 m drawdown contour is predicted to be continuous around the entire approved mining.

The largest approved mining groundwater drawdown (in the Dysart target coal seams), based on the 1 m change in groundwater levels predictions, is predicted to extend as follows at the end of 2031:

- approximately 3,400 m to the east opposite the Project site
- approximately 29,000 m north south (a continuous 1m drawdown contour).

The 200 m drawdown contour is smaller in the Project site area when the pits do not extend down dip (pit depths to some 300 m) in this area. The predicted 1 m drawdown contour is slightly smaller without the Project.

10.1.1 Summary

Table 19 provides a summary of the predicted drawdown, in the different model layers, for both model scenarios allowing for an indication of similarities and/or differences in drawdown contours.

Table 19 Summary of Predicted Drawdown

Model Layer	Without Project Scenario	Including Project Scenario
Model Layer 1 - Tertiary and Quaternary cover	• Two distinct 1 m drawdown contours • 1 m drawdown extends approximately 560 m to the east • 1 m drawdown contour extends approximately 7,000 m north-south (associated with northern pits) • 1 m drawdown contour extends approximately 19,000 m north-south (associated with southern pits)	• Two distinct 1 m drawdown contours • 1 m drawdown extends approximately 1,100 m to the east • 1 m drawdown contour extends approximately 7,000 m north-south (associated with northern pits) • 1 m drawdown contour extends approximately 19,000 m north-south (associated with southern pits)
Model Layer 6 - H16 coal seam	• Two distinct 1 m drawdown contours • 1 m drawdown extends approximately 4,200 m to the east • 1 m drawdown contour extends approximately 7,000 m north-south (associated with northern pits) • 1 m drawdown contour extends approximately 19,000 m north-south (associated with southern pits)	• Two distinct 1 m drawdown contours • 1 m drawdown extends approximately 4,500 m to the east • 1 m drawdown contour extends approximately 7,000 m north-south (associated with northern pits) • 1 m drawdown contour extends approximately 19,000 m north-south (associated with southern pits)
Model Layer 10 - Dysart Lower (D14, D24) coal seam	• Continuous 1 m drawdown contour • 1 m drawdown extends approximately 3,400 m to the east • 1 m drawdown contour extends some 29,000 m north-south • Smaller 200 m drawdown contour in Project site area	• Continuous 1 m drawdown contour • 1 m drawdown extends approximately 3,900 m to the east • 1 m drawdown contour extends some 29,400 m north-south • 300 m contour within the Project site

Overall the proposed extension of the open cut pits, between 2017 and 2031, will only result in a minor increase in the drawdown of groundwater levels to the east of the Project site due to the deep (approximately 300 m) open cut mining in the extension area.

The drawdown, considering the 1 m change in groundwater levels, is predicted to extend:

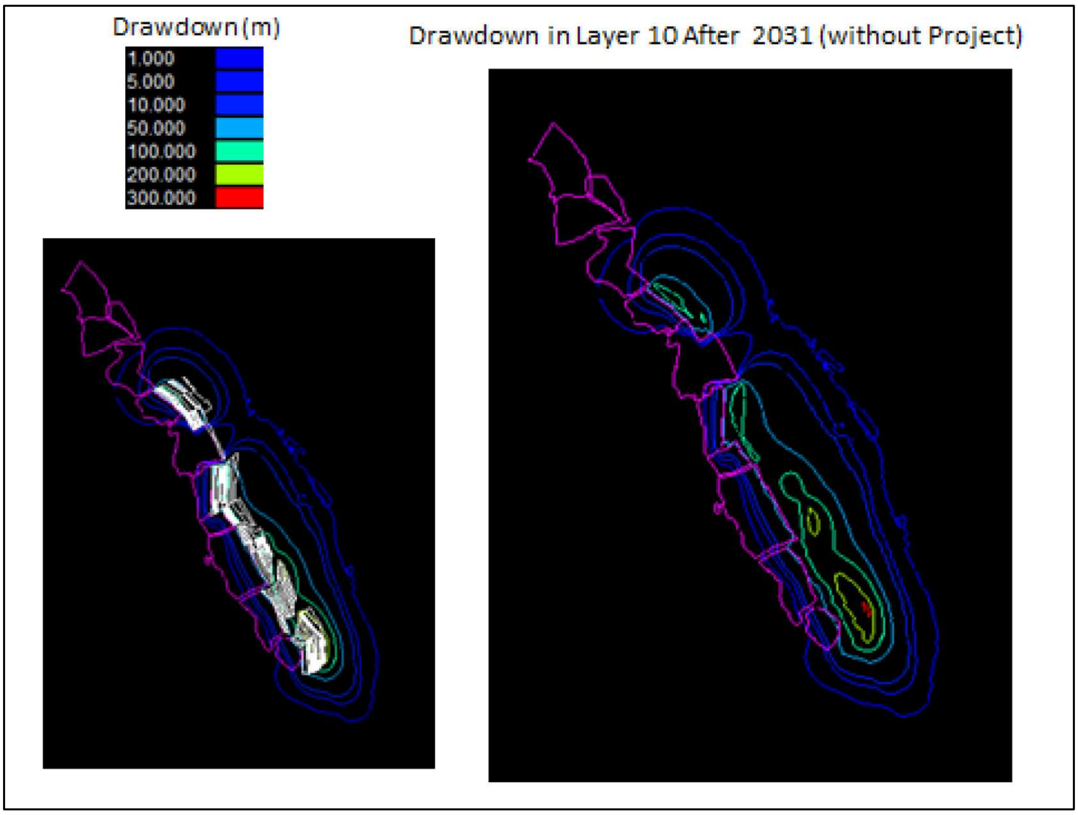
- approximately 500 m to the east within the Tertiary and Quaternary cover
- approximately 300 m to the east within the H16 coal seam
- approximately 500 m to the east within the target Dysart coal seams

This occurs as a result of the deep open cut resulting in increased gradients (head difference between the water level at the bottom of the pit and the surrounding water levels).

No marked change in the drawdown along strike (north-south) is predicted in the Tertiary and Quaternary sediments as well as the target H16 coal seam as a result of the Project.

A slight increase in the extent of the 1 m drawdown contour (approximately 400 m) is predicted along strike in the Dysart coal seams.

Figure 39 Predicted Groundwater Drawdown in Layer 10 in 2031 (approved mining only)



10.2 Groundwater Ingress Estimates

The modelling approach adopted for the drawdown assessment, considering mining activities with and without the proposed Project, allowed for the estimate of annual groundwater ingress into the mine workings.

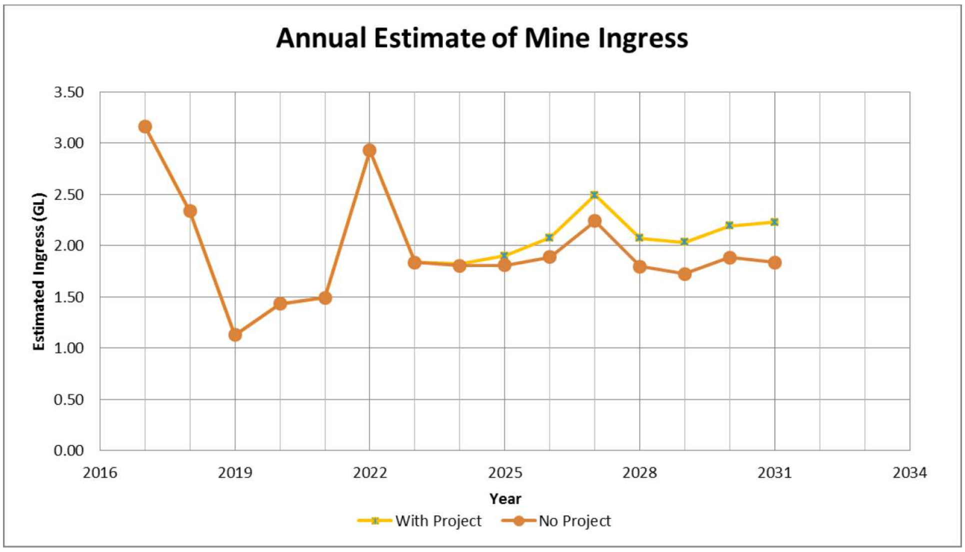
Table 20 presents the estimates of groundwater ingress, across the current and approved approximately 22.5 km mining operations (along north-south strike). The annual estimated total ingress for the two options (with and without the Project) is included in Table 20.

Table 20 Groundwater Ingress Estimate

Year	With Project (m^3/year)	No Project (m^3/year)
2017	3.17E+06	3.17E+06
2018	2.34E+06	2.34E+06
2019	1.13E+06	1.13E+06
2020	1.43E+06	1.43E+06
2021	1.49E+06	1.49E+06
2022	2.93E+06	2.93E+06
2023	1.84E+06	1.84E+06
2024	1.82E+06	1.81E+06
2025	1.90E+06	1.81E+06
2026	2.08E+06	1.89E+06
2027	2.49E+06	2.24E+06
2028	2.07E+06	1.79E+06
2029	2.03E+06	1.72E+06
2030	2.19E+06	1.88E+06
2031	2.23E+06	1.84E+06
TOTALS	**3.11E+07**	**2.93E+07**

The estimate of groundwater ingress, as included in Table 20, is presented in Figure 40.

Figure 40 Annual Groundwater Ingress Estimates



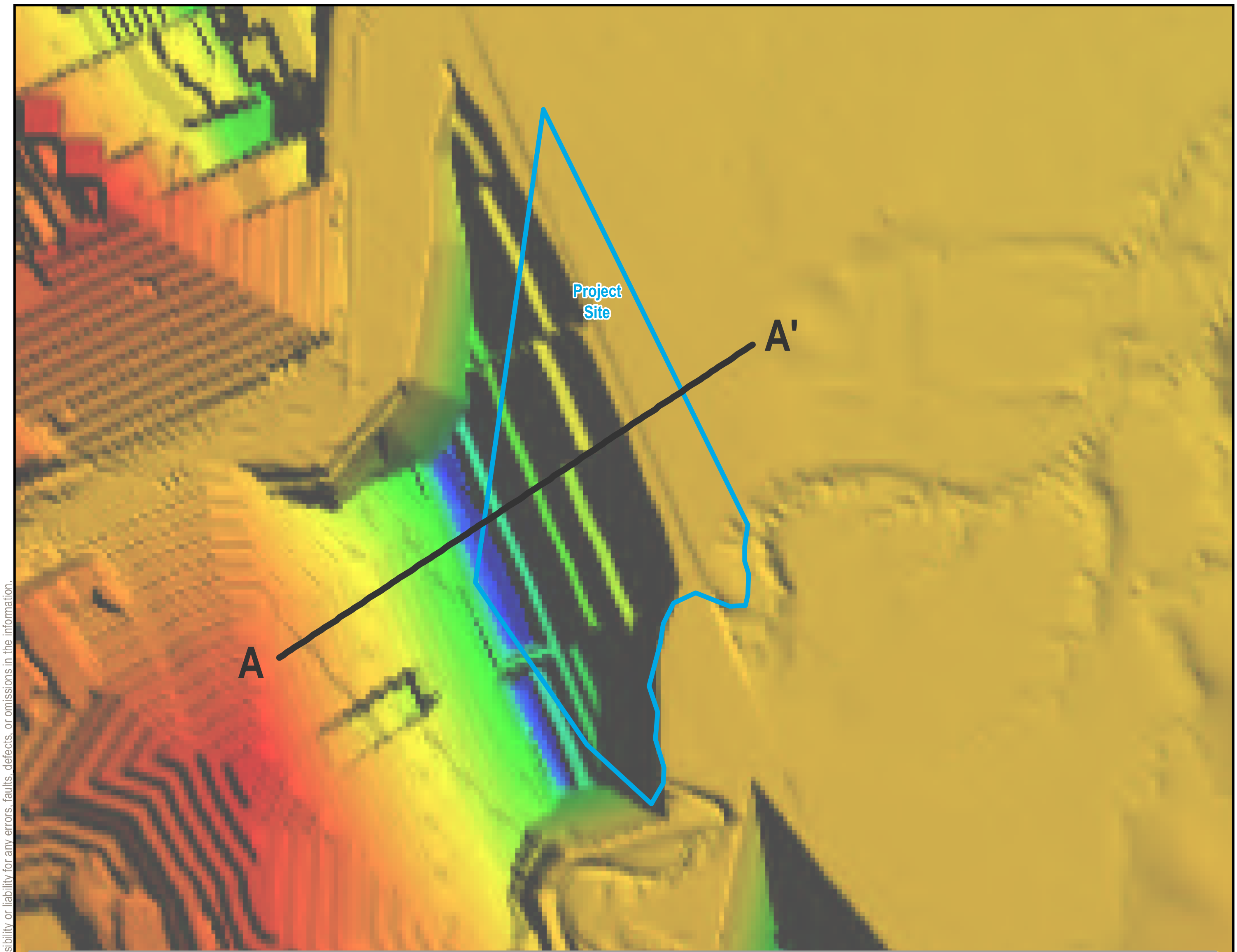
The difference between the estimates for the two options is 1,828,550 cubic meters (m^3), considered to be derived from the Project.

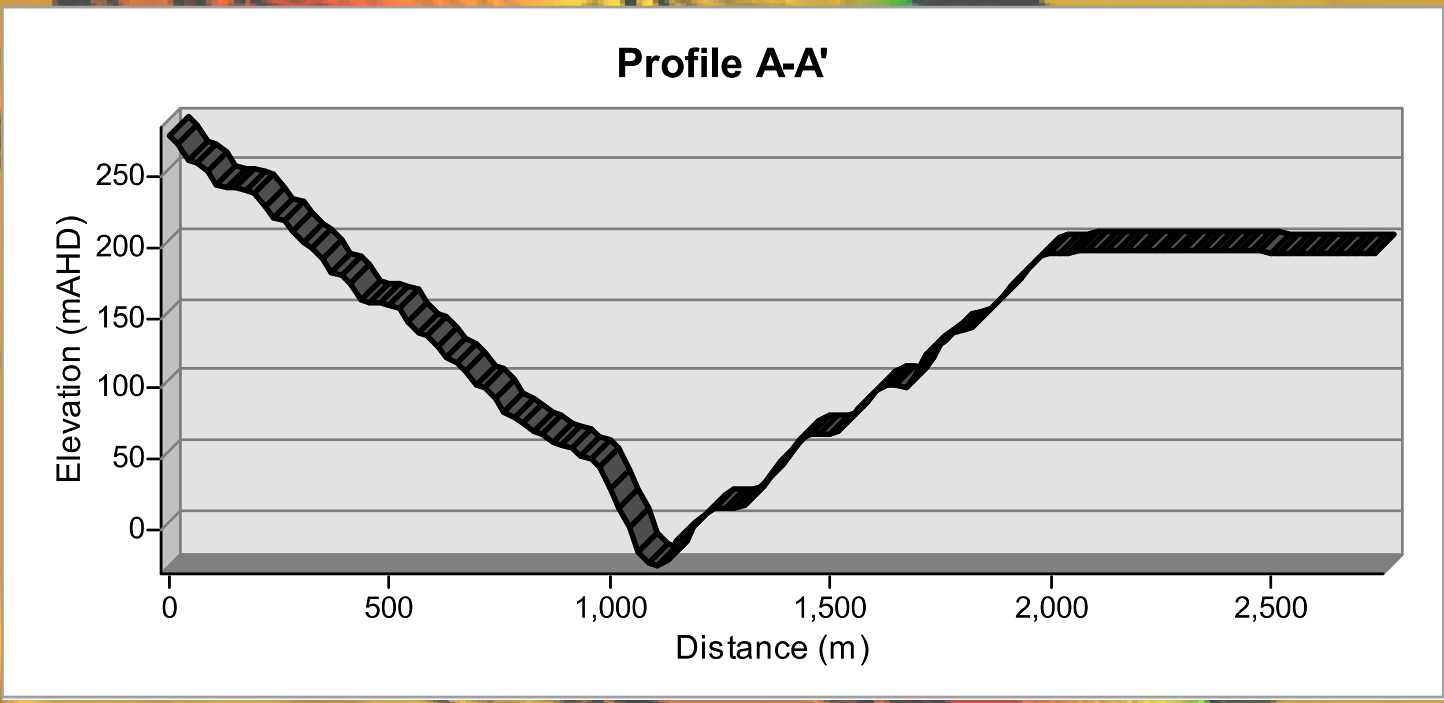
The amount of additional groundwater to be abstracted through mining (as wet coal and evaporation along pit walls) is an additional 6%. The contribution is related to the depth of the proposed mining in this area, some 300 m (Figure 41).

Comment:

Total groundwater ingress estimates across the entire approximately 22.5 km strike length over 15 years is estimated at 3.11 GL (31,129,800 m^3), which equates to approximately 66 L/s over 22.5 km (some 1 L/s over 340 linear meters).

This ingress is considered to occur as wet coal (where coal moisture ranges from 1 to 2% in the target coal seams) and seepage (damp) pit walls, which is removed by coal extraction and evaporation, respectively.





LEGEND

Project Site

Elevation (mAHD)

High : 350

Low : -31.9051

Data sources:

1. Project Site, Final Landform © BMA 2016 (RFI)

Figure 41
Final Landform Across the Project in 2031

Saraji Open Cut Extension Project Environmental Assessment Report

0 0.25 0.5 1
Kilometres

Scale: 1:30,000 (when printed at A4)

Projection: Map Grid of Australia - Zone 55 (GDA94)

BMA
BHP Billiton Mitsubishi Alliance

DATE: 29/11/2016 VERSION: 1

10.3 Long Term Groundwater Levels

For the assessment of the Project, using the predictive groundwater model, an assessment of groundwater recovery and long term groundwater flow patterns was conducted. This model scenario assumed a simplified modelling scenario where all Saraji Mine and Project open cut operations will cease at the end of 2031 and that mine dewatering will end at the same time.

Groundwater recovery was assessed in terms of groundwater level changes over time in response to increased permeability in the backfill, natural low recharge across the model domain, and evaporitic losses from the final voids (assumed to be the last mine workings excavated in 2031).

The resultant groundwater levels, showing recovery after 50 years after mining, with and without the Project are included in:

- Figure 42 Groundwater levels in Layer 1 after 50 years
- Figure 43 Groundwater levels in Layer 6 after 50 years
- Figure 44 Groundwater levels in Layer 10 after 50 years.

Figure 42 Groundwater Levels in Layer 1 after 50 years

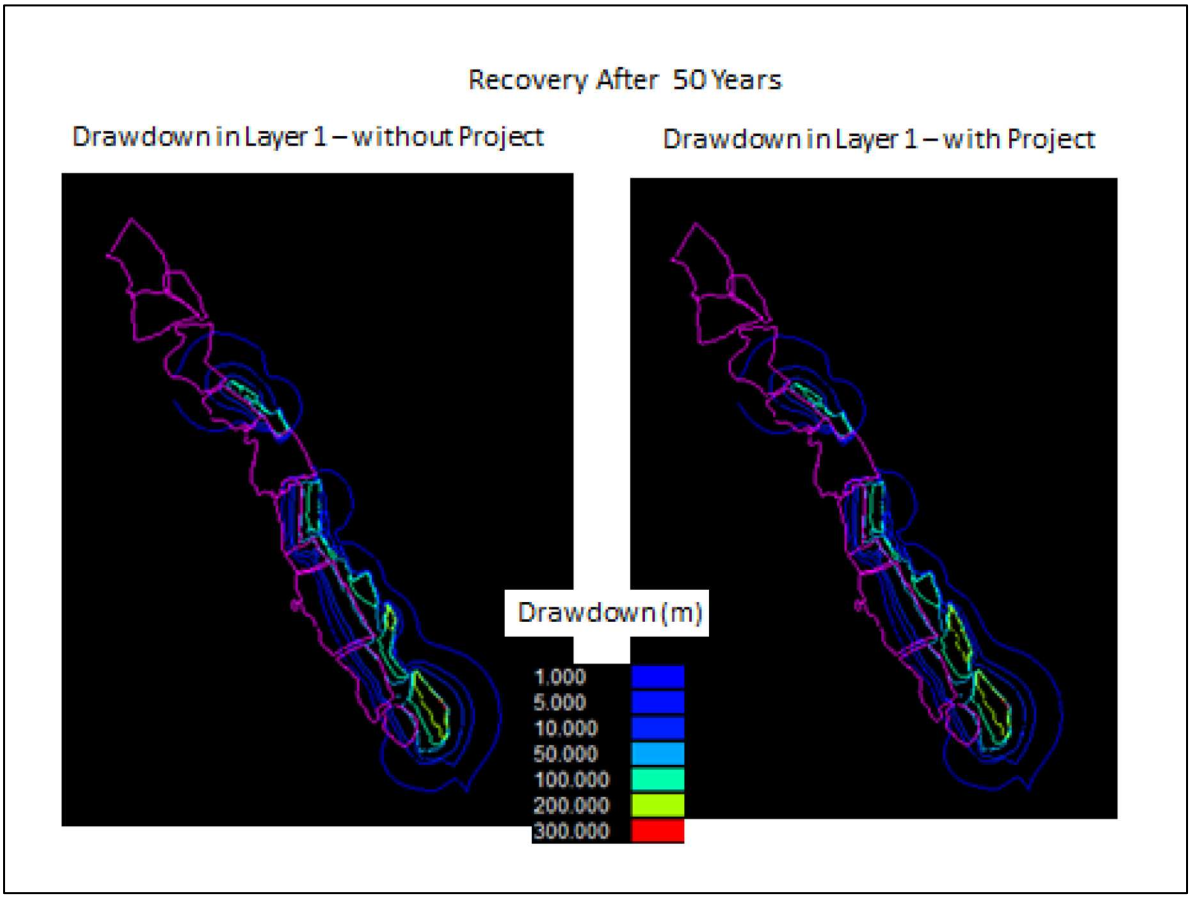


Figure 43 Groundwater Levels in Layer 6 after 50 years

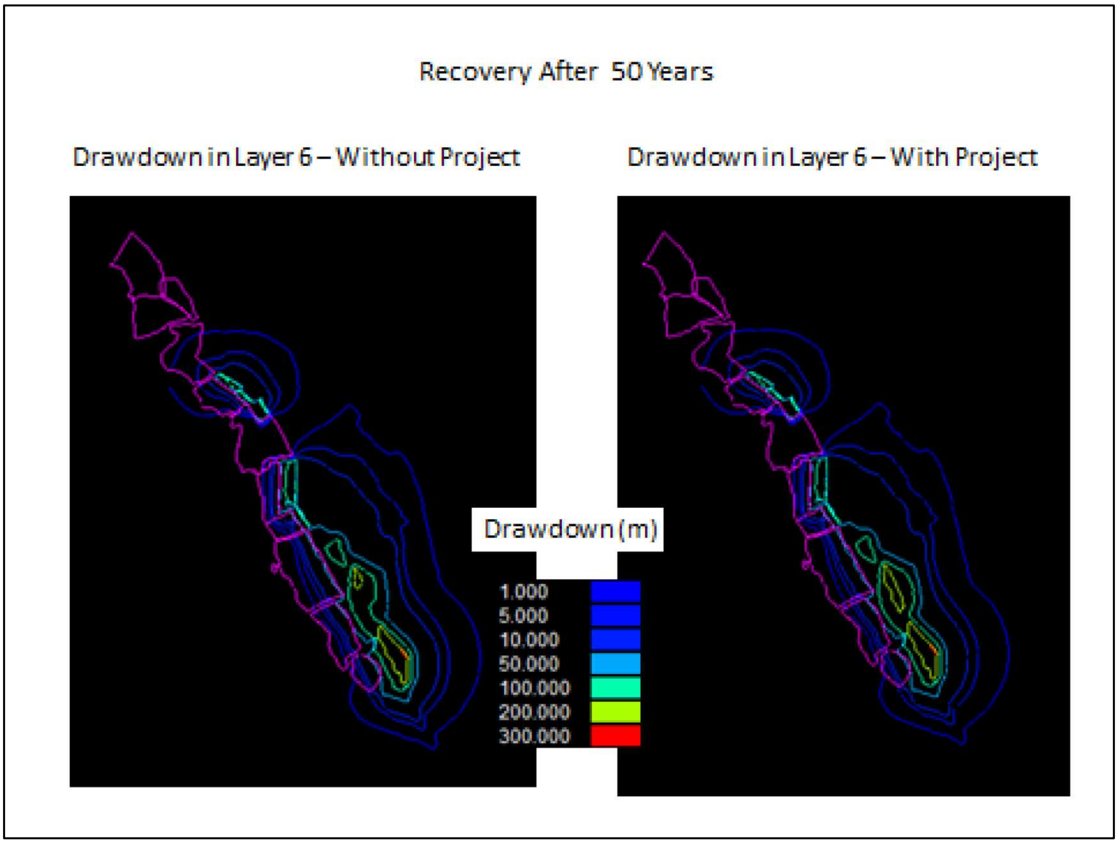
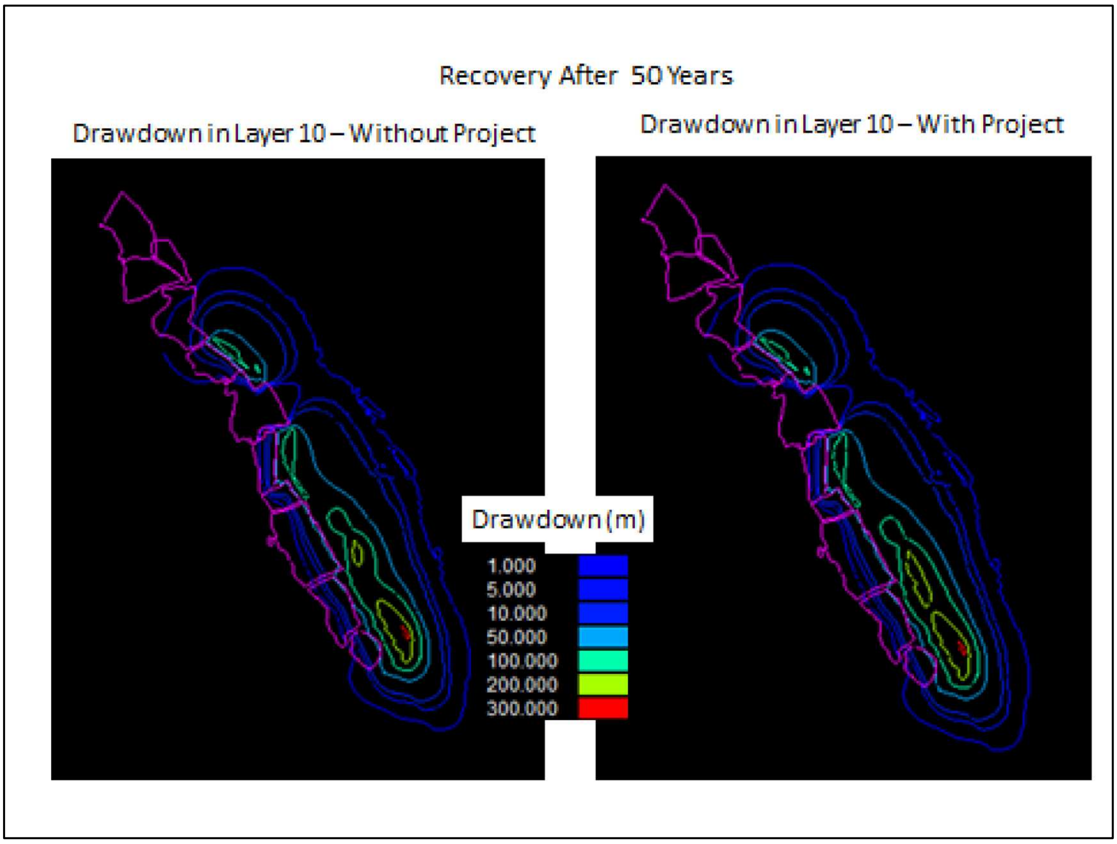


Figure 44 GroundwaterLevels in Layer 10 after 50 years



It is predicted that there will be limited recovery in groundwater levels over 50 years at the localised scale with or without project when considering the simplifying assumption that all mining ceases in 2031. A review of Figure 42, Figure 43 and Figure 44, indicates:

- slight reduction in the 1 m drawdown contours
- small reduction in the size of the deepest drawdown contours 200 and 300 m
- minor change in the 10 m drawdown contour associated with the H16 coal seam, indicating a slightly steeper gradient around the pits over time
- little or no change to the predicted groundwater drawdown in the Tertiary is evident after 50 years, due to the presence of the final voids (no alteration in drainage mechanisms into the final voids).

It is considered that the groundwater recovery is slow due to:

- limited rainfall recharge
- the long term mine dewatering (since 1974) has resulted in groundwater being removed from storage which needs to be replaced before marked changes in groundwater levels will be observed
- high evaporation over large final void areas modelled to remain after 2031 (across the approximately 22.5 km strike length)
- low permeability within the sediments surrounding the open pits.

It is noted that continued mining will occur in the already authorised areas throughout the mine site to 2056 (excluding the Project site which will be depleted of coal by 2013) (Section 1.1). This continuous mining will further constrain groundwater recovery within the Project in the long term.

11.0 Impact Assessment

11.1 Impacts on Groundwater Levels and Existing Groundwater Users

Figure 45 shows the location of existing registered bores plus bores identified during the bore census studies in relation to the predicted extent of groundwater drawdown at the end of the Project mining in 2031 (the cumulative drawdown contours for the approved and proposed Project mine dewatering).

The drawdown contours, associated with the approved deep Saraji Mine open cut pits and the Project, results in drawdown of groundwater levels in several bores. The 5 m drawdown (change in groundwater levels) was considered when assessing potential impacts on neighbouring groundwater bores. These assessment criteria are based on the Water Act, where:

The Water Act defines a "bore trigger threshold" (section 362) as:

> *a decline in the water level in the aquifer that is-*
>
> *(c) If a regulation prescribes the bore trigger threshold for an area in which the aquifer is situated – the prescribed threshold for the area; or*
>
> *(d) Otherwise-*
>
> *i. For a consolidated aquifer - 5 m; or*
>
> *ii. For an unconsolidated aquifer - 2 m.*

For the consolidated Permian coal measures it is judged to be appropriate to represent the extent of drawdown for up to 5 m from the original water level. The 2 m drawdown contour has not been utilised as the unconsolidated (Tertiary and Quaternary) sediments are generally unsaturated within the Project area.

These bores include:

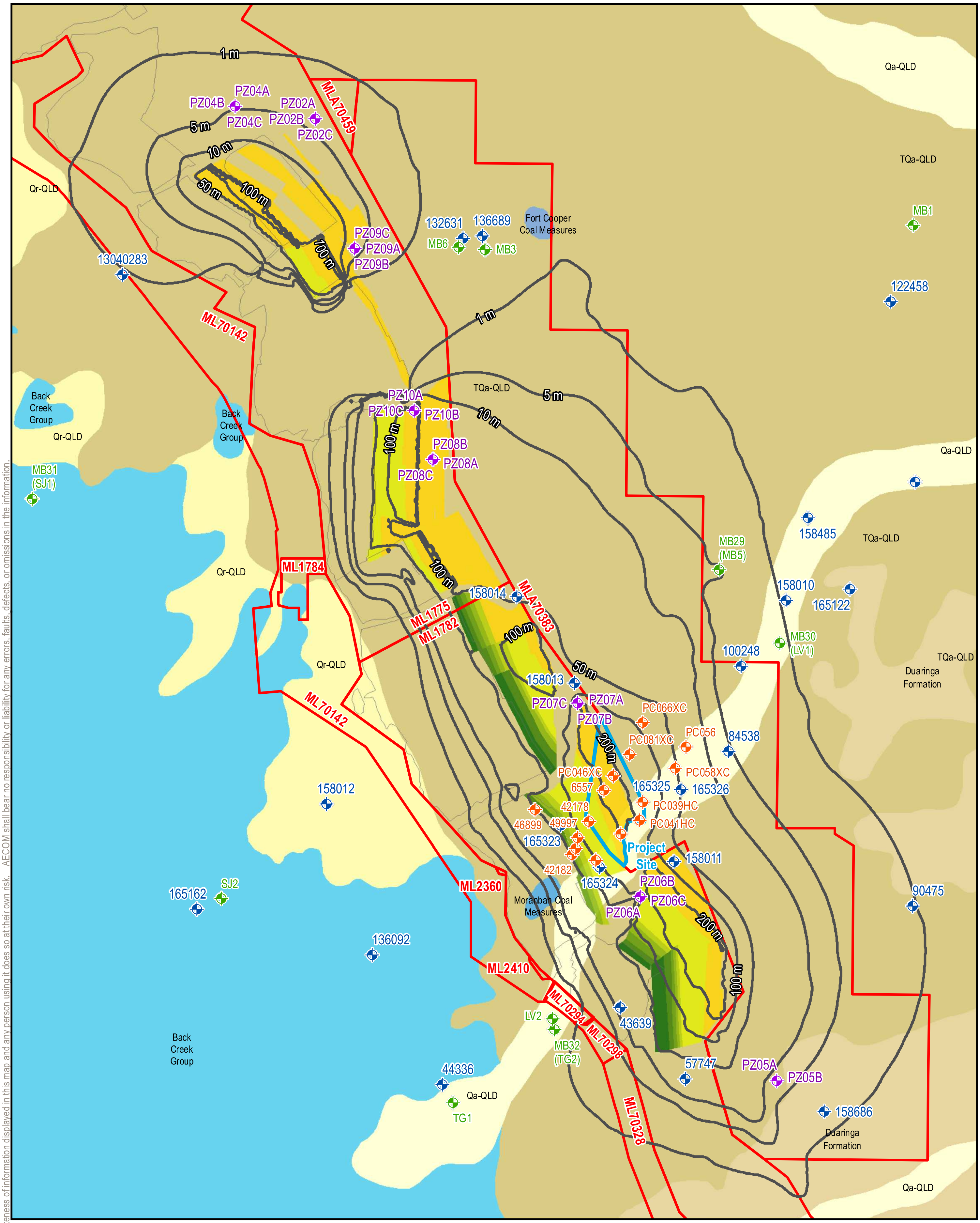
- Registered bores; 165325, 84538, 57747, and 43639
- Monitoring bores: MB33, MB34, MB36, PZ10A/B/C, PZ08A/B, PZ06A/B/C, PZ05A/B

The review of the registered bores potentially impacted by mine dewatering includes:

- Bore 165325 is a BMA piezometer recently (2016) installed on Saraji Mine
- Bore 84538 is an old (1954) bore, open from 27m to 110 m with a very low yield (0.07 L/s)
- Bore 57747 is located in the Back Creek Group some 750 m south of the approved Saraji Mine pits
- Bore 43639 is a lost / destroyed bore.

Only bore 57747, with a reported yield of 4 L/s, is considered a usable groundwater supply bore. This bore is, however, located within the footwall Back Creek Group sediments. The 5 m drawdown in Figure 45 is for the target coal seam, thus the drawdown within the underlying sediments are not expected to decline by the same amount (i.e. the largest drawdown will occur within the target seams). It is therefore considered that the proposed Project will not markedly impact on the groundwater resources associated with this bore.

This bore is on land owned by BMA so no action is warranted in relation to mitigating the impact on this bore, BMA will ensure that a groundwater monitoring bore(s) are suitably located within the predicted groundwater drawdown zone to allow for the validation and verification of model predictions and/or to provide an early warning of unexpected impacts beyond the predicted impact area. Any unexpected impacts on third parties will be avoided or addressed via make good agreements.



LEGEND

Predicted Layer 6 Drawdown (m)
Project Site
BMA Tenure / Tenement

Groundwater Bore

BMA Core Hole
Census Bore
Registered Bore
Saraji Monitoring Bore

Existing Open-Cut Extent

Conceptual Mine Plan

FY2017
FY2018
FY2019
FY2020
FY2021
FY2022 - FY2026
FY2027 - FY2031

Surface Geology

Back Creek Group (Pb)
Duaringa Formation (Tu)
Fort Cooper Coal Measures (Pwt)
Moranbah Coal Measures (Pwb)
Qa-QLD (Qa)
Qr-QLD (Qr)
TQa-QLD (TQa)

Data sources:

1. Tenements, Bores, Infrastructure © BMA 2016 (RFI)
2. Geology, Bores © State of Queensland (Department of Natural Resources and Mines) 2016

N

Figure 45
Bores Located Within the Predicted Drawdown Cone in Layer 6

Saraji Open Cut Extension Project Environmental Assessment Report

0 0.5 1 2
Kilometres

Scale: 1:110,000 (when printed at A4)

Projection: Map Grid of Australia - Zone 55 (GDA94)

BHP Billiton Mitsubishi Alliance

DATE: 23/11/2016 VERSION: 0

Filename: \\aubne1fp003\Projects\605X\60507031\4. Tech Work Area\4.99 GIS\02_MXDs\04 Saraji OC Environmental Assessment Report\00 Technical Report\Groundwater\60507031_G047_v0_A4P.mxd

11.2 Cumulative Impacts

Cumulative impact assessments are highly specific to the impact under analysis and may consider, for example, the following (Franks et al, 2010):

- multiple areas of groundwater abstraction (e.g. adjacent mining operations)
- overlapping cones of drawdown
- dewatering discharge locations
- distributions of ecosystems around the project
- catchment-scale groundwater levels.

For the open cut expansion a cumulative impact of the existing approved mining plus the proposed extension was assessed.

Multiple Areas of groundwater abstraction

The predictive modelling allowed for the assessment of multiple areas of groundwater abstraction (through pit dewatering) with and without the open cut extension.

The results of the predictive modelling indicate:

- minor additional drawdown impacts as a result of the open-cut extension (to the east)
- an increase in groundwater extraction associated with mine dewatering, some 6% increase.

Overlapping cones of drawdown

The drawdown cones of the multiple Saraji Mine open pits are included in the modelling. The Project relates to the extension of Grevillea pit.

The drawdown cones associated with the Saraji Mine pits to the north (Bauhinia, Jacaranda and Acacia pits) and the south (Coolibah, Dogwood, Ebony, Grevillea, and Hakea pits) are recognised from the predictive modelling not to overlap. The predicted 1 m drawdown (from initial 2016 groundwater levels) at the end of mining in 2031 is recognised not to overlap (Section 10.0).

This indicates reduced cumulative zones of influence (where drawdown cones overlap) between separated open pits due to the low permeable nature of the Permian strata.

Dewatering discharge locations

No dewatering discharge locations are required due to the low volumes of groundwater seeping into the open pits, i.e. no active mine dewatering is required.

Distributions of ecosystems around the Project

No GDEs are reported within the Project site (Section 6.9) and the groundwater, due to depth and salinity, has limited environmental values with regards to ecosystems.

Impacts of the mine dewatering associated with the Project, considered in connection with the approved Saraji Mine, are considered low for the following reasons:

- Surface water creeks in the area are ephemeral and groundwater levels (more than 20 m below surface) are below the level that would provide baseflow to existing alluvium or to root zone of plants.
- Groundwater level drawdown will occur predominantly within the Permian coal seams, which are separated from surficial groundwater regimes by aquitards, are not expected to impact surface ecosystems.
- The proposed open cut extension only results in a minor (100s of metres) increase in the 1 m drawdown contour to the east.

Catchment-scale groundwater levels

Groundwater level impacts due to historic mining are recognised to be limited, with 600 m (MB2) to 1.5km (MB33 and MB34) of the Saraji Mine even though this mine has been operational since 1974.

Long term groundwater levels are predicted to be influenced by ongoing groundwater abstraction as final voids act as groundwater ‘sinks”, i.e. pit water abstraction through evaporation. This maintenance of a pseudo-steady pit water level will maintain cones of drawdown immediately around the final voids.

These zones of influence are reduced; however, due to increased recharge rates through the more permeable backfill.

11.3 Impacts on Groundwater Quality

During mining the existing cone of depression developed around the Saraji Mine will be maintained or expanded over time. This results in localised groundwater flow into the pits, including the Project open pit extension. The risk of the pit water (a blend of groundwater from different strata, surface water runoff, direct rainfall, and increased salinity due to evaporation) impacting on groundwater quality, away from the pits is therefore negligible.

Based on the depth of the final voids, some 300 m in the deepest pits, the negative climate balance, plus the inclusion of surface water levees will ensure the pseudo steady state pit water levels will be maintain well below the surface elevation. The large void space and the maintenance of deep pit water levels negates the risk of water decant from these pits (final voids).

11.4 Potential Environmental Impacts

The potential environmental impacts of the proposed open cut extension are considered low due to:

- The surface water system in the Project area is ephemeral.
- The Quaternary sediments (recent deposits from Phillips Creek) were reported to be of limited extent and were dry in several bores.
- The Tertiary sediments were recorded to intersect groundwater at depth but often have insufficient groundwater sampling, due to poor groundwater recovery after sampling due to low permeability.
- The largest predicted drawdown extends within the target coal seams, which are not recognised to discharge into the down gradient Isaac River, in addition the drawdown cones do not extent to the Isaac River to the east.
- Groundwater quality is not suitable for drinking, too deep for surface ecosystems, and is often too saline for livestock watering.
- The surface water systems are separated from the predicted impacted groundwater resources by low permeable sediments, which reduce the potential for the Project to impact on the alluvium and surface water flows.

Summary

The proposed extension of the Grevillea pit is predicted to have long term locally contained impacts on the quantity and quality of groundwater resources on the Project site. These impacts include:

- The overall mining will have impacts on existing groundwater use and long term impacts associated with ongoing final void pit water evaporation.
- Blending (mixing of groundwater from the different aquifers) and water deterioration due to evaporation from the Project final void will permanently alter water quality in the final void.

In order to protect against unexpected impacts and ensure ongoing validation of the predictive modelling in the vicinity of Grevillea pit it is considered that ongoing groundwater monitoring during and after the Project development be conducted. The groundwater monitoring approach, including adaptive management and the instigation of further investigations, is detailed in Section 12.0.

12.0 Groundwater Monitoring Recommendations

12.1 Groundwater Monitoring Bore Network

The objective of the groundwater monitoring network is to monitor potential effects of the proposed mining on overlying and underlying aquifers, as recognised in such that informed management decisions can be made.

The current groundwater monitoring network provides lateral and vertical coverage of the potentially impacted groundwater resources, taking into account the hydrogeological regimes and groundwater resources.

The network provides an early warning of potential impacts, so that early intervention can be implemented to reduce potential environmental harm. Should monitoring indicate an undesirable trend, the requirement for additional monitoring bores, both in other aquifers and laterally away from the Project is to be assessed, and actioned if deemed necessary.

12.1.1 Existing Monitoring Bores

A summary of the current groundwater monitoring network is presented per monitoring unit in Table 21 Figure 10 provides locality figures showing all the bore locations.

Table 21 Existing Groundwater Monitoring Bores

Bore	Easting	Northing	Unit
Standpipe Bores			
MB31 (SJ1)	625942	7522560	Permian coal
MB32 (TG2)	637595	7510716	Alluvium
MB33	636640	7520199	Permian overburden
MB34	637926	7518269	Permian interburden
MB35	642646	7520110	Permian interburden
MB36	640150	7514283	Permian overburden
MB37	632389	7515571	Permian interburden
PZ02A	632019.46	7530674.70	Tertiary
PZ02B			Permian interburden
PZ02C			Dysart D24
PZ04A	630242.09	7530952.12	Tertiary
PZ04B			H16
PZ04C			Dysart (D47)
PZ09B	632911.79	7527778.59	H16
PZ09C			Dysart (D24)
PZ10B	634236.37	7524164.33	H16
PZ10C			Dysart (D24)
Vibrating Wire Piezometers			
PZ05A	642326.97	7509220.73	H16
PZ05B			Dysart (D52)
PZ06A	639271.67	7513325.56	Permian overburden
PZ06B			H16

Bore	Easting	Northing	Unit
PZ06C			Dysart (D142)
PZ08A	634647	7523069	P07 coal
PZ08B			H16
PZ08C			Dysart (D24)

12.1.2 Existing Water Level Monitoring

Groundwater level measurements are collected manually from monitoring wells located across the site. Manual readings are procured during each monitoring event (prior to any sampling).

Historic data indicates automated readings via dedicated level logger have been used. It is recommended that these be reinstated and that these loggers are programed to collect static water level (SWL) measurements at least once a week.

Several vibrating wire piezometers are installed at three separate locations (PZ05, PZ06, and PZ08) and provide pressure readings from eight sensors.

These VWPs should be assessed and where possible remediated into service and then added to the groundwater level monitoring program.

12.2 Augmentation

The existing groundwater monitoring network will be augmented in the vicinity of the Grevillea pit focused Project site (and over time) to ensure the following:

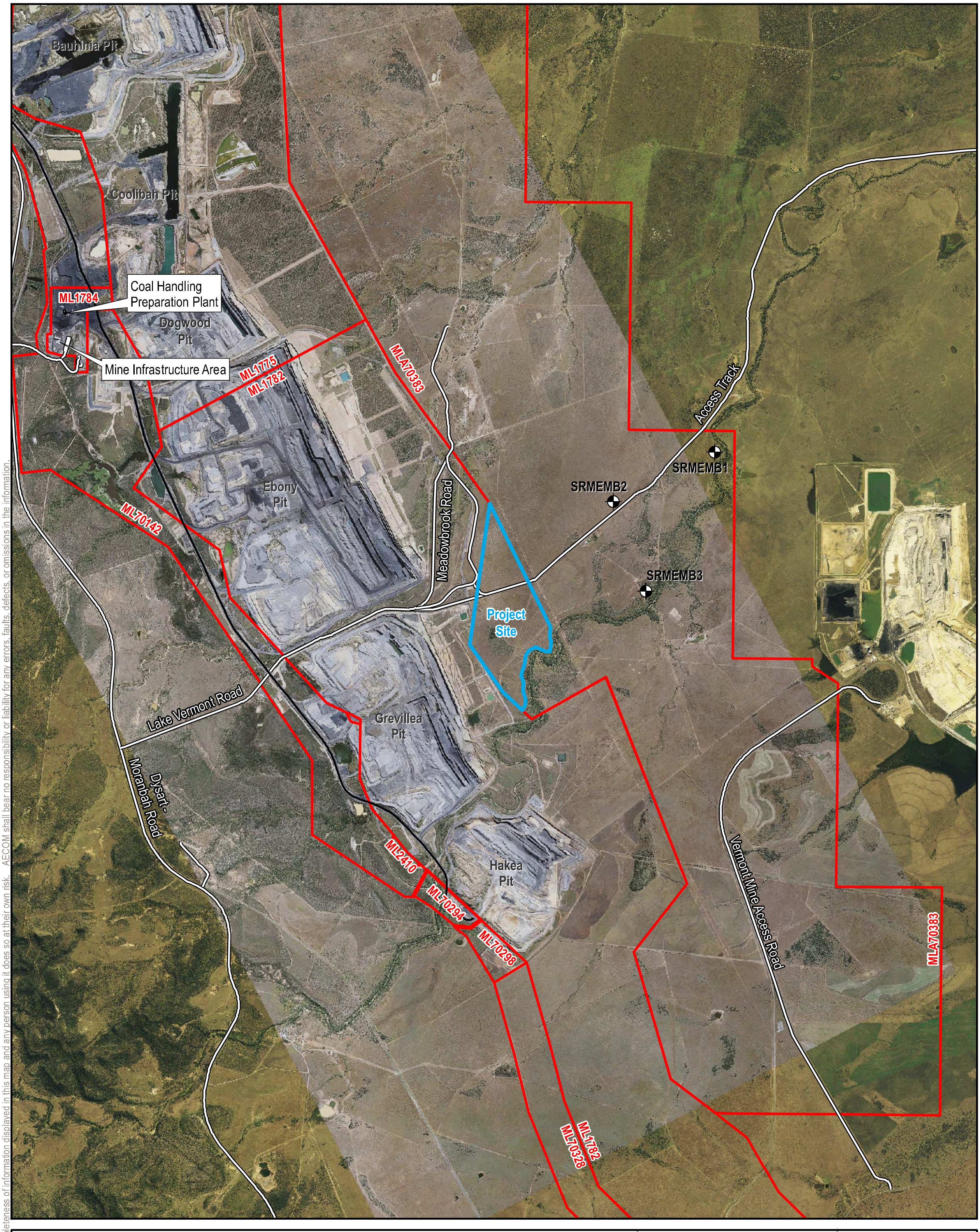
- The determination of groundwater level responses to mine activities within the Project site. The comparison of water level decline will allow for the identification of groundwater resources which may be unduly affected by mine dewatering, where unduly affected is where drawdown is projected to be greater than the model predictions.
- The extent and magnitude of drawdown in each aquifer in the vicinity of the Grevillea pit is adequately monitored for comparison to modelled projections over time, particularly the intervening aquitards which control projected drawdown (induced flow).
- The identification and management of any potential impacts on surface water in Phillips Creek immediately downstream of the circa 2031 projected extent of Grevillea pit.
- It is considered, based on reported issues regarding sampling Tertiary sediments at bores PZ02A and PZ04A, that additional groundwater monitoring bores in this unit may be required to ensure the collection of representative groundwater data from this unit.

The groundwater monitoring network will, during operations, act as an early warning system for potential drawdown impacts. Therefore the groundwater monitoring network should be modified as mining extends to the east. The monitoring network augmentation will ensure the replacement of monitoring points that are lost during mining, and the groundwater monitoring program is to be modified in response to mine activities change (i.e. operations or closure).

12.2.1 Recommended new groundwater monitoring bores

With regards to ensuring the collection of representative groundwater monitoring data, allowing for the assessment of the potential predicted impacts of the Project on local groundwater resources, and considering the existing groundwater monitoring bore network (Figure 10), recommended additional monitoring bores are suggested to be constructed prior to the Project mining activities (Table 22).

These bores are included in Figure 46.



LEGEND

- Recommended Monitoring Bore
- Haul Road
- Public Road
- Project Site
- BMA Tenure / Tenement
- Infrastructure

Data sources:

1. Existing Infrastructure, Proposed ML © BMA 2016 (RFI)
2. BMA Imagery 29 May 2016
3. QLD SISP Imagery 2012

N

Figure 46
Recommended Monitoring Bores

Saraji Open Cut Extension Project
Environmental Assessment Report

0 0.5 1 2
Kilometres

Scale: 1:80,000 (when printed at A4)

Projection: Map Grid of Australia - Zone 55 (GDA94)

BHP Billiton Mitsubishi Alliance

DATE: 29/11/2016 VERSION: 1

Table 22 Recommended Project Monitoring Bores

Recommended bore	Easting	Northing	Target
SRMEMB1	642149	7518381	alluvium
SRMEMB2	640499	7517578	VWP in coal seams
SRMEMB3	641035	7516129	Tertiary

12.2.2 Bore Design and Drilling

All monitoring bores are to be drilled using a water bore drilling rig, using mud-rotary or air-percussion techniques. The groundwater monitoring bores are to be designed in accordance with the Minimum Construction Requirements for Water Bores in Australia, 3rd Edition (NWC, 2012).

Particular consideration must be given to casing and annular seal requirements to ensure that no pathway is provided for the movement of water between aquifers.

Each standpipe monitoring bore is to be complete with 50 mm diameter uPVC casing (threaded), machine slotted screen and fitted with a lockable monument cover. The bore annulus of the screened interval is to be filled with washed 2 mm silica sand, sealed with a bentonite plug and grouted to surface with a cement-bentonite grout mix. Each bore must be developed (flushing or airlifting).

12.3 Groundwater Monitoring Program Attributes

This section describes the groundwater monitoring program attributes that will guide implementation before, during, and after the proposed mining activities. In accordance with an adaptive management approach, these monitoring attributes will be modified on an on-going basis to ensure optimal understanding of the groundwater regimes and the envisaged mining impacts.

12.3.1 Parameters

Optimum parameter selection allows for the measure of the cause and effect relationship between mining activities and the environmental response to those activities. Suitable indicators include those:

- commonly found in the environment
- relatively easy to measure
- sensitive to environmental change
- specific to disturbance impacts.

The selected parameters, as included in the Saraji Mine EA Condition W51 Table W11 (Figure 46), allow for the description of the groundwater resource, the physical, chemical and biological aspects of the groundwater system, while other selected parameters relate to anthropogenic activities.

The groundwater monitoring program allows for the evaluation of both groundwater quantity (levels) and quality parameters.

12.3.2 Groundwater Level Monitoring

Noting that no third party impacts are predicted, groundwater level monitoring is the key parameter for assessing changes to the groundwater regime, particularly as the ‘make good’ agreements with landholders is typically predicated on a water level change.

12.3.2.1 Frequency and Duration

At a minimum, groundwater levels within the groundwater monitoring network are reviewed annually. The majority of the groundwater monitoring bores will have permanent groundwater level monitoring devices (either VWP pressure sensors or automated water level loggers) installed. These dataloggers compile water level data at a minimum weekly interval, with the data being downloaded and assessed on a regular basis (during groundwater sampling events).

Groundwater level monitoring is to continue through operations and post closure at selected representative groundwater monitoring points (providing representative assessment of groundwater level changes in the various groundwater units).

Figure 46 Saraji Mine EA Condition Table W11

Table W11 (Groundwater contaminant trigger levels)

Parameter	Unit	Trigger Levels	Limit Type
Groundwater Level	RL	Greater than 2 metre drawdown from the background level.	Maximum
pH	pH Units	6.5 - 8.5	Minimum/Maximum
Electrical Conductivity	µS/cm	To be provided as per condition **W52**	
Total Dissolved Solids	mg/L		
Calcium	mg/L		
Magnesium	mg/L		
Sodium	mg/L		
Potassium	mg/L		
Chlorine	mg/L		
SO4	mg/L		
CO3	mg/L		
HCO3	mg/L		
PO_4	mg/L		
NO_3	mg/L		
Iron	mg/L		
Aluminium	mg/L		
Arsenic	mg/L		
Mercury	mg/L		
Antimony	mg/L		
Total Petroleum Hydrocarbons	mg/L		

During post closure it is envisaged that the groundwater level data will provide recovery data, which will be compared to long-term model predictions.

The details of the monitoring bores, units to be monitored and monitoring frequency details for each of the mine phases, are included in Table 23.

Table 23 Mining Phases and Monitoring Details

Mining Phase	Groundwater Level	Frequency	Groundwater Quality	Frequency	Monitoring points
Operations	Automated loggers	Weekly	Every 3 months	During Project mining	Table 20
Post closure	Automated loggers	Weekly	Every 6 months	For first 10 years	To be determined

12.3.2.2 Instrumentation and Control

Groundwater levels are measured manually with an electronic water level probe each time a bore is visited. The probe is decontaminated between bores.

Automated water level monitoring devices are to be installed in the monitoring bores. This will comprise automated water level loggers or vibrating wire piezometers with dataloggers for recording the measurements.

12.3.2.3 Groundwater Level Indicators

Changes in quantity of groundwater (or availability of groundwater), flow volumes in aquifers and interaction between groundwater and surface water features are primarily determined based on groundwater level/pressure levels and related changes in these levels.

Mining-induced changes in groundwater levels can be caused by removal of groundwater from an aquifer, changes in groundwater balances (due to land cover changes including backfilling) and pressure effects due to depressurisation of aquifers.

The primary indicator for groundwater quantity is, therefore, defined as the temporal change to groundwater level/pressure in a defined aquifer interval at an established monitoring location.

As a result, groundwater levels will be assessed against the background data which has been collected to date. Comparison to established baseline conditions will be used to assess for mine related influences.

12.3.3 Groundwater Quality Monitoring

Groundwater samples have and will be obtained from the representative groundwater monitoring points which has allowed for establishing representative groundwater chemistry contaminant levels prior to the Project.

The groundwater units monitored on site, based on the potential for mine activities to impact on these units, includes:

- Quaternary alluvium
- Tertiary sediments
- Permian non-coal bearing strata
- Permian coal seam aquifers.

12.3.3.1 Methods

The low-flow sampling method is to be adopted so as to minimise the volume of purge water to be managed while ensuring that samples collected are representative of the aquifer or groundwater unit. Groundwater samples are collected when field parameters have stabilised as per Table 24.

Table 24 Field Parameter Stabilisation Criteria prior to Sampling

Measurement	Variability	Recording
pH	± 0.1 pH unit	Continuous readings until stabilised, i.e. three to five consecutive readings within the variability range
Temperature	± 0.2°C	
Electrical Conductivity	± 3%	
Dissolved oxygen	± 0.3 mg/L	
Redox potential (Eh)	± 5%	

Groundwater sampling is to be undertaken in accordance with the most recent edition of the DEHP Water Quality Sampling Manual, which allows for the collection of repeatable representative groundwater data.

Groundwater samples are to be analysed as per Section 12.3.1.

12.3.3.2 Quality Assurance / Quality Control Sampling

Field monitoring equipment, such as electrical conductivity and pH meters, are to be calibrated on a daily basis during sampling events using appropriately ranged and preserved calibration solutions.

Quality assurance/quality control laboratory samples are to be collected at 1 duplicate sample for every ten groundwater samples collected, or if less than ten samples in a sampling event, one duplicate sample per batch. The duplicate sample is sent to the primary analytical laboratory. Duplicate samples are to be analysed for the full suite of parameters for which the primary sample is analysed.

Collected samples are to be transported under chilled conditions to the laboratory without compromising the sample holding limits.

12.4 Data Analysis

12.4.1 Data Analysis Process

Different methods exist for the assessment of groundwater monitoring data, one of which is the use of statistical tests for the development of indicator parameter limits. It is recognised that alternative methods exist, however, statistics honour natural data variability and facilitate tracking of quality and quantity trends.

BMA will, in discussion with the regulator, finalise groundwater chemistry contaminant limits and groundwater level thresholds. It is considered that the contaminant limits will be based on statistics, against which monitoring data is to be assessed.

The groundwater level thresholds will be based on predictive groundwater modelling.

Hydrochemistry

Once sufficient (statistical) groundwater dataset is available (a minimum of 12 sample events) and assessment of statistical trends for representative parameters within each groundwater unit monitored will be derived.

These contaminant trigger levels and contaminant limits can be based on the 85th and 99th percentile values, respectively for each measured parameter (Figure 46) in each geological unit, possibly impacted by mine operations, as detailed in Section 12.3.3.

Trends can be identified and follow-up investigations initiated per the established approach outlined in Section 12.4.2. The intent of the investigative follow-up is to identify natural exceptions to the proposed trigger levels and contaminant limits and facilitate revision of the targets as per the adaptive management approach (i.e. an assessment of potential for environmental harm will be conducted and if it is found that the trigger levels are exceeded due to natural conditions (not mine related) then the limits are to be re-evaluated).

Water Level

It is recognised that drawdown, as a result of mine dewatering or depressurisation, can impact on groundwater resources and potentially cause environmental harm.

In order to identify potential drawdown impacts the monitoring points will act as early warning and model prediction validation points, when assessing Grevillea Pit extension mine dewatering drawdown.

The monitoring points will act as early warning bores for impacts beyond those predicted.

12.4.2 Investigation and Response Processes

12.4.2.1 Hydrochemistry

First Step

Should any agreed groundwater quality trigger levels be exceeded, an investigation will be undertaken within 14 days of detection to determine if the exceedance is a result of:

- mining activities authorised under this environmental authority
- natural variation
- neighbouring land use resulting in groundwater impacts.

Second Step

If the investigation determines that the exceedance was the result of mining, then investigations will be undertaken to establish whether environmental harm has occurred or may occur.

This would include:

- The relevant monitoring point(s) will be resampled and the samples analysed for major cations and anions, and selected dissolved metals.
- If elevated concentrations (above trigger levels) are recorded on two consecutive sampling events then an investigation into cause, optimum response, and the potential for environmental harm will be conducted.

12.4.2.2 Water Levels

In the event that groundwater level decline in excess of the levels defined through predictive modelling, an investigation will be instigated within 14 days of detection.

The investigation will aim at determining if the fluctuations in groundwater levels are a result of:

- mining activities authorised under this environmental authority
- pumping from licensed bores
- seasonal variation
- neighbouring land use resulting in groundwater impacts.

If the trigger exceedance is as a result of authorised mining activities then BMA will notify the administering authority within 28 days and provide the following:

- details of whether actual environmental harm has occurred or is likely to occur
- any proposed mitigation measures required to address the affected groundwater resource
- proposed actions to reduce the potential for environmental harm.

12.5 Data Reporting

Monitoring results, both groundwater levels and water quality, are verified and stored in the monitoring database. Review of these data will be undertaken on a regular basis and will be made available for inspection by the administering authority upon request.

13.0 References

- 4T, 2012. Desktop Assessment Likelihood of Stygofauna Occurrence in the Bowen Basin, ref. R_20120922_Stygofauna_238_Final, dated October 2012
- AGE, 2007. Report on Hydrogeological Regime and Impact Assessment Saraji Mine, Project No. G1387, December 2007
- AGE, 2011. Report on Saraji East Project Groundwater Impact Assessment, Project No. G1549, December 2011
- AGE, 2012a. Australian Groundwater & Environmental Consultants Memorandum – Predicted Inflows and Drawdown Extents – Saraji East Underground Mine, ref. G1549, dated 24 February 2012
- AGE, 2012b. Review of Groundwater Monitoring Data Saraji Mine, Project No. G1609, December 2012
- AGE, 2013. Annual Review of Groundwater Data and Monitoring Network – 2013 Saraji Mine, Project No. G1609A, October 2013
- ANZECC & ARMCANZ, 2000. Australian and New Zealand Guidelines for Fresh and Marine Water Quality
- Arrow, 2012. Arrow Bowen Gas Project EIS Chapter 14 Groundwater
- Arrow, 2014a. Underground Water Impact Report – For Authority to Prospect 1031, February 2014
- Arrow, 2014b. Underground Water Impact Report – For Authority to Prospect 1103, November 2014
- Barnett, B. et al, 2012. Australian Groundwater Modelling Guidelines, June 2012
- BMA, 2010. Saraji East Coal Mine Project – Baseline Environmental Studies, Draft B 4 June 2010
- BMA, 2011. Saraji East Coal Mine Project – Baseline Environmental Studies, Final Draft 18 February 2011
- BMA, 2012. Saraji East Project Environmental Impact Statement Groundwater Resources – Chapter 7, 19 April 2012
- Department of the Environment and Heritage, 2001. Directory of important wetlands in Australia; third edition
- Department of Natural Resources and Mines registered bore database
- Doherty et al, 1994. PEST Model-Independent Parameter Estimation https://www.epa.gov/sites/production/files/documents/PESTMAN.PDF
- Franks, J.M., Breteton, D., Moran, C.J., Sarker, T. & Cohen, T., 2010. Cumulative Impacts- A Good Practice Guide for the Australian Coal Mining Industry. Centre for Social Responsibility in Mining & Centre for Water in the Minerals Industry, Sustainable Minerals Institute, The University of Queensland
- Gauge, 2015. Annual Groundwater Monitoring Report Saraji Coal Mine June 2015 Gauge Industrial and Environmental Version 1.0 dated 25 June 2015
- IESA, 2011. Monitoring Saraji East Mine Monthly Service Records and Data Reporting, ref doc. SJIENov11
- IESA, 2012. Monitoring Saraji East Mine Monthly Service Records and Data Reporting, ref doc. SJIEMar12
- JBT, 2014. Lake Vermont Northern Extension Groundwater Impact Assessment report prepared by JBT Consulting for AARC on behalf of Bowen Basin Coal Pty Ltd, ref. JBT01-036-001, August 2014

- Mining One, 2011. BMA Saraji East Extension: Packer test Program, ref. 1597_G\2813, dated 27 July 2011
- National Health and Medical Research Council, 2011. Australian Drinking Water Guidelines, updated November 2016
- National Water Commission, 2012. Minimum Construction Requirements for Water Bores in Australia, third edition
- Raymond and McNeil, 2011. Regional Chemistry of the Fitzroy Basin Groundwater. Brisbane: Department of Environment and Resource Management, Queensland Government
- SKM, 2010. High Level Review of Hydrogeological Data, ref. QE09634, dated 7 May 2010
- SKM, 2011. Saraji East Groundwater Sampling and Analysis Plan, ref. QE09816, dated 31 May 2011
- URS, 2012. Report Groundwater Impact Assessment Bowen Gas Project, Ref. 42626960, November 2012
- URS, 2014. Groundwater Chapter for the Dysart Coal Mine Project prepared for Bengal Coal Pty Ltd, ref. 42627233/GW dated 10 February 2014
- Zolfaghar Sepideh, Villalobos-Vega Randol, Cleverly James, Zeppel Melanie, Rumman Rizwana, Eamus Derek, 2014. The influence of depth-to-groundwater on structure and productivity of Eucalyptus woodlands. Australian Journal of Botany 62, 428-437