SARAJI EAST MINING LEASE PROJECT

Environmental Impact Statement

Appendix F-1
Groundwater Technical Report

BHP

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Saraji East Mining Lease Project
BM Alliance Coal Operations Pty Ltd
25-Feb-2019

Groundwater Technical Report

Groundwater Technical Report

Client: BM Alliance Coal Operations Pty Ltd

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Abbreviations

AECOM	AECOM Australia Pty Ltd
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
DES	Department of Environment and Science
DNRME	Department of Natural Resources, Mines and Energy
DEE	Department of the Environment and Energy
DEHP	Department of Environment and Heritage Protection
EA	Environmental Authority
EC	Electrical Conductivity
EIS	Environmental Impact Statement
EP Act	*Environmental Protection Act 1994*
EPP (Water)	Environmental Protection Policy (Water) 2009
EPBC Act	*Environment Protection and Biodiversity Conservation Act 1999*
ERA	Environmentally Relevant Activity
EV	Environmental Value
FCCM	Fort Cooper Coal Measures
Fitzroy Basin WRP	Fitzroy Basin Water Resource Plan 2011
GDE	Groundwater Dependant Ecosystems
GMA	groundwater management area
HCO_3	Bicarbonate
Hg	Mercury
IESC	Independent Expert Scientific Committee
K	Potassium
kh	Horizontal hydraulic conductivity
kv	Vertical hydraulic conductivity
km	kilometre
LTAA	Long-term affected area

LOR	Limit of Reporting
m	metres
MB	Monitoring Bore
mbGL	metres below ground level
MCM	Moranbah Coal Measures
Mg	Magnesium
MIA	Mine Infrastructure Area
ML	Mining Lease
MLA	Mining Lease Application
MNES	Matters of National Environmental Significance
Mtpa	Million tonnes per annum
Na	Sodium
NATA	National Association of Testing Authorities
NO_3	Nitrate
P	Phosphorous
PEST	Parameter Estimation software
RCM	Rangal Coal Measures
RN	Registration number
ROM	Run-of-Mine
Sb	Antimony
Sc	Storativity
SEMLP	Saraji East Mining Lease Project (the Project)
SO_4	Sulfate
Sy	Specific yield
TDS	Total Dissolved Solids
ToR	Terms of Reference
UWIR	Underground Water Impact Report
VWP	Vibrating Wire Piezometer
Water Act	*Water Act 2000*

1.0 Introduction

AECOM Australia Pty Ltd (AECOM) was engaged by BM Alliance Coal Operations Pty Ltd (BMA) to undertake the groundwater environmental assessment in support of an Environment Impact Assessment (EIS) for the Saraji East Mining Lease Project (the Project).

1.1 Project overview

BMA proposes to develop the Project, a greenfield single-seam underground mine development on Mining Lease Application (MLA) 70383 commencing from within Mining Lease (ML) 1775.

The Project proposal also includes a Coal Handling and Preparation Plant (CHPP), a coal transport conveyor network, a Mine Infrastructure Area (MIA), a water pipeline, 66 kilovolt (kV) powerline and a new rail spur and balloon loop; which are proposed to be located on the site of the existing adjacent Saraji Mine. Additionally, a new infrastructure and transport corridor will be constructed on MLA 70383 and MLA 70459.

The Project is expected to mine up to eleven million tonnes per annum (Mtpa) of run-of-mine (ROM) coal and produce up to 8 Mtpa of metallurgical product coal for the export market over a life of approximately 20 years (Financial Year (FY) 2023 to FY 2042).

The current approved mine plan for the adjacent Saraji Mine, an open-cut operation, sees open-cut production across ML 1775 and ML 70142 until approximately 2031.

As a portion of the Project covers an area currently approved for open cut mining (ML 1175), this EIS (and the subsequent approvals required) will offer BMA the flexibility to mine the coal within this area using the most effective and economic mining method. For the purpose of this groundwater assessment, areas of underground mining will take precedence over areas previously identified for open cut extraction on the basis that they can only be mined once using one mining method.

Progressive rehabilitation of disturbed areas following completion of mining and decommissioning of the infrastructure areas is planned and will be undertaken in accordance with the approved environmental authority (EA) conditions.

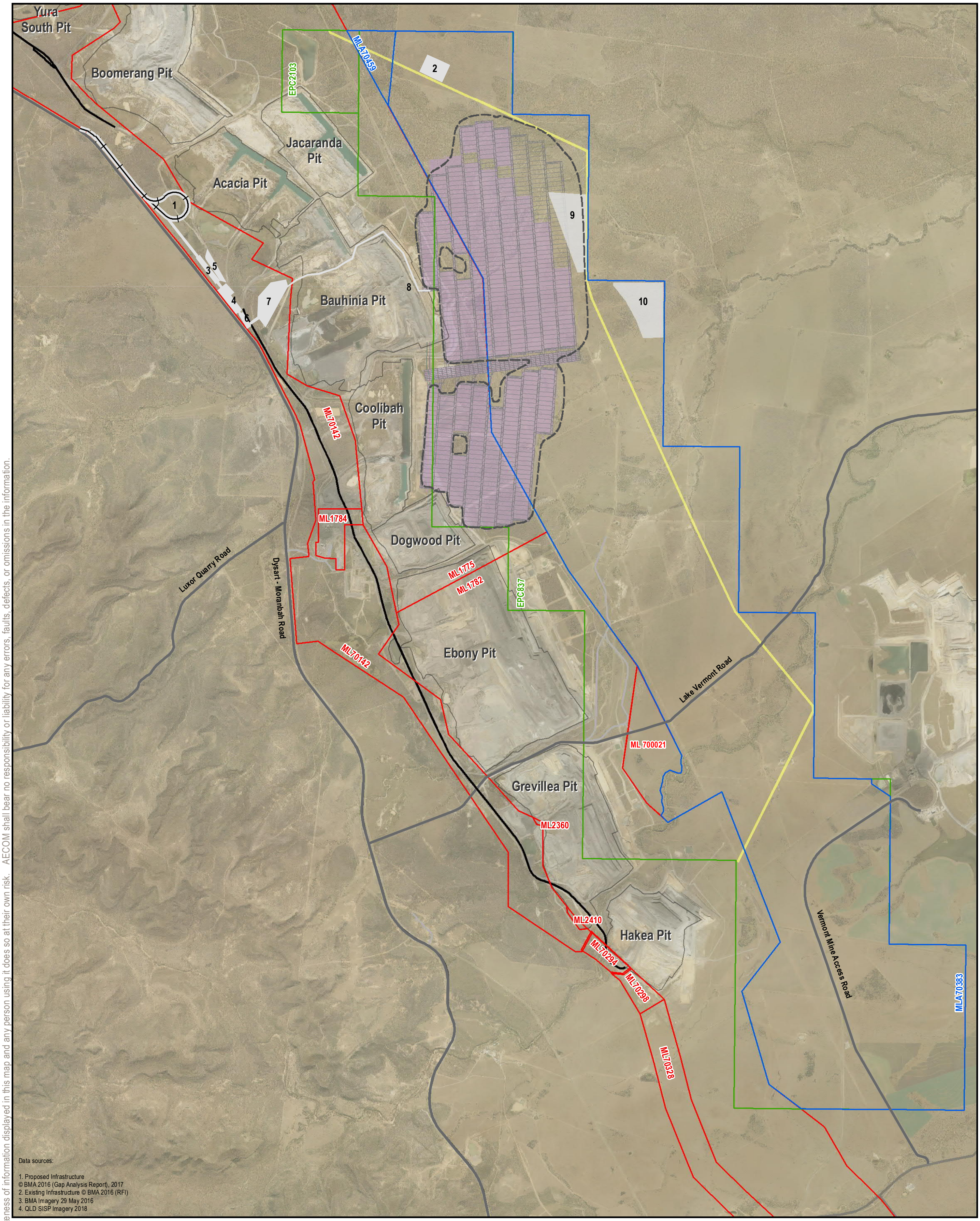
The combined existing approved Saraji Mine and the Project, located approximately 30 kilometres (km) north of Dysart in Central Queensland, are shown in Figure 1. Figure 1 shows the:

- relevant mining tenements
- proposed surface infrastructure and key project elements
- maximised underground layout – a maximised mine layout
- optimised underground layout – a mine layout related to the optimised production schedule for the assumed FY 2042 – FY 2042 period.

For the purposes of this groundwater technical report the Project Area is defined as the area within a 15 km radius of the Project.

This report assesses the potential environmental impacts associated with the underground layout (optimised) and associated FY 2023 to 2042 production schedule. The optimised underground layout was developed based on consideration of a range of factors including resource recovery, coal quality, production rates and site constraints including social and environmental considerations. The optimised underground layout is designed to provide a generally consistent coal quality and production output.

However, to provide a conservative assessment, groundwater modelling was informed by a project footprint based on the potential ground and surface disturbance associated with a maximised underground layout.



LEGEND

- Haul Road
- Public Road
- Rail Loop
- Underground layout (optimised)
- Underground layout (maximised)
- Limit of Subsidence (Maximised)
- Existing Open-Cut Extent
- Transport and Infrastructure Corridor
- Surface Infrastructure

Mining Tenement

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

1 Rail Loading Balloon Loop
2 Process Water Dam
3 Product Stockpiles
4 CHPP
5 Raw Water Dam
6 ROM Pad
7 Future MIA
8 Conveyor
9 Construction Village
10 Operations Village

N

Figure 1
Locality Plan

Groundwater Technical Report
Saraji East Mining Lease Project

0 0.5 1 2
Kilometres

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

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

BHP

DATE: 21/02/2019 VERSION: 0

2.0 Scope of assessment

2.1 Study scope and objectives

The groundwater assessment includes a description of the groundwater resources, an assessment of environmental values, conceptualisation of the groundwater resources and the assessment of potential impacts utilising a predictive groundwater model.

The objectives of the groundwater environmental assessment, in line with the Project's Terms of Reference (EHP, 2017) (ToR) are provided in Table 1 below.

Table 1 Groundwater related Project objectives

Objective	Relevant Terms of Reference Section
1. Identify the environmental values of groundwater within the project area and immediately downstream that may be affected by the project with reference to the Environmental Protection (Water) Policy 2009 and section 9 of the EP Act, including any human uses of the water and any cultural values, as well as the *EIS Information Guideline – Water*	Section 5
2. Define the relevant water quality objectives applicable to the environmental values and demonstrate how these will be met by the project during construction, operation and following completion.	Section 5, 7
3. Detail the chemical, physical and biological characteristics of surface waters and groundwater within the area that may be affected by the project during construction, operation and following completion consistent with the *EIS Information Guideline – Water*.	Section 5.5
4. Provide details of any proposed impoundment, extraction, discharge, injection, use or loss of surface water or groundwater.	Section 6
5. Describe present and potential users and uses of water in areas potentially affected by the project, including municipal, agricultural[2], industrial, recreational and environmental uses of water.	Section 6
6. The EIS must include a specific section responding to the information requirements contained in the *IESC's Information Guidelines for the Independent Expert Scientific Committee advice on coal seam gas and large coal mining development proposals* (Commonwealth of Australia, 2015).	Section 3.1

The description and assessment of groundwater resources are compiled in this technical groundwater report to supplement the EIS submission.

3.0 Legislation and policy

This groundwater technical report has been prepared with consideration to key policies and legislation from the Commonwealth of Australia and the State of Queensland. This section provides an overview of the legislation and policies which are relevant to the Project.

3.1 Federal legislation

3.1.1 Commonwealth *Environment Protection and Biodiversity Conservation Act 1999*

The *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) is the Australian Government's central piece of environmental legislation. It provides a legal framework to protect and manage nationally and internationally important environmental assets, defined in the EPBC Act as matters of national environmental significance (MNES).

The 'water trigger' amendment to the EPBC Act includes water resources as MNES in relation to coal seam gas (CSG) and large coal mining developments. This means that CSG and large coal mining developments require federal assessment and approval if they are likely to have a significant impact on a water resource.

The Department of the Environment and Energy (DoEE), who are responsible for administering the EPBC Act, has determined that the Project has the potential for significant impacts on water resources.

The EPBC Act requires that all CSG and large coal mining developments which are expected to have water-related impacts be referred to the Independent Expert Scientific Committee (IESC) for advice. The EIS for the Project must include a specific section responding to the information requirements in the IESC *Information Guidelines for the Independent Expert Scientific Committee advice on coal seam gas and large coal mining development proposals* (Commonwealth of Australia, 2015). The IESC information requirements checklist relevant to groundwater is presented in Table 2. The EIS must also include a specific section which focusses on MNES including water resources.

The EIS must also include a specific section which focusses on MNES including water resources.

Table 2 IESC Information Requirements Checklist - Groundwater

IESC Specific Information Needs - Groundwater	Section in this Report
Description of the Proposal	
A regional overview of the proposed project area including a description of the geological basin, coal resource, surface water catchments, groundwater systems, water-dependent assets, and past, current and reasonably foreseeable coal mining and CSG developments.	Section 5.0
A description of the statutory context including information on the proposal's status within the regulatory assessment process and on any water management policies or regulations applicable to the proposal.	Section 3.0
A description of the proposal's location, purpose, scale, duration, disturbance area, and the means by which it is likely to have a significant impact on water resources and water-dependent assets.	Sections 1.0 and 4.2
A description of how impacted water resources are currently being regulated under state or Commonwealth law, including whether there are any applicable standard conditions.	Section 3.0
Groundwater – Context and Conceptualisation	
Descriptions and mapping of geology at an appropriate level of horizontal and vertical resolution including: • Definition of the geological sequence/s in the area, with names and descriptions of the formations with accompanying surface geology and cross-sections. • Definitions of any significant geological structures (e.g. faults) in the area and their influence on groundwater, in particular, groundwater flow, discharge or recharge.	Section 5.2
Data to demonstrate the varying depths to the hydrogeological units and associated standing water levels or potentiometric heads, including direction of groundwater flow, contour maps, hydrographs and hydrochemical characteristics (e.g. acidity/alkalinity, electrical conductivity, metals, major ions). Time series data representative of seasonal and climatic cycles.	Section 5.3
Description of the likely recharge, discharge and flow pathways for all hydrogeological units likely to be impacted by the proposed development.	Section 5.3
Values for hydraulic parameters (e.g. vertical and horizontal hydraulic conductivity and storage characteristics) for each hydrogeological unit.	Section 5.3
Assessment of the frequency, location, volume and direction of interactions between water resources, including surface water/groundwater connectivity, inter-aquifer connectivity and connectivity with sea water.	Section 5.3
Groundwater – Analytical and Numerical Modelling	
A detailed description of all analytical and/or numerical models used, and any methods and evidence (e.g. expert opinion, analogue sites) employed in addition to modelling.	Sections 4.3 and 6.0
Undertaken in accordance with the Australian Groundwater Modelling Guidelines[1], 2009), including peer review.	Section 4.3

IESC Specific Information Needs - Groundwater	Section in this Report
Calibration with adequate monitoring data, ideally with calibration targets related to model prediction (e.g. use baseflow calibration targets where predicting changes to baseflow).	Section 4.3.5
Representations of each hydrogeological unit, the thickness, storage and hydraulic characteristics of each unit, and linkages between units, if any.	Sections 4.3.4.3 and 4.3.4.4.
Representation of the existing recharge/discharge pathways of the units and the changes that are predicted to occur upon commencement, throughout, and after completion of the development activities.	Section 4.3
Incorporation of the various stages of the proposed development (construction, operation and rehabilitation) with predictions of water level and/or pressure declines and recovery in each hydrogeological unit for the life of the project and beyond, including surface contour maps.	Section 4.3, 6.2 and 6.3
Identification of the volumes of water predicted to be taken annually with an indication of the proportion supplied from each hydrogeological unit.	Section 6.2.2
An explanation of the model conceptualisation of the hydrogeological system or systems, including key assumptions and model limitations, with any consequences described.	Section 4.3, 4.3.1 and 4.3.7
Consideration of a variety of boundary conditions across the model domain, including constant head or general head boundaries, river cells and drains, to enable a comparison of groundwater model outputs to seasonal field observations.	Section 4.3.4.2.
Sensitivity analysis of boundary conditions and hydraulic and storage parameters, and justification for the conditions applied in the final groundwater model.	Section 6.2.2 and Appendix D
An assessment of the quality of, and risks and uncertainty inherent in, the data used to establish baseline conditions and in modelling, particularly with respect to predicted potential impact scenarios.	Section 4.3.7
A programme for review and update of the models as more data and information become available, including reporting requirements.	Section 7.5
Information on the time for maximum drawdown and post-development drawdown equilibrium to be reached.	Section 6.2
Groundwater – Impacts to Water Resources and Water-Dependent Assets	
An assessment of the potential impacts of the proposal, including how impacts are predicted to change over time and any residual long-term impacts: • Description of any hydrogeological units that will be directly or indirectly dewatered or depressurised, including the extent of impact on hydrological interactions between water resources, surface water/groundwater connectivity, inter-aquifer connectivity and connectivity with sea water. • The effects of dewatering and depressurisation (including lateral effects) on water resources, water-dependent assets, groundwater, flow direction and surface topography, including resultant impacts on the groundwater balance. • Description of potential impacts on hydraulic and storage properties of hydrogeological units, including changes in storage, potential for physical transmission of water within and between units, and estimates of likelihood of leakage of contaminants through hydrogeological units.	Section 6.0

IESC Specific Information Needs - Groundwater	Section in this Report
• Consideration of possible fracturing of and other damage to confining layers. • For each relevant hydrogeological unit, the proportional increase in groundwater use and impacts as a consequence of the development proposal, including an assessment of any consequential increase in demand for groundwater from towns or other industries resulting from associated population or economic growth due to the proposal.	
Description of the water resources and water-dependent assets that will be directly impacted by mining or CSG operations, including hydrogeological units that will be exposed/partially removed by open cut mining and/or underground mining.	Section 6.3
For each potentially impacted water resource, a clear description of the impact to the resource, the resultant impact to any water-dependent assets dependent on the resource, and the consequence or significance of the impact.	Section 6.3
Description of existing water quality guidelines and targets, environmental flow objectives and other requirements (e.g. water planning rules) for the groundwater basin(s) within which the development proposal is based.	Section 5.5
An assessment of the cumulative impact of the proposal on groundwater when all developments (past, present and/or reasonably foreseeable) are considered in combination.	Section 6.3.2
Proposed mitigation and management actions for each significant impact identified, including any proposed mitigation or offset measures for long-term impacts post mining.	Section 7.0
Description and assessment of the adequacy of proposed measures to prevent/minimise impacts on water resources and water-dependent assets.	Section 7.0
Groundwater – Data and Monitoring	
Sufficient physical aquifer parameters and hydrogeochemical data to establish pre-development conditions, including fluctuations in groundwater levels at time intervals relevant to aquifer processes.	Section 5.3
A robust groundwater monitoring programme, utilising dedicated groundwater monitoring wells and targeting specific aquifers, providing an understanding of the groundwater regime, recharge and discharge processes and identifying changes over time.	Sections 5.3 and 7.0
Long-term groundwater monitoring, including a comprehensive assessment of all relevant chemical parameters to inform changes in groundwater quality and detect potential contamination events.	Sections 5.3 and 7.0
Water quality monitoring complying with relevant National Water Quality Management Strategy (NWQMS) guidelines[2] and relevant legislated state protocols[3].	Sections 5.3 and 7.0
Cumulative Impacts – Context and Conceptualisation	
Cumulative impact analysis with sufficient geographic and time boundaries to include all potentially significant water-related impacts.	Section 6.3.2
Cumulative impact analysis identifies all past, present, and reasonably foreseeable actions, including development proposals, programs and policies that are likely to impact on the water resources of concern.	Section 6.3
Cumulative Impacts – Impacts	

IESC Specific Information Needs - Groundwater	Section in this Report
An assessment of the condition of affected water resources which includes: • Identification of all water resources likely to be cumulatively impacted by the proposed development. • A description of the current condition and quality of water resources and information on condition trends. • Identification of ecological characteristics, processes, conditions, trends and values of water resources. • Adequate water and salt balances. • Identification of potential thresholds for each water resource and its likely response to change and capacity to withstand adverse impacts (e.g. altered water quality, drawdown).	Section 6.0
An assessment of cumulative impacts to water resources which considers: • The full extent of potential impacts from the proposed development, including alternatives, and encompassing all linkages, including both direct and indirect links, operating upstream, downstream, vertically and laterally. An assessment of impacts considered at all stages of the development, including exploration, operations and post closure / decommissioning. • An assessment of impacts, utilising appropriately robust, repeatable and transparent methods. • Identification of the likely spatial magnitude and timeframe over which impacts will occur, and significance of cumulative impacts. • Identification of opportunities to work with others to avoid, minimise or mitigate potential cumulative impacts.	Section 6.0
Cumulative Impacts – Mitigation, Monitoring and Management	
Identification of modifications or alternatives to avoid, minimise or mitigate potential cumulative impacts	Section 7.0
Identification of measures to detect and monitor cumulative impacts, pre and post development, and assess the success of mitigation strategies	Section 7.0
Identification of cumulative impact environmental objectives.	Section 7.0
Appropriate reporting mechanisms.	Section 7.0
Proposed adaptive management measures and management responses.	Section 7.0

[1] Barnett et al, 2012.

[2] ANZECC & ARMCANZ, 2000.

[3] DEHP, 2009.

3.2 Queensland legislation

3.2.1 Water Act 2000

General

The *Water Act 2000* (Water Act) provides for the sustainable management of water and the management of impacts on underground water and for other purposes. The main purposes of the Water Act are to provide a framework for the following:

- sustainable management of Queensland's water resources by establishing a system for the planning, allocation and use of water;
- sustainable and secure water supply and demand management for the south-east Queensland region and other designated regions;
- management of impacts on underground water caused by the exercise of underground water rights by the resource sector; and
- effective operation of water authorities.

The Water Act covers water in a watercourse, lake or spring, underground water (or groundwater), overland flow water, or water that has been collected in a dam.

Water Act and Underground Water Management

The Water Act provides for the management of impacts on underground water caused by the exercise of underground water rights by resource tenure holders.

Chapter 3 of the Water Act has a stated purpose to provide for the management of impacts on underground water caused by the exercise of underground water rights by resource tenure holders.

BMA, as a resource operator, has the right to take associated water under the *Mineral Resources Act 1989* (MR Act) as a necessary activity in the process of extracting the resource. BMA has an obligation to comply with the underground water management framework under the Water Act.

To achieve the stated purpose, a regulatory framework is provided which requires the following:

- resource tenure holders monitor and assess the impacts of the exercise of underground water rights on water bores and to enter into make good agreements with the owners of the groundwater bores as necessary;
- the preparation of underground water impact reports (UWIR) that establish underground water obligations, including obligations to monitor and manage impacts on aquifers and springs; and
- manage the cumulative impacts of the activities of two or more resource tenure holders' underground water rights on underground water.

Section 362 of the Water Act refers to bore trigger thresholds. The bore trigger threshold is the maximum allowable groundwater level decline in a groundwater bore, due to the exercise of resource tenure holders' underground water rights, prior to triggering an investigation into the water level decline. The bore trigger threshold for consolidated aquifers is five metres (m) and for unconsolidated aquifer it is two metres.

Provided the underground water management framework under is complied with, Section 334ZP of the MR Act gives resource operators the right to take 'associated water' as a necessary activity in the process of extracting the resource. The volume of any 'associated water' taken must be measured and reported, with the Chief Executive of the DNRME notified within three months of the initial taking.

BMA will seek an EA with a condition permitting the impacts to groundwater, which will include the preparation of a UWIR and associated consultation.

3.2.2 Environmental Protection Act 1994

The *Environmental Protection Act 1994* (EP Act) has the objective to protect Queensland's environment while allowing for development that improves the total quality of life, both now and in the future, in a way that maintains ecological processes on which life depends i.e. ecologically sustainable development.

BMA is applying for a new site-specific EA for the Project. The Department of Environment and Science (DES), who are responsible for the administration and regulation of resource activities under the EP Act, has confirmed that the Project requires assessment through an EIS.

Environmental values

The EP Act defines an environmental value (EV) as:

- a quality or physical characteristic of the environment that is conducive to ecological health or public amenity or safety; or
- another quality of the environment identified and declared to be an environmental value under an environmental protection policy or regulation.

3.3 Policies, plans and guidelines

3.3.1 Environmental Protection (Water) Policy 2009

Under the EP Act, the Environmental Protection (Water) Policy 2009 *(*EPP (Water)) is established as subordinate legislation to achieve the objective of the EP Act in relation to Queensland waters. The purpose of the EPP (Water) is achieved by the following:

- identifying environmental values and management goals for Queensland waters;
- stating water quality guidelines and water quality objectives to enhance or protect the environmental values;
- providing a framework for making consistent, equitable and informed decisions about Queensland waters; and
- monitoring and reporting on the condition of Queensland waters.

Environmental values relevant to the Project are presented in detail in Section 5.5 of this report.

3.3.2 Water Plan (Fitzroy Basin) 2011

Water plans have been developed under the Water Act to sustainably manage and allocate water resources in Queensland. The Project is located within the Isaac Connors Groundwater Management Area (GMA) as defined in Schedule 3 of the Water Plan (Fitzroy Basin) 2011.

With the Isaac Connors GMA, water licences and/or development permits are not required for stock and domestic bores, generally groundwater monitoring bores are also excluded from the requirement for development permits.

Other groundwater-related activities, such as drilling of test pumping bores and undertaking pumping tests, require authorisation (by way of permits), as well as a development permit to allow drilling and construction of water bores. Any long-term water take or interference from groundwater sources requires authorisation by way of a licence. The Project will require a water licence for groundwater interfered with as a result of mining activities.

4.0 Methodology

The groundwater impact assessment comprises two components - a description of the existing hydrogeological environment, and an assessment of the impacts of mining on that environment. The groundwater assessment was divided between four stages, these being:

Description of existing environment:

Stage 1 – data review

- included review of historical groundwater studies undertaken for the Project, groundwater management reports for the existing Saraji Mine operations, and publicly available data from bores on the surrounding agricultural land.

Stage 2 – update of geological and groundwater baseline conditions

- updated the existing geological and groundwater baseline descriptions and conceptualisation of current groundwater resources (previously compiled for the Grevillea Open-Cut Extension Project).

Impact assessment:

Stage 3 – impact assessment

- included construction of a groundwater flow numerical model to assess and predict groundwater seepage rates to the mine and evaluate the potential impact of the Project.

Stage 4 – reporting

- documenting the findings of the study in this report.

4.1 Data sources and historical studies

A groundwater impact assessment for underground longwall mining for the Project was previously undertaken by AGE (2011) using a now outdated mine plan and schedule. Predicted inflows to the underground mine workings and drawdown extents were further reported by AGE (2012b).

Several previous groundwater studies have been undertaken at the adjacent Saraji Mine. Most recently, a groundwater technical report was prepared by AECOM (2016) to support an amendment to the Saraji Mine EA to include an extension of the existing open-cut Grevillea Pit. Other investigations at the Saraji Mine have largely focussed on addressing groundwater issues related to geotechnical and dewatering feasibility studies, characterisation of the hydrogeological regime, and review of groundwater monitoring and water quality data.

Key reports reviewed for the groundwater impact assessment (specific to the Saraji Mine) included the following:

- AECOM (2016). Saraji Open-Cut Extension Project – Groundwater Technical Report.
- AGE (2013). Annual Review of Groundwater Data and Monitoring Network – 2031 - Saraji Mine.
- AGE (2012a). Review of Groundwater Monitoring Data – Saraji Mine, dated December 2012.
- AGE (2012b). Australian Groundwater & Environmental Consultants Memorandum – Predicted Inflows and Drawdown Extents – Saraji East Underground Mine, dated 24 February 2012.
- AGE (2011). Report on Saraji East Project Groundwater Impact Assessment.
- AGE (2007). Report on Hydrogeological Regime and Impact Assessment - Saraji Mine.
- Gauge (2016). Annual Groundwater Monitoring Report - Saraji Coal Mine - September 2016.
- Gauge (2015). Annual Groundwater Monitoring Report - Saraji Coal Mine - June 2015.
- IESA (2011a). Saraji East Mine Stygofauna Survey Report – September 2011.
- IESA (2011b). Saraji East Mine Stygofauna Survey Report – December 2011.

- Mining One (2011). BMA Saraji East Extension: Packer Test Program.
- Minserve, 2017. Subsidence over Longall Panels – Saraji East Underground Mine, February 2017. Prepared for AECOM Australia Pty Ltd.

The above reports and associated data were reviewed to refine understanding of the hydrogeological system within and surrounding the Project Area. For the purposes of this groundwater technical report the Project Area is defined as the area within a 15 km radius of the Project.

Numerous reports have also been undertaken for nearby mining projects. The following additional publicly available reports from nearby projects were also reviewed to gain an appreciation of the regional groundwater system within the Project Area:

- Arrow (2012). Arrow Bowen Gas Project EIS - Chapter 14 – Groundwater.
- JBT (2014). Lake Vermont Northern Extension Groundwater Impact Assessment.
- URS (2014). Groundwater Chapter for the Dysart Coal Mine Project prepared for Bengal Coal Pty Ltd, ref. 42627233/GW dated 10 February 2014.
- URS (2012). Report Groundwater Impact Assessment Bowen Gas Project.
- URS (2009). Caval Ridge Groundwater Impact Assessment.

4.2 Mine plan assessment

The Project is a single-seam operation involving extraction of the Dysart Lower (D14 / D24) seam.

This assessment is informed by groundwater modelling undertaken based on a maximised underground layout which relates to the maximum limit of predicted subsidence as estimated by subsidence modelling (Minserve, 2017). This approach incorporates a 19 year production schedule which spatially relates to the maximised mine plan. The mine plan for the Project is shown in Figure 2. The groundwater modelling has been undertaken based on a maximised spatial footprint which relates to the limit of subsidence (refer Figure 2) (herein referred to as the maximised footprint). It is considered that the use of the maximised footprint allows for a conservative assessment which considers the largest potential impacts of mining on the groundwater resources.

The assessment considers the potential for goaf alteration resulting from longwall mining, as estimated in the subsidence modelling (Minserve, 2017). The subsidence assessment considers the potential subsidence related impacts of mining the Dysart Lower seam (within the Mining Leases (MLs) and Mining Lease Applications (MLAs)).

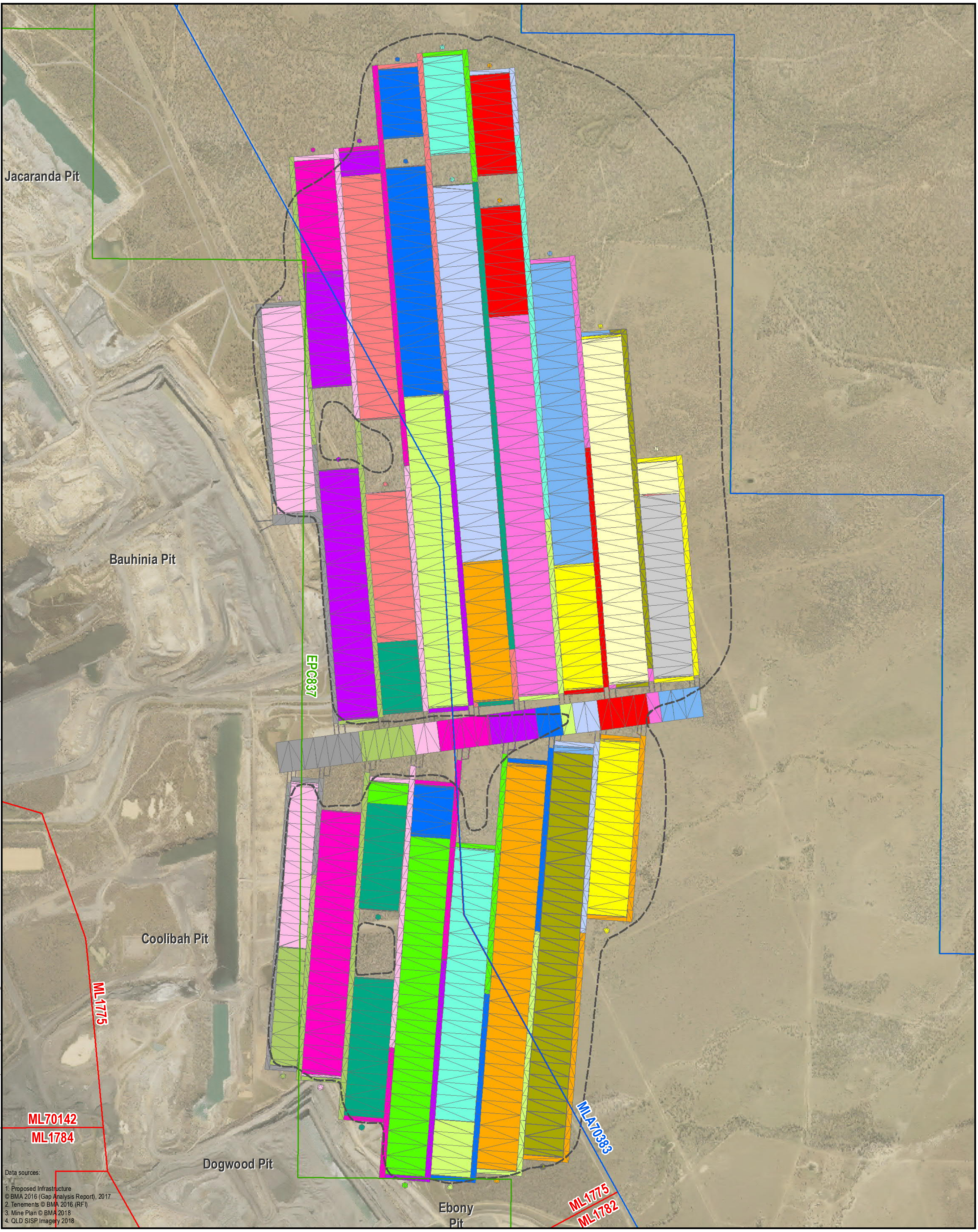
Coal will be mined by longwall methods consisting of a northern region of panels and a southern region of panels separated by a portal which will be progressively mined out and developed as mining progresses. Panels within the northern region will be oriented northwest-southeast whilst panels in the southern section will be oriented northeast-southwest.

Mining will commence from the western end within ML 1775, adjacent to the existing Saraji open-cut operations, and progressing towards the east into MLA 70383.

The approved Saraji open-cut mine plan (Figure 3), shows that open-cut operations, which extract coal seams to the Dysart Lower seam, are expected to continue until 2031 (in some pits reaching the ML boundary). This means that the proposed underground mining and approved open-cut mining will occur concurrently on the Project site between 2023 and 2031 i.e. an eight year overlap.

It is noted that in areas where there are both open-cut mining and underground mining proposed (overlap presented in Figure 4), the sections of open-cut have been removed and replaced by underground mining only. Figure 4 illustrates the overlap between the approved Saraji Mine open-cut mining and the maximised footprint.

The overlap and alteration from open-cut to underground is included in Figure 5.



LEGEND

Optimised Mine Plan

Year 1
Year 2
Year 3
Year 4
Year 5
Year 6
Year 7
Year 8
Year 9
Year 10
Year 11
Year 12
Year 13
Year 14
Year 15
Year 16
Year 17
Year 18
Year 19
Year 20

Mining Tenement

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

Limit of Subsidence (Maximised)

N

Figure 2
Mine Plan

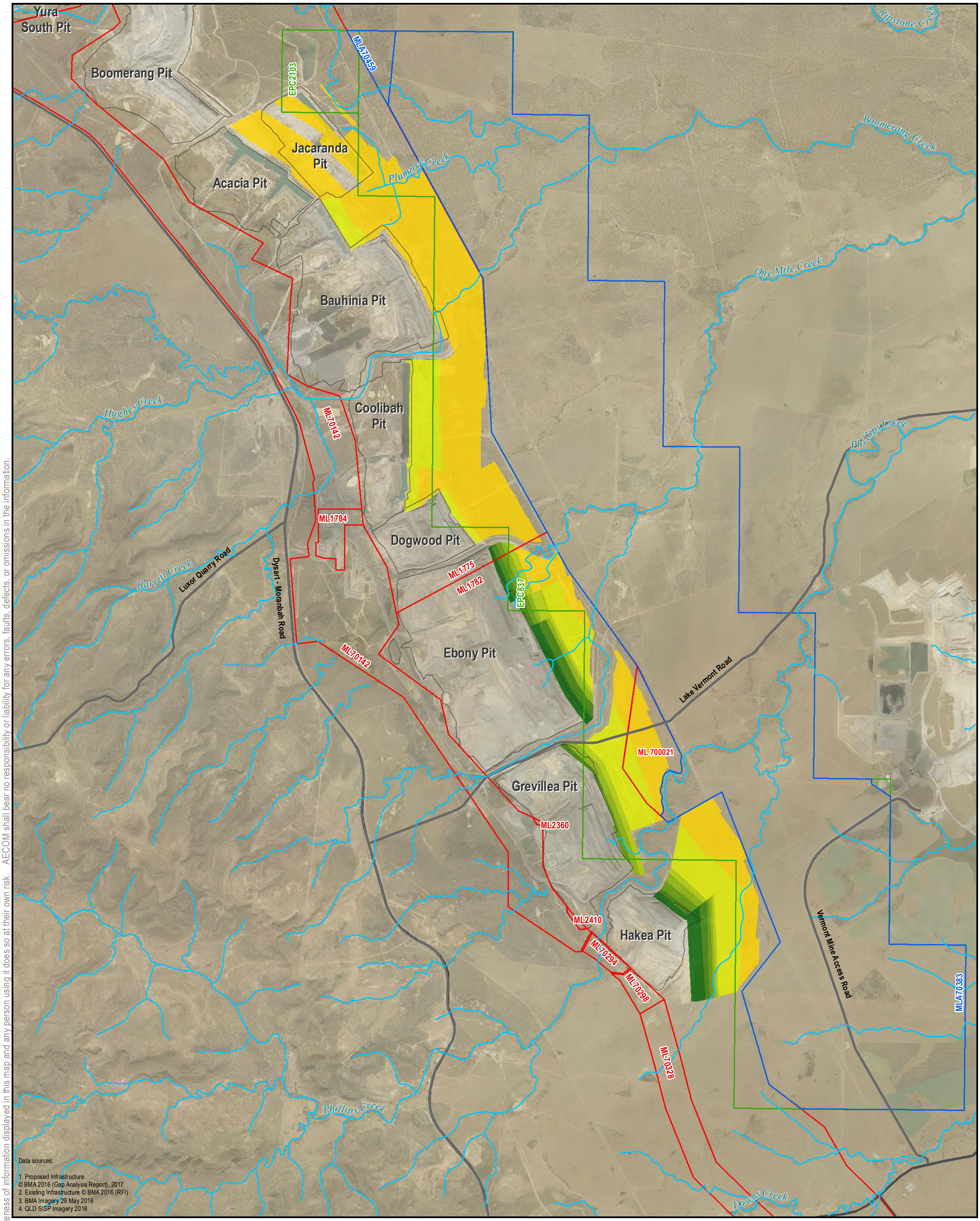
Groundwater Technical Report
Saraji East Mining Lease Project

0 0.25 0.5 1
Kilometres

Scale: 1:40,000 (when printed at A4)
Projection: Map Grid of Australia - Zone 55 (GDA94)

BHP

DATE: 21/02/2019 VERSION: 1



LEGEND

- Watercourse
- Public Road
- Existing Open-Cut Extent

Conceptual Mine Plan

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

Mining Tenement

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

N

Figure 3
Approved Saraji Open-cut Mine Plan

Groundwater Technical Report
Saraji East Mining Lease Project

0 0.5 1 2
Kilometres

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

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

BHP

DATE: 23/04/2019 VERSION: 0

Filename: P:\605X\60507031\4. Tech Work Area\4.99 GIS\02_MXDs\06 Environmental Impact Statement\F-1 Groundwater Technical Report\60507031_G192_v0_A4P.mxd

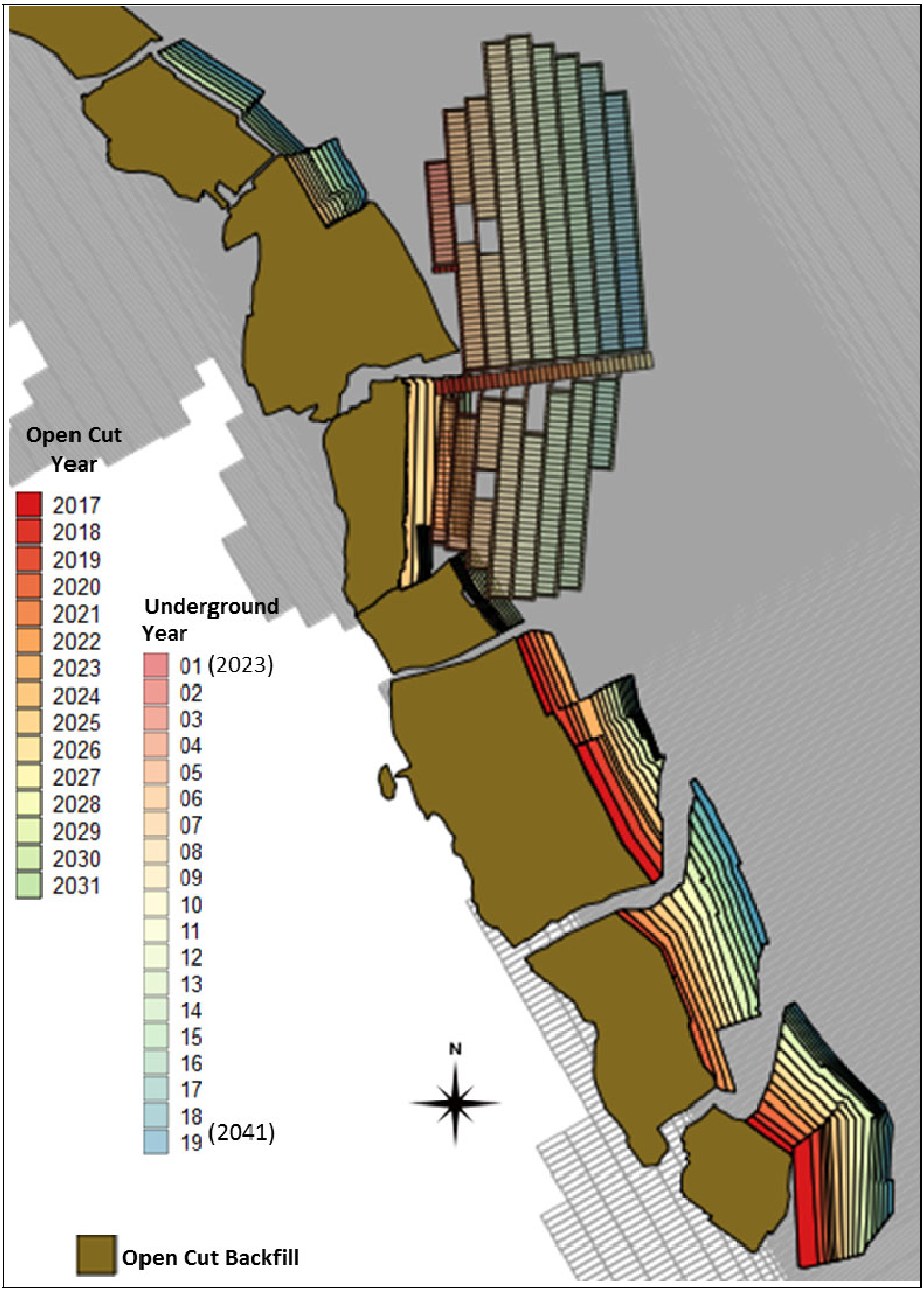


Figure 4 **Underground mine panels (maximised) and the Saraji Mine open-cut pit mining sections per year**

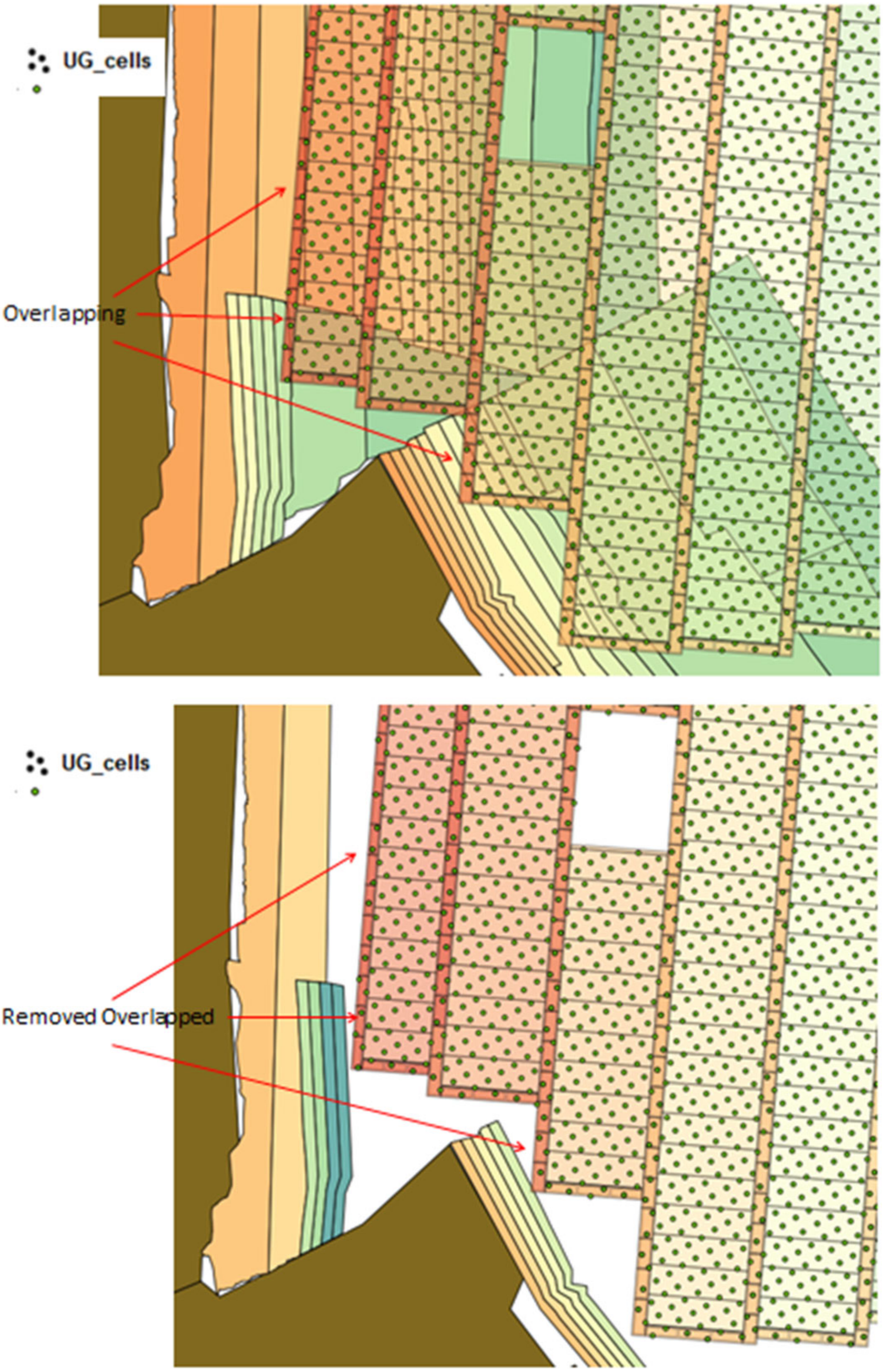


Figure 5 Overlap of mining techniques

4.2.1 Groundwater assessment approach considering existing and proposed mining

Groundwater impacts from the approved open-cut operations were previously modelled by AECOM (2016) with results showing groundwater drawdown contours extending into the footprint of the proposed underground workings.

Given that the underground mine and open-cut mine are intrinsically linked through drawdown contour overlap, operational scheduling overlap and proximity, impacts from underground mining were assessed by simulating continuous operation of the open-cut (albeit a revised open-cut mine plan to facilitate the underground mining on the MLs in Figure 4) and underground mining operations. This approach means that drawdown contours and impacts from underground mining can be considered as cumulative impacts with the Saraji Mine open-cut mining.

4.3 Groundwater modelling

Predictive groundwater modelling was conducted to assess the potential impacts of the proposed longwall mining. The modelling looked at mine dewatering impacts (groundwater ingress and groundwater level drawdown) considering the approved Saraji Mine open-cut workings 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.

The objective of groundwater modelling was to produce a tool that can suitably represent the current conceptual understanding of the groundwater systems within the Project Area and predict changes in groundwater conditions due to the Project.

The existing AGE finite difference numerical groundwater model (2012), utilised and refined by AECOM (2016), was further refined as part of this assessment to assess the potential impacts from the proposed underground mining.

The predictive groundwater modelling objectives were to:

- estimate groundwater ingress into the mine over the life of the proposed underground mine
- predict the zone of influence on pre-Project groundwater levels (due to mine dewatering), including the level and rate of drawdown at specific locations
- predict the impact of mine dewatering on groundwater discharges and existing groundwater users
- assess groundwater level recovery and long-term groundwater flow patterns after cessation of the underground mining.

4.3.1 Conceptual model

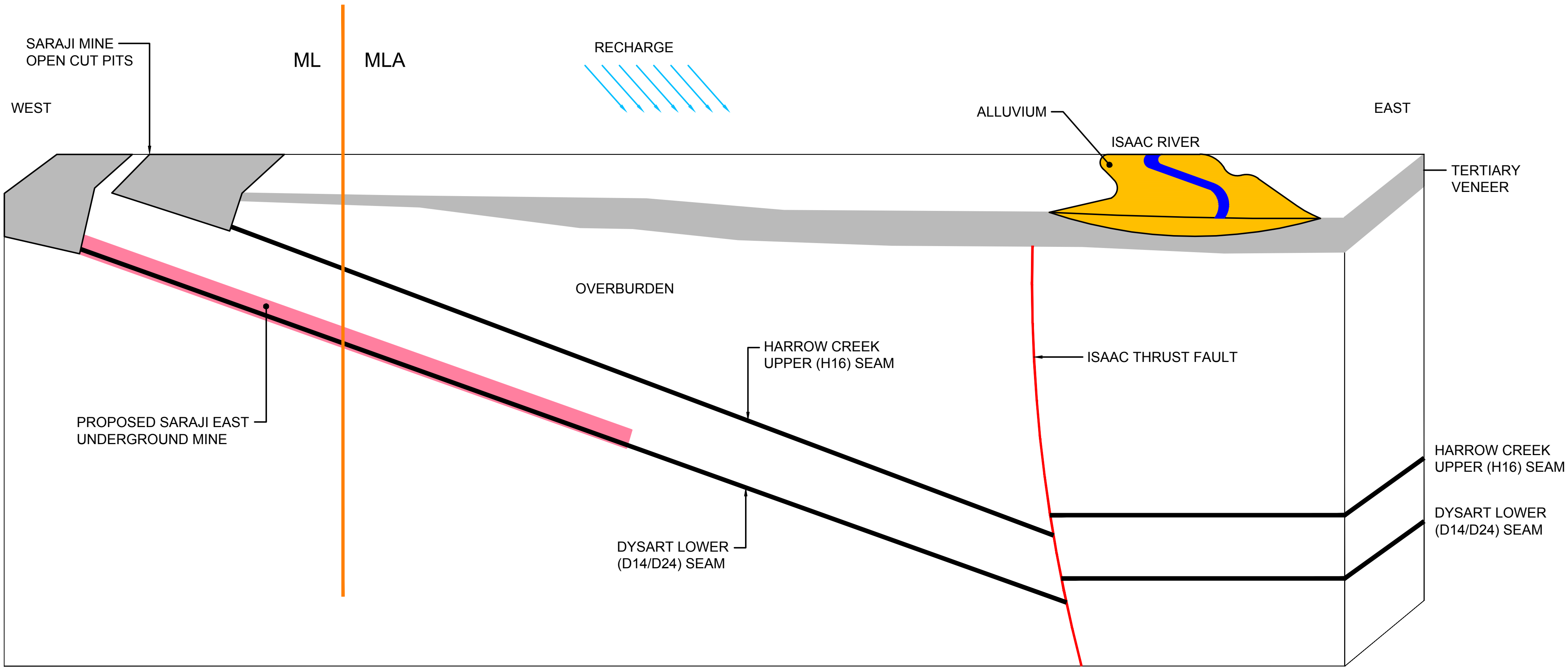
The existing information and field data were used to develop a conceptual understanding of the groundwater regime(s) across the Project Area.

A conceptualised west to east cross-section showing the proposed underground mine in relation to the regional geological setting is shown in Figure 6.

The data used to develop the conceptualisation indicates two separate groundwater systems occur within the Project Area; these aquifer systems are associated with the following geological units:

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

Figure 7 shows the hydrogeological conceptualisation of the Project Area.

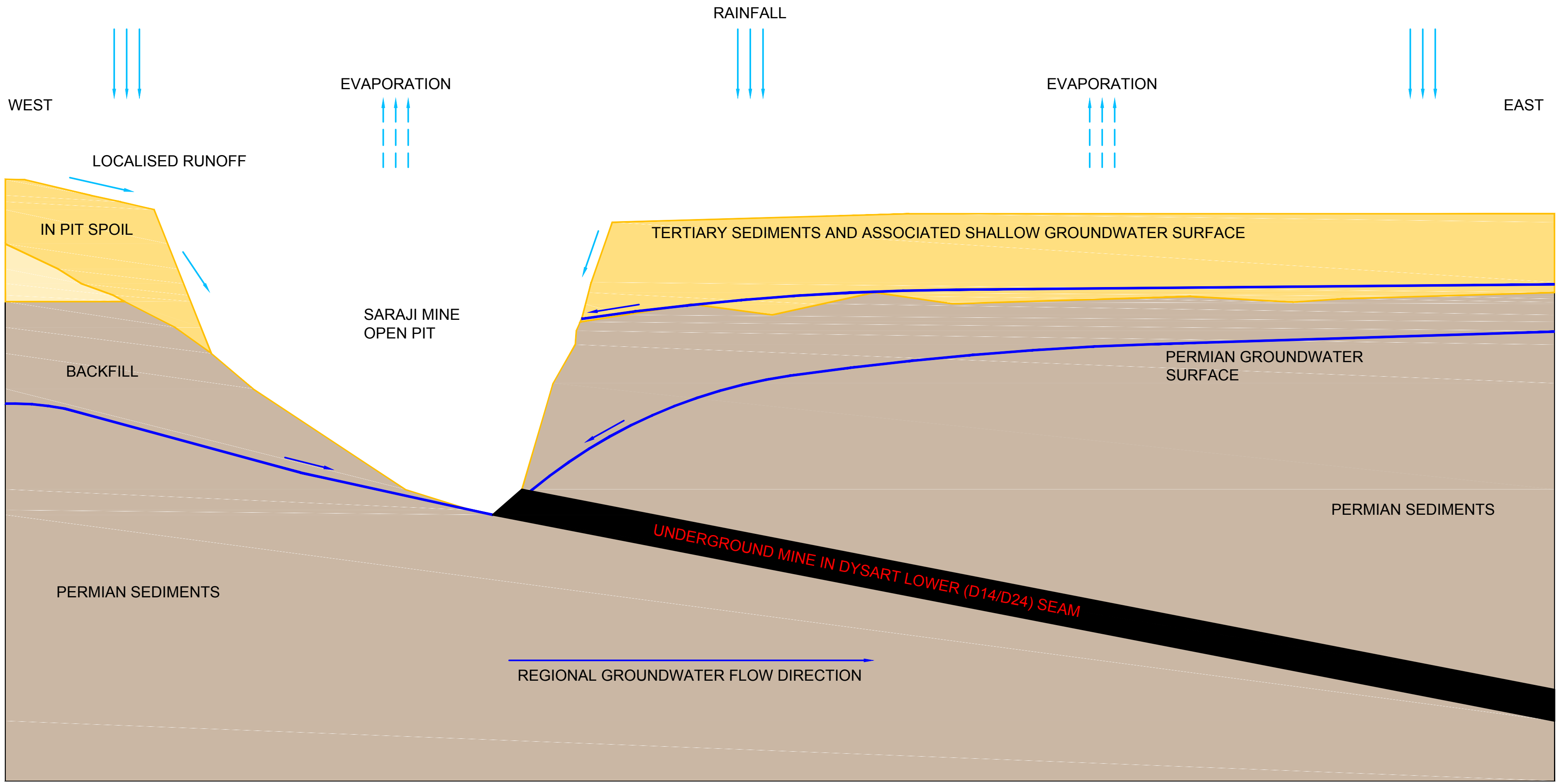


NOT TO SCALE

SARAJI APPROVALS

CONCEPTUAL WEST TO EAST REGIONAL CROSS SECTION OF THE UNDERGROUND MINING

FIGURE 6



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SARAJI APPROVALS
CONCEPTUAL GROUNDWATER MODEL

FIGURE 7

Key understandings from the conceptualisation include the following:

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-cut 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 indicates lower groundwater levels to the east even though the permeability decreases with depth (Section 5.3.7.3). It is considered that faulting facilitates more complex groundwater movement to the east of the Project Area.

The development of the numerical model was based on the conceptual understanding.

4.3.2 Predictive simulations

The calibrated groundwater model was utilised to assess potential impacts of the Project on groundwater resources. Evaluation of groundwater level drawdown in the target Dysart Lower coal seam (Layer 10), Harrow Creek coal seam (Layer 6) and overlying Tertiary and Quaternary sediment (Layer 1) was undertaken.

As discussed in Section 4.2.1, all model predictions of underground mining impacts also included simulation of the approved Saraji Mine open-cut operations (including the Grevillea Pit extension) as previously undertaken by AECOM (2016) and shown in the open-cut mine plan (Figure 3).

As there was overlap between the approved open-cut mine plan and the proposed underground mine plan, the open-cut mine plan was modified for simulation of underground mining activities by removing those open-pit mining areas which overlapped with the proposed underground workings (Section 4.2); the justification being that these areas cannot be mined by open cut mining methods if they are being mined using the underground mining methods. The modifications to the open-cut mine plan are shown in Figure 4 and Figure 5.

The simulation timings were undertaken as per Table 3.

Table 3 Simulation timings

Model Year	Simulation
1	Open-cut mining commence
5.5	Commence gas drainage
6.5	Commence underground mining
15	Stop open-cut mining
24.5	Stop underground mining
75.5	50 years of recovery (post mining)

The predictive model simulations included the following:

- predictions of groundwater levels at the end of life of the proposed underground mining operations (Model layers 1, 6, and 10)
- predictions of groundwater level recovery in observation holes to assess rebound within underground workings noting that final void dewatering is ongoing at Saraji Mine
- the prediction of groundwater ingress into the approved Saraji Mine open-cut operations (including Grevillea Pit) with and without the proposed underground mining, allowing for the estimate of groundwater ingress into the underground mine.

4.3.2.1 Groundwater level drawdown

Initial (2016) groundwater levels were established throughout the model domain from the model calibration (i.e. groundwater levels measured and calibrated in 2012 by AGE were projected, using the Saraji Mine open-cut mine and backfill sequence plus open-cut sizes and water levels, to 2016 for use as initial heads in the model). The groundwater model was then used to simulate changes in initial groundwater levels in response to the approved open-cut and proposed underground mining plans. To facilitate the more accurate assessment of impacts the mining operations were divided and simulated at three monthly intervals (i.e. the model time step was three months).

As per the AECOM (2016) model, backfilling of the open-cut pits was simulated to occur after one year, allowing for the change in model layer parameters, as detailed in Table 8.

The combination of backfill of open-cut pits (recharge), open-cut workings (dewatering), and underground workings (goaf alteration and dewatering) were simulated to allow for the evaluation of groundwater levels in response to complex mining operations.

4.3.2.2 Bore trigger thresholds

Sections 376(b)(iv) and 376(b)(v) of the Water Act refer to bore trigger thresholds in relation to Underground Water Impact Reports (UWIR). 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).

To align with the requirements of the Water Act in relation to UWIRs, groundwater drawdown contours were produced to be consistent with the bore trigger thresholds as follows:

- The Quaternary/Tertiary sediments (model layer 1) are unconsolidated and thus two metre drawdown contours were produced which is consistent with the bore trigger threshold for unconsolidated sediments.
- The Permian sediments (model layers 6 and 10) are consolidated and thus five metre drawdown contours were produced which is consistent with the bore trigger threshold for consolidated sediments.

The two and five metre triggers relate to change in groundwater levels from the initial groundwater levels at the start of model predictions (i.e. pre-activities).

4.3.3 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 for the Project.

SURFACT is capable of simulating unsaturated conditions, which is critical for the requirements of the proposed underground coal mine where panels 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.

4.3.4 Modelling method

Modelling was undertaken in several stages as follows:

- Review the existing AECOM (2016) SURFACT model.
- Assess existing data compiled since the existing model was constructed and calibrated in 2016, including additional mining, DNRME registered bore data, and groundwater monitoring.
- Review the existing open-cut mining areas, pit depths, and backfill areas.
- Include the proposed underground mine plan and scheduling.
- Run model predictions and ingress estimates for the proposed underground mining through assessing scenarios of the approved open-cut mining with and without the Project (noting that the approved open-cut mining will continue and this mining will result in changing groundwater levels and resources over time, thus to best assess the impacts of the Project, the Project was added to the open-cut mining to allow for a comparison of scenarios and assessment).

4.3.5 Model and refinement

4.3.5.1 Model geometry

The model domain comprised 94,292 active cells aligned in 417 rows and 213 columns. The cell sizes range in size from 50 m x 50 m up to 500 m x 500 m.

The model extent was 30.5 km x 40.5 km, covering an area of approximately 1,235 km^2.

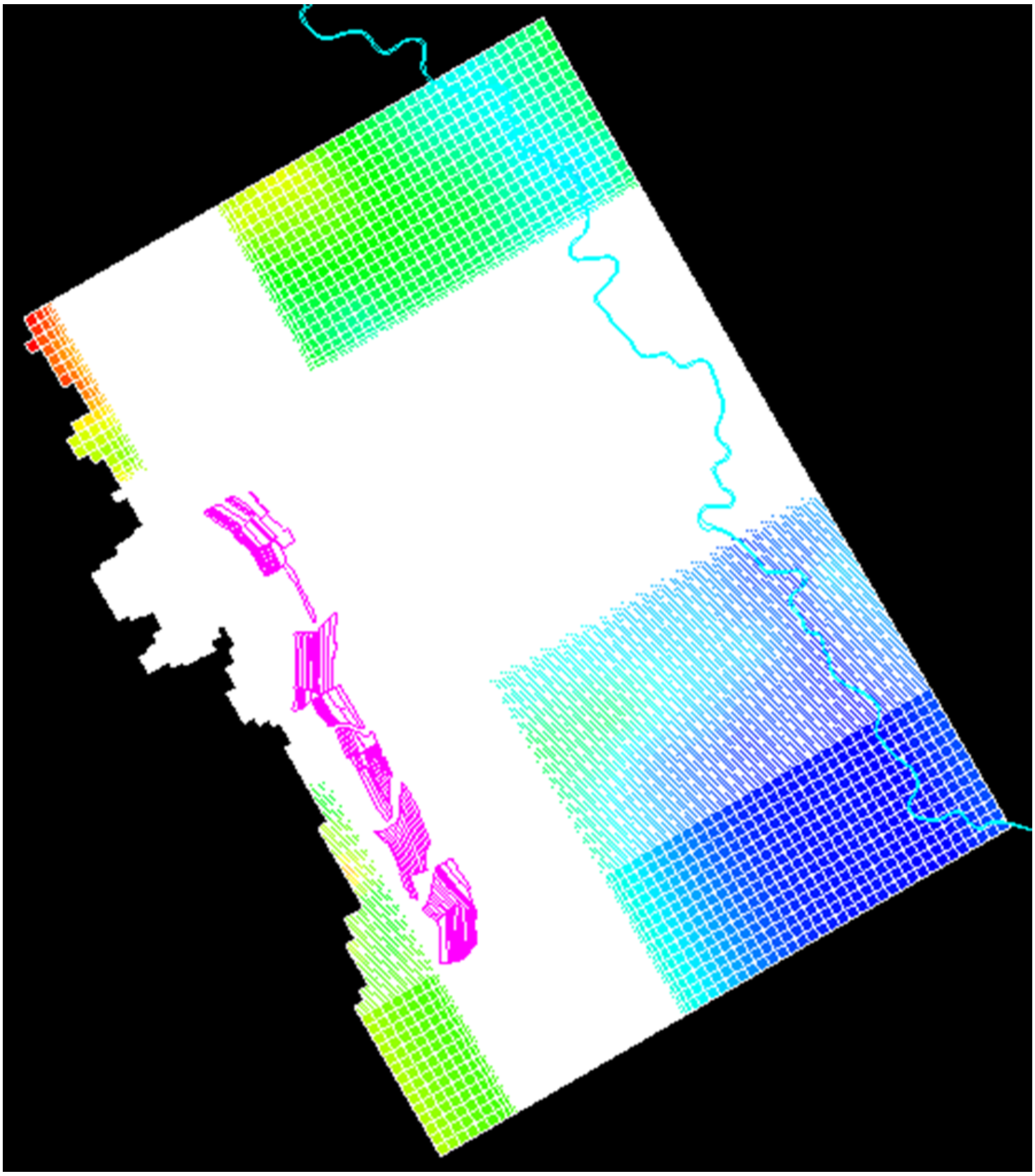


Figure 8 Model Domain Grid and Extent

4.3.5.2 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 because 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 proposed mining area.

The major surface drainage alignment in the model area is the Isaac River which runs in a south south-east 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 underground and open-cut mining areas so as not to markedly influence model predictions.

Except for 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 4.3.5.3).

4.3.5.3 Model layers

The structure of the coal seams within the Project Area 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.

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 4.

Table 4 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.

4.3.5.4 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 (exponential equations) of the coal seams with depth (Section 5.3.7.3) was used for the Harrow Creek and Dysart coal seams.

4.3.5.5 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 4.3.6).

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. Using drains involved the setting of a reference (drain target) elevation (base of the target Dysart Lower (D14 / D24) seam and a conductance (leakage) term.

4.3.5.6 Impacts of longwall mining - goaf

To estimate mine impacts and estimates of groundwater ingress from underground longwall mining activities, aquifer alteration due to goaf was taken into consideration.

Longwall mining results in collapse of the overlying rock strata into the void left by coal extraction. The collapsed or disturbed overburden material is referred to as goaf. The collapse propagates upwards from the extracted seam until bulking of the goaf limits vertical movement and the tensile strength of the rock is sufficient to hold up the overburden without failure. Where propagation extends to the land surface, subsidence of the land surface occurs.

Kendorski (1993) defines five zones in the goaf as shown in shown in Figure 9 and described below:

- Caved Zone: This is the zone of complete disruption of broken and rubble-sized strata extending from 2 to 10 times the seam thickness, in height above the caving roof.
- Fractured Zone: This zone occurs above the caved zone to a height of 24 to 30 times the seam thickness. The strata do not fall and detach but cracks and settles, resulting in fractures extending through individual beds, opening of bedding planes and shearing and dislocation of beds. The caved and fractured zones have increased vertical and horizontal transmissivity and storativity and both attributes decrease exponentially with height above the seam roof.
- Dilated Zone: This zone is often referred to as the “Aquiclude Zone”. In this zone the strata sag allows bed separations, but not connecting fracturing and drainage into the mine. It occurs at a height of 30 to 60 times the seam thickness. The water level of aquifers located in this zone may be lowered in response to the relatively rapid increases in void space laterally, but the water level generally recovers given sufficient time, as the voids are filled.
- Constrained Zone: This zone occurs where the extracted seam is deeper than 60 times the seam thickness plus about 15 m and is characterized by overall tensile strains of less than 1 mm/m, a stress level at which rock masses are not disrupted sufficiently to increase their permeability. Hence there is no significant change in transmissivity or storativity, and therefore aquifers which occur in this zone, are largely unaffected.
- Surface Fracture Zone: The surface fractures generally relate to panel and trough edges and extend to a depth of about 15 m. If transmitted into soils, the soil properties may allow little or no crack development due to the plastic and non-brittle nature of many soils. If in rock, the natural pre-existing fracturing will be dilated, having little effect on continuity. The cracks are transmissive zones and the increased void space may result in a temporary lowering of shallow groundwater levels as the voids fill. The cracks will not provide pathways for deeper migration of groundwater unless extending into the “fracture zone”. This may happen where the “dilated zone” is absent due to shallow mining, that is, shallow overburden thickness. Surface cracks also generally fill quickly with sediment or close due to spalling.

The subsidence zones described by Kendorski (1993) above are generic; the depth of cover, overlying stratigraphy and panel widths vary between mines and each of these factors have to be taken into account when assessing subsidence effects.

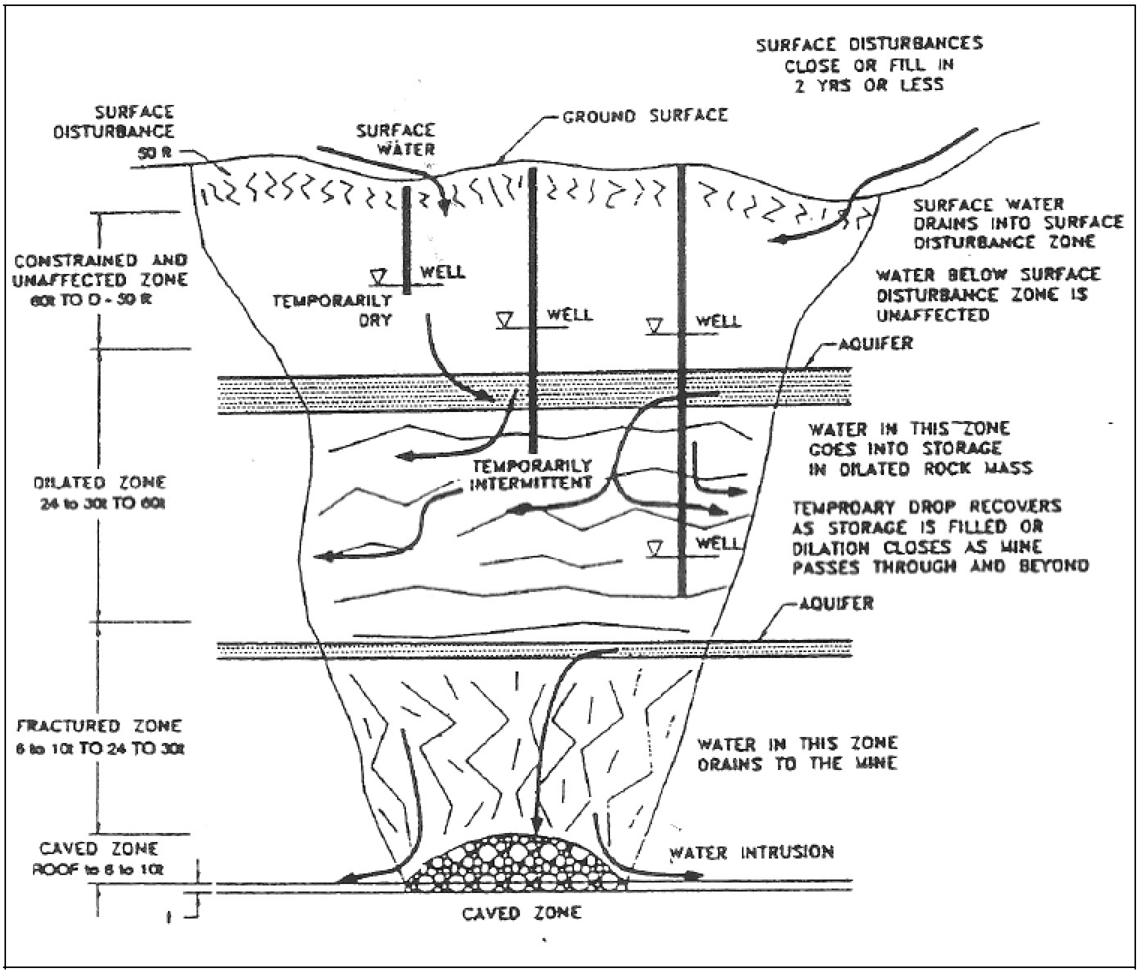


Figure 9 Subsidence Zones (Kendorski, 1993)

4.3.5.7 Simulation of subsidence effects due to goaf alteration

Modelling of subsidence predictions specific to the proposed underground mine workings were undertaken by Minserve (2017) using the maximised footprint which has a larger spatial distribution than the optimised footprint. Using the maximised footprint means that subsidence predictions are conservative. The Minserve subsidence report allowed for an estimate of the vertical extents of alteration above the longwall mining panels. In addition, the Minserve subsidence assessment provided estimates of possible changes to aquifer hydraulic properties, dependent on the hydrostratigraphic unit, because of goaf.

For the assessment of longwall mining, Minserve (2017) considered:

- the thickness of the target Dysart Lower (D14/D24) coal seam varies between 4.9 and 7 m in thickness
- the depth of the target coal ranges from 120 to 450 m below surface
- the clay-rich Tertiary cover ranges from 35 to 65 m thick.

The subsidence model was set up to include the major geological strata with properties which reflected pre-mining conditions. The subsidence model simulated the effect of bed separation, opening of joints and the formation of new cracks in the originally intact overburden rock mass. Changes in stress and the induced deformation in the surrounding rock mass associated with rock fracture and bedding plane separation were calculated.

Main findings of the subsidence modelling undertaken by Minserve (2017) are summarised below:

- Bedding plane separation and roof collapse (i.e. fracturing zone) can be expected to extend 100 m above the mined Dysart Lower (D24) longwall panel, typically extending into the H16 coal seam.
- Tertiary sediments are predicted to crack on surface up to 10 or 15 m deep but will swell and self-seal over time.
- Tensile cracks are expected to propagate into the overlying Tertiary sediments, but it is unlikely that cracks could further extend to the surface.
- Maximum surface subsidence of 3.5 m is predicted within the southern panels.

Based on the subsidence modelling results, it was assumed that the fractured zone extends 150 m above the mined panel in the groundwater model. Vertical and horizontal hydraulic conductivity were increased 100 times in the groundwater model for those model layers which intersected the fractured zone in order to simulate development of fractures and bedding planes. This approach utilised the time-variant properties capabilities of the MODFLOW SURFACT model by assuming that vertical and horizontal K values were increased 100 times from the original values for the goaf area. This 100 fold increase in hydraulic conductivity is representative of conservative conditions (typically 10 times is used but Minserve modelling indicates the potential for 100 fold increases).

It was assumed for groundwater modelling purposes, that goaf fully develops a year after extraction of each mine panel.

4.3.5.8 Simulation of incidental mine gas extraction

Removal of gas from the Permian sediments is required to ensure that the underground mine workings are unhindered by seam gas emissions during extraction of the coal.

Conceptual gas extraction modelling for the maximised underground layout was undertaken by GeoGas (2016). The maximised underground layout was separated into five regions representing differing gas characteristics (Figure 10). Modelled gas and associated water extractions were simulated from a number of pre-drainage wells to achieve pre-determined gas contents within three years, five years and eight years following gas and water extraction.

The eight-year gas and water extraction predictions, assessed by GeoGas, were adopted for the inclusion in the groundwater modelling. This allowed for the realistic simulation of groundwater extraction before and across longwall panels, as well as the dewatering associated with the actual underground mine panel mining.

A summary of the drainage bores and water extraction volumes is provided in Table 5. The location of the water extraction bores is shown in Figure 11.

Table 5 Gas Drainage Simulation

	Region 1	Region 2	Region 3	Region 5
ML 1775				
Number of bores	2	-	-	4
Bore spacing (m)	250	-	-	110
Total pumped volume / 8 years (ML)	13,800,000	-	-	7,700,000
Total pumped volume per year (L)	1,725,000	-	-	962,500
Continuous Extraction over 8 years (L/s)	0.05	-	-	0.03
MLA 70783				
Number of bores	4	13	7	20
Bore spacing (m)	250	140	90	110
Total pumped volume / 8 years (L)	23,000,000	57,700,000	18,800,000	70,800,000
Total pumped volume per year (L)	2,875,000	7.212,500	2,350,000	8,850,000
Continuous Extraction over 8 years (L/s)	0.09	0.23	0.07	0.28

It was assumed for groundwater modelling purposes, that pumping of gas extraction bores commenced one year prior to underground mining and continued for a period of 8 years (as envisaged by GeoGas), allowing for the effective management of incidental mine gas within the maximised footprint.

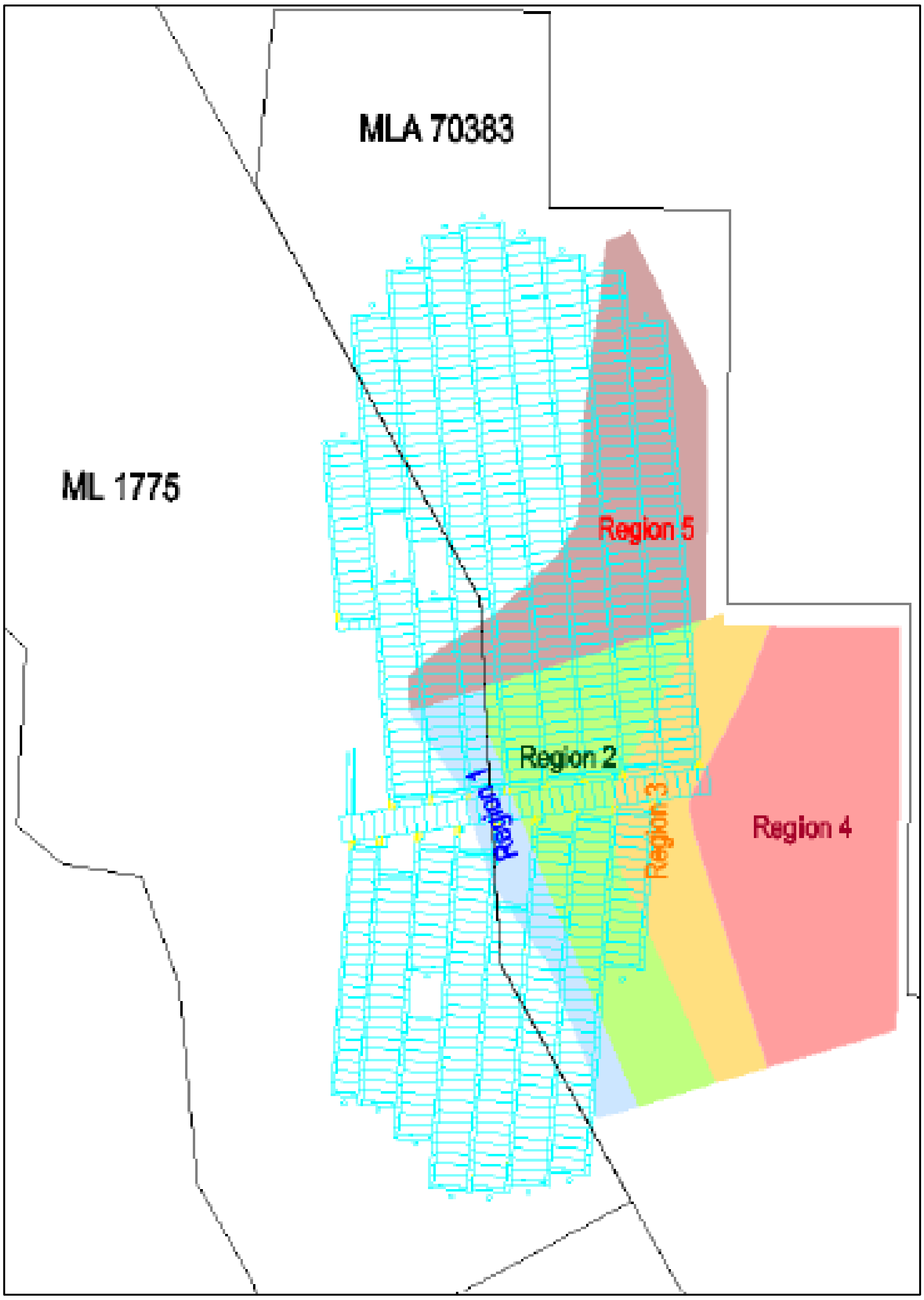
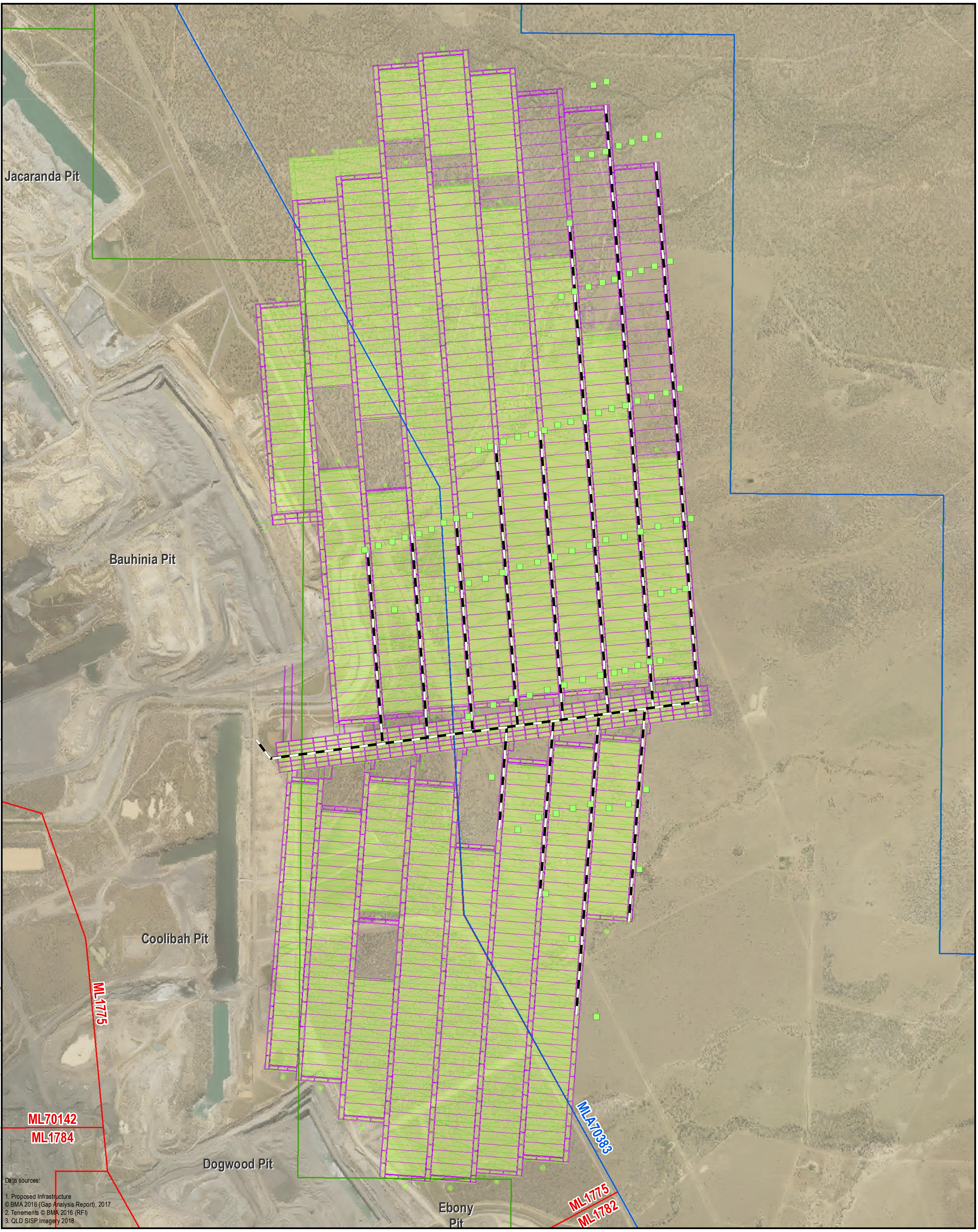


Figure 10 Incidental Mine Gas Regions (from GeoGas, 2016)



LEGEND

- Gas Drainage Location
- Gas Collection Line (to be collected at Centrally Located Location)
- Underground layout (optimised)
- Underground layout (maximised)

Mining Tenement

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

N

Figure 11
Location of Modelled Gas Extraction Bores

Groundwater Technical Report
Saraji East Mining Lease Project

0 0.25 0.5 1
Kilometres

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

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

BHP

DATE: 8/03/2019 VERSION: 1

4.3.6 Model calibration

Model calibration was performed in 2016 during construction of the existing groundwater model (AECOM, 2016) and is described below.

The groundwater model was calibrated to groundwater level measurements determined 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.

Backfill areas and pit depths were estimated based on landform data provided by BMA.

Water levels in the pits (Table 6) were included in the model to aid with simulating 2016 groundwater conditions on site during the calibration process.

Table 6 Saraji Mine pit water storages (02/11/2016)

Saraji Water Storages	Latitude	Longitude	Current Level (mAHD)	Pit Floor (mAHD)	Current Depth (m)
Ramp 17	-22.33	148.278	161.26	102.60	58.66
Ramp 0	-22.339	148.259	160.11	114.90	45.21
Ramp 1	-22.345	148.268	160.11	109.10	51.01
Ramp 1A	-22.355	148.278	117.26	96.50	20.76
Ramp 6	-22.3909	148.295	184.20	138.00	46.20
Ramp 8N	-22.406	148.295	180.47	121.40	59.07
Ramp 8S	-22.414	148.303	93.50	75.10	18.40

4.3.6.1 Calibration statistics

Representative groundwater level data[1] 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 7.

The bore locations are shown in Figure 30.

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

Table 7 Refined model groundwater level data

Well	Latitude	Longitude	Observed Water Level (mAHD)	Layer	Calibrated Water Level (mAHD)
MB32	-22.506	148.3366	197.73	1	197.7798
MB33	-22.4189	148.3276	172.83	2	170.2456
MB34	-22.4362	148.3402	172.51	3	168.12
MB35	-22.4192	148.3859	166.87	2	165.1977
MB36	-22.4720	148.362	178.97	2	176.0876
PZ06A	-22.4807	148.3537	185.90	2	182.7568
PZ06B	-22.4807	148.3537	179.60	3	182.7553
PZ06C	-22.4807	148.3537	183.40	7	183.2552
PZ08A	-22.3931	148.3080	177.60	4	178.0589
PZ08B	-22.3931	148.308	173.60	5	176.2955
RN132627	-22.3742	148.4527	141.29	2	152.7143
RN122458	-22.3588	148.408	149.11	2	160.9717
RN132631	-22.3469	148.315	156.88	9	165.7325
LV2370W	-22.3847	148.4379	157.70	1	155.7693
32924	-22.4736	148.3441	182.10	7	177.2417
42182	-22.4724	148.3388	182.07	7	175.9728
49997	-22.4690	148.340	176.36	2	182.1012
PC056	-22.4506	148.3633	174.00	3	169.1632
PC058XC	-22.4549	148.3611	173.98	3	170.3148

The refined model calibration indicates a SRMS error of 9.5%, which is considered 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 12 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

- uncertain bore log stratigraphy possibly resulting in incorrect model layer assignment.

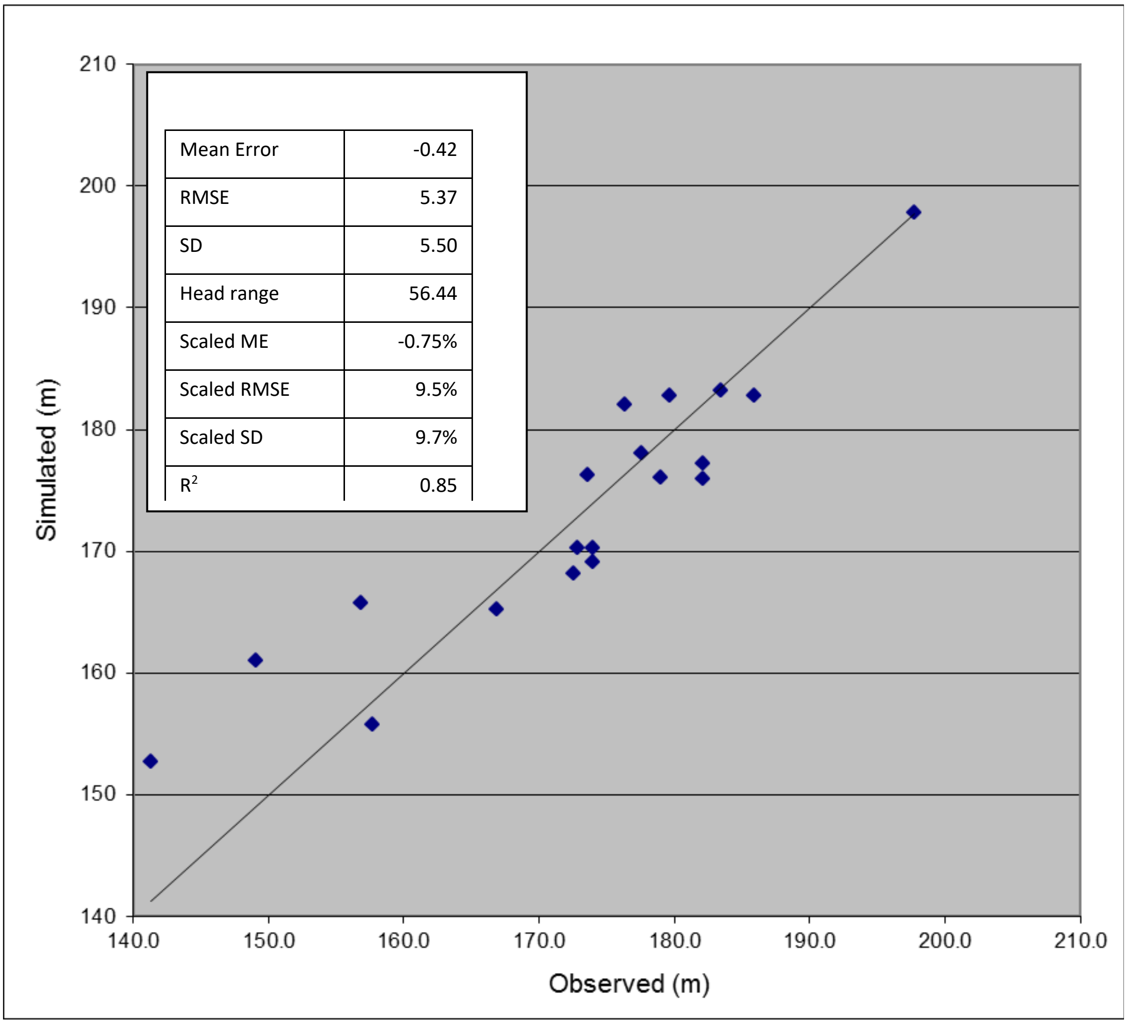


Figure 12 Refined Model Statistics

4.3.6.2 Hydraulic conductivity

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

The open-cut backfill areas 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 13), which includes high permeability associated with the Isaac River alluvium.

Layer 2, the FCCM is represented as a single thick layer with a uniform hydraulic conductivity of 0.025 m/day (Figure 14).

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 15).

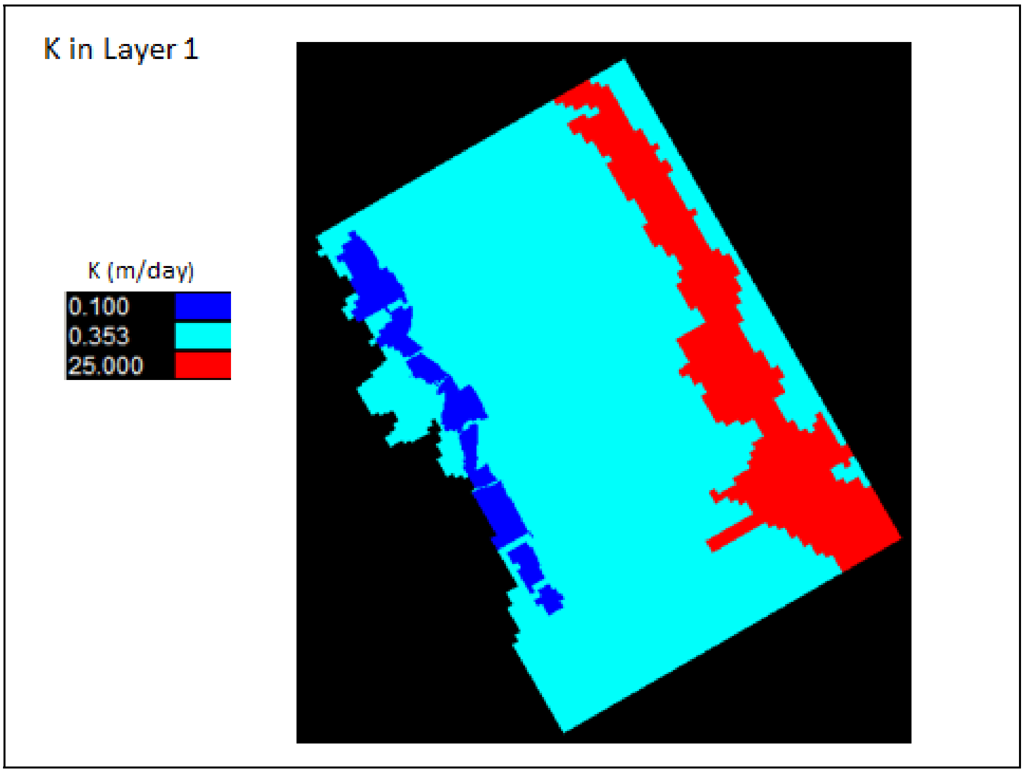


Figure 13 Hydraulic conductivity (k) distributions in layer 1

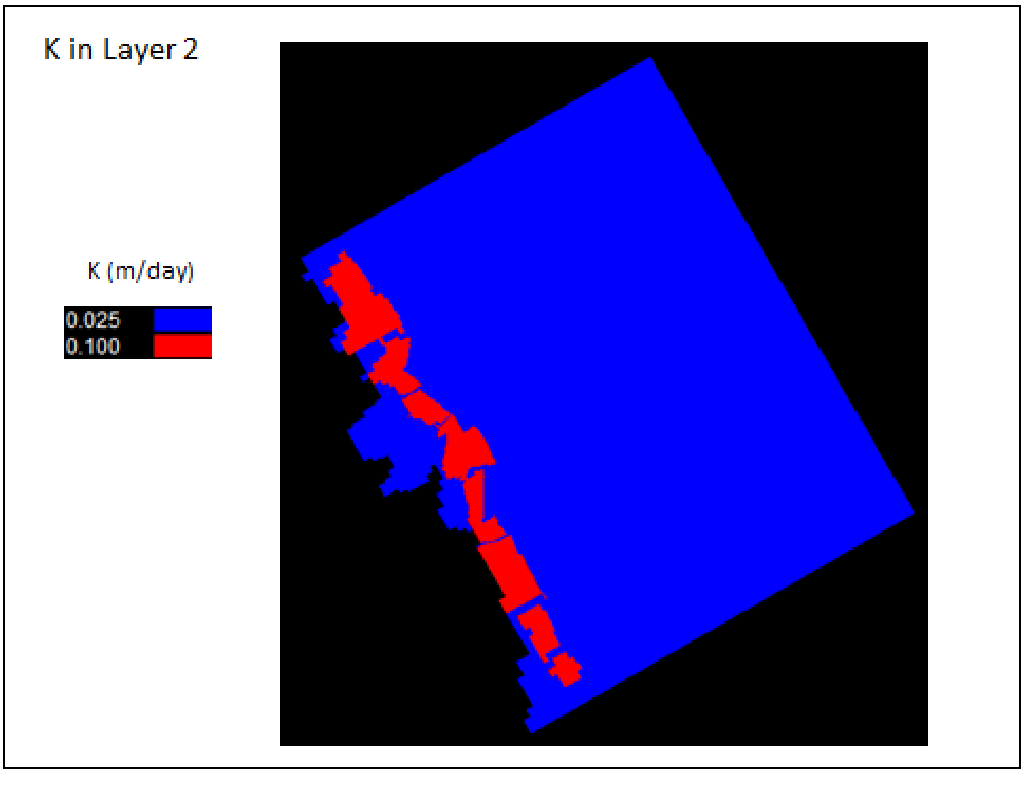


Figure 14 Hydraulic conductivity (k) distributions in layer 2

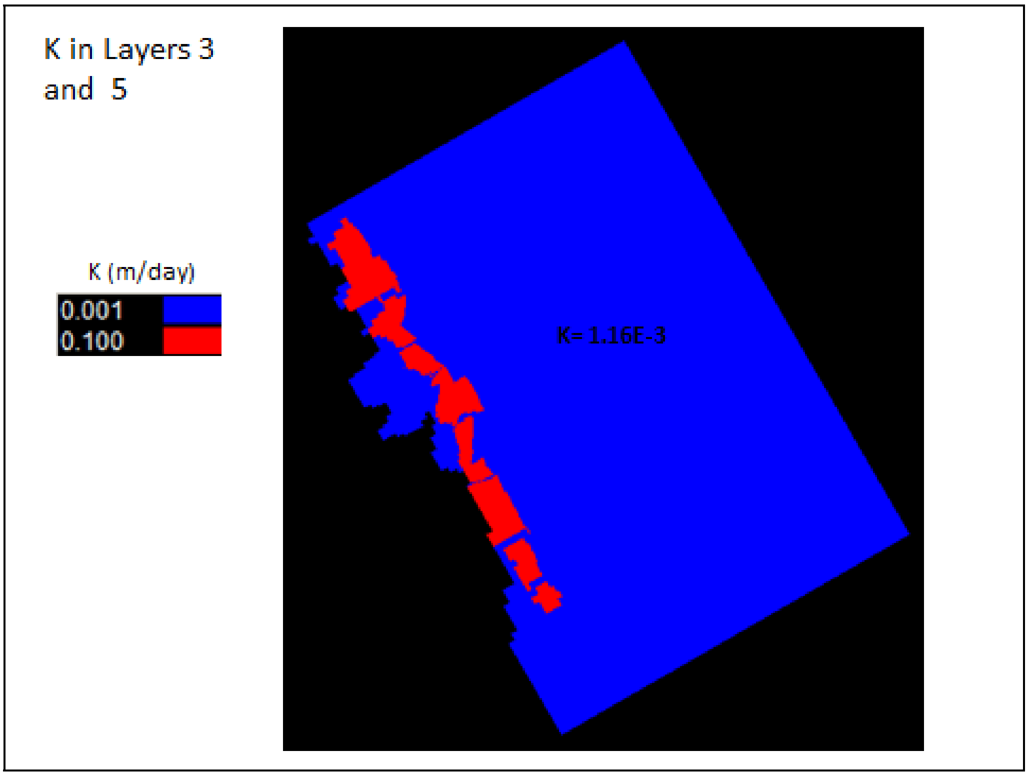


Figure 15 Hydraulic conductivity (k) distributions in layer 3 and 5

The calibration process, using the automatic calibration software package Parameter Estimation 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 $e^{-0.016 \times depth}$

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 $e^{-3.53E-3 \times depth}$

The resultant distribution of horizontal hydraulic conductivity across layers 4, 6, and 8, is presented in Figure 16.

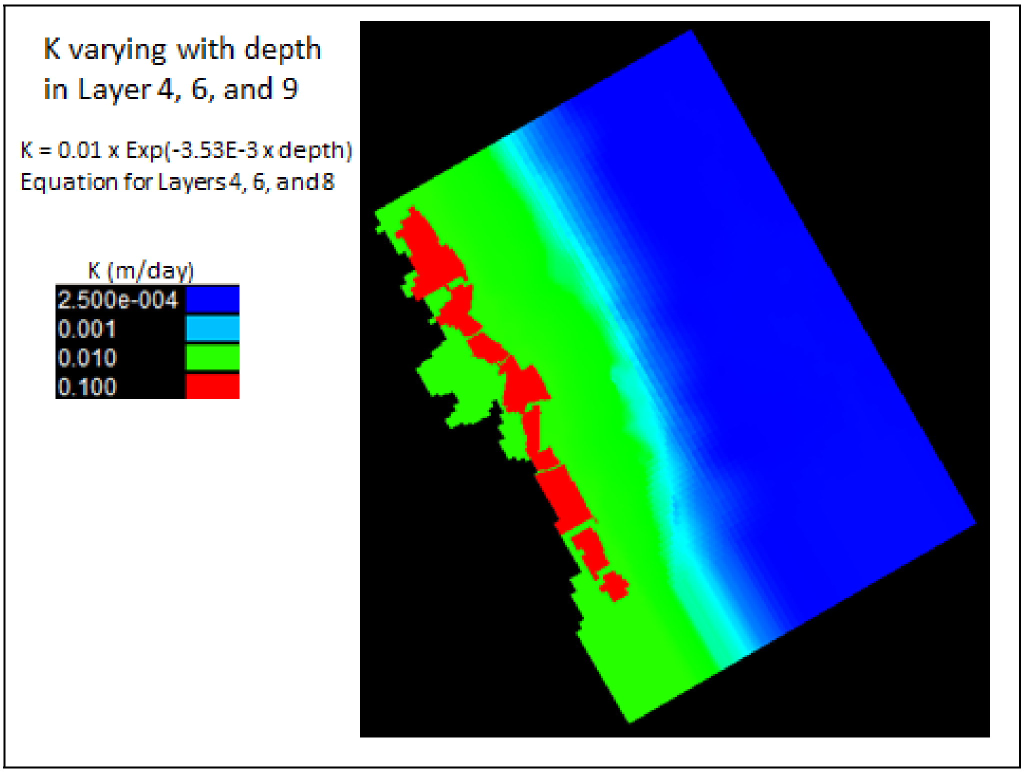


Figure 16 Hydraulic conductivity (k) distributions in layer 4, 6, and 8

The hydraulic distribution for model Layer 7, as determined through the calibration process is presented in Figure 17.

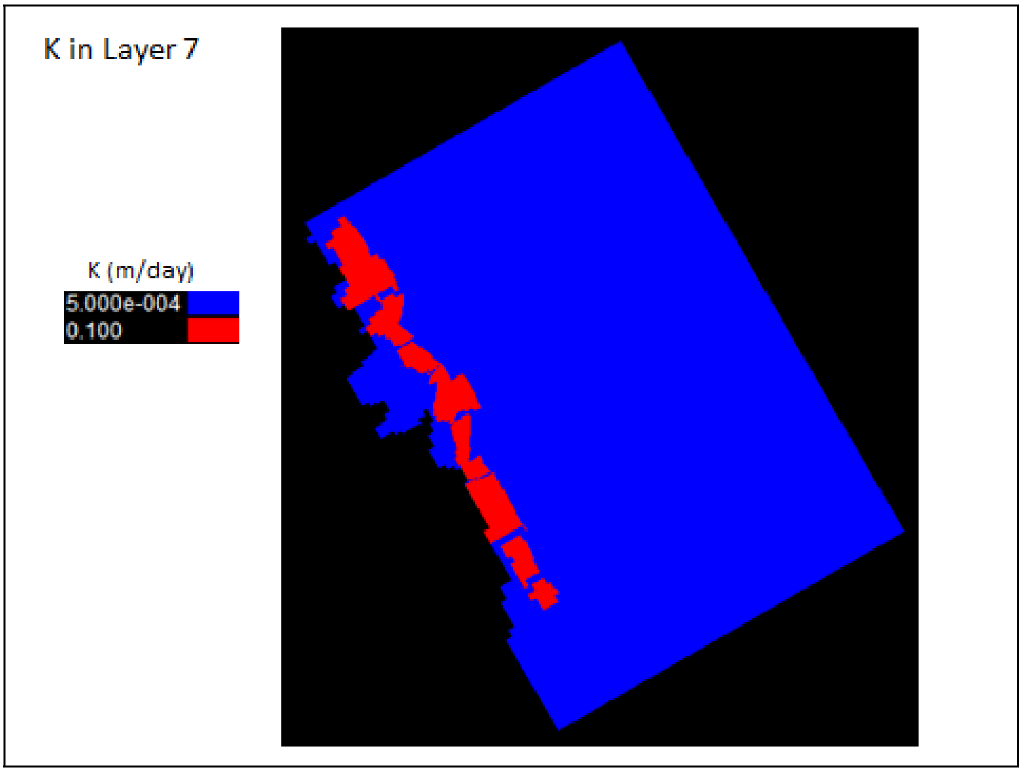


Figure 17 Hydraulic conductivity (k) distribution in layer 7

The hydraulic distribution for model Layer 9, MCM interburden above the Dysart coal, as determined through the calibration process is presented in Figure 18.

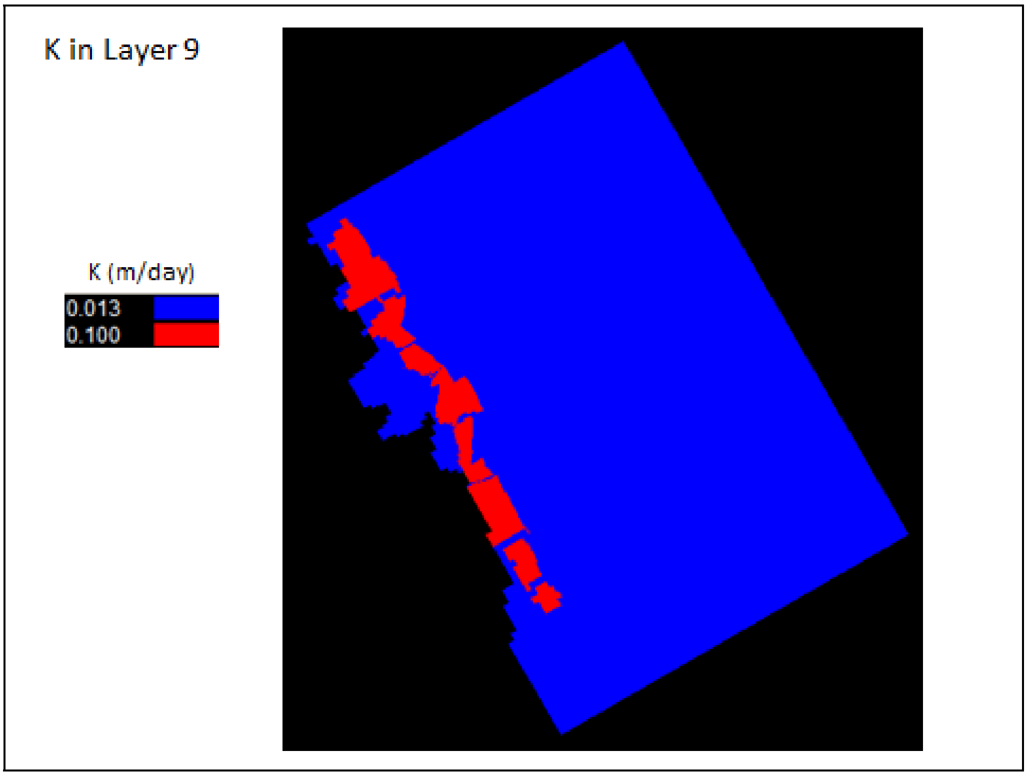


Figure 18 Hydraulic conductivity (k) distribution in layer 9

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

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

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

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

The resultant hydraulic conductivity distribution for Layer 10 is presented in Figure 19.

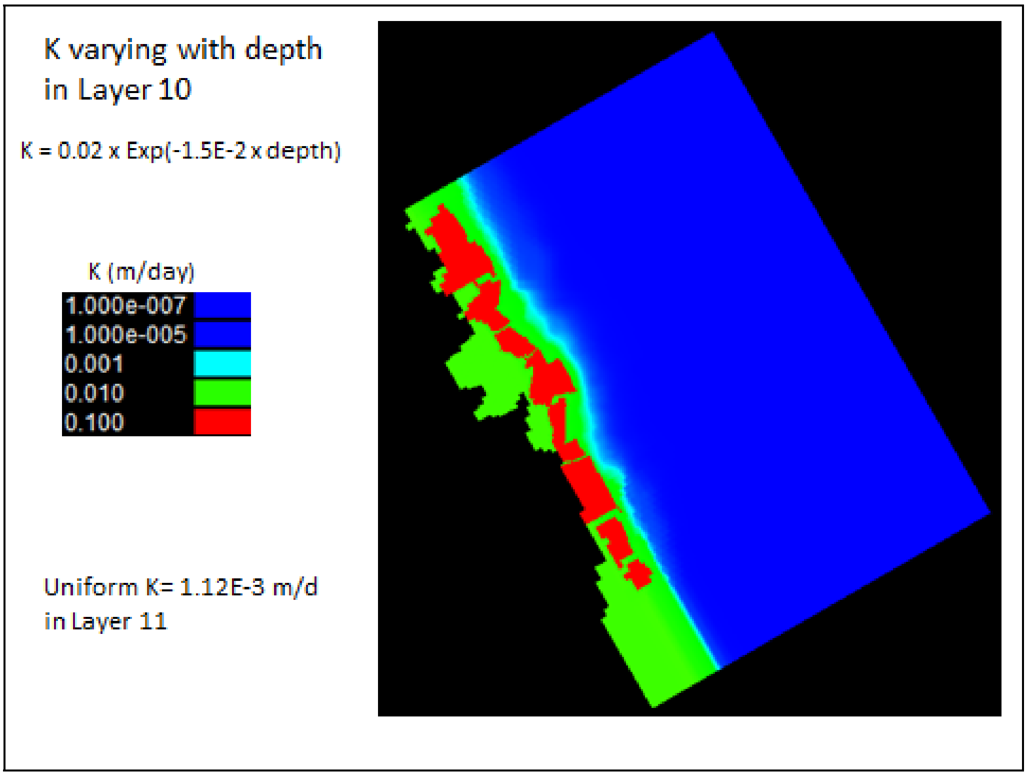


Figure 19 Hydraulic Conductivity (k) Distributions in Layer 10

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

4.3.6.3 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 20).

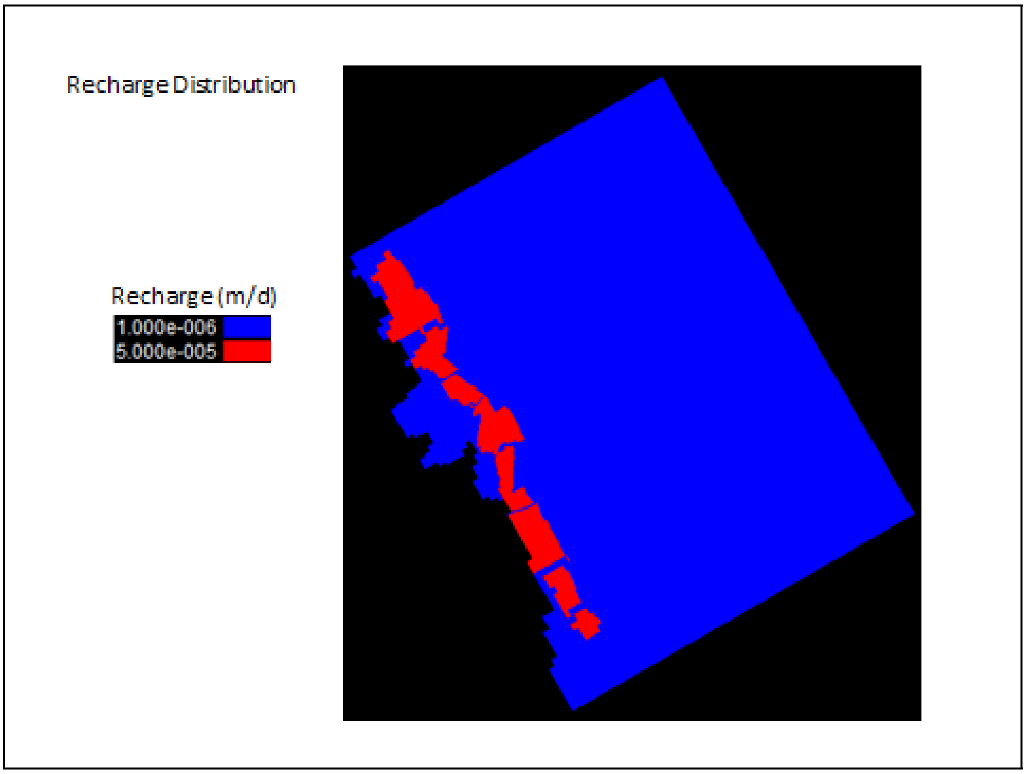


Figure 20 Recharge Distribution

4.3.6.4 Calibrated model parameters

Table 8 presents the model layer parameters after steady state calibration of the refined groundwater model.

Table 8 Model Parameters

Layer	Unit	Kx	Calibrated	Min	Max	Kz	Calibrated
1	Alluvium	K1x	2.5E+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-0*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		K=0.02*Exp(-0.015*depth)				Kz/kx=0.02

Layer	Unit	Kx	Calibrated	Min	Max	Kz	Calibrated
	depth)						
	Backfill	K3x	1.00E-02	1.00E-02	1.00E+00	K3z	1.00E-02
11	Interburden	K4x	1.16E-03	1.00E-04	1.00E-02	K4x	1.16E-05
	Recharge on backfilled areas	Rch1	1.00E-06	1.00E-06	6.00E-05		
	Recharge outside 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 (in the modelling software): K_x = Horizontal hydraulic conductivity and K_z is the vertical hydraulic conductivity

The prediction modelling storage values for specific yield (S_y) and storativity (S_c) were included in the model, as presented in Table 9. Note that these base case parameters were used to provide an assessment of groundwater impacts, related to ingress and drawdown cone extent.

Table 9 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

4.3.7 Model water budget

The assumed water volumes, storages and movement rates relevant to the model (known as the model water budget), as determined from the AECOM (2016) model, was assessed to:

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

The difference between the calculated model inflows and outflows at the completion of the calibration (known as the mass balance error), 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 10 presents the model water balance for the steady state simulation.

Table 10 Calibrated steady state refined model water budget (total model run)

Component	Rate for Simulation (m^3)
IN	
Storage	72,143,360
Constant Head	631.79
Fractured Well (FWL) Storage	16.05
Fractured Wells (gas drainage bores)	0.00
Drains	0.00
Recharge	37,066,180
River Leakage	0.00
TOTAL IN	**109,210,188**
OUT	
Storage	54,237,324
Constant Head	10,097,774
FWL Storage	15.48
Fractured Wells	253,754.91
Drains (ingress)	36,289,364
Recharge	0.00
River Leakage	9,053,592
TOTAL OUT	**109,931,824**
IN - OUT	- 721,636.54
Percent Discrepancy	-0.66%

4.3.8 Cumulative impacts

For the proposed underground mine, a cumulative impact assessment was undertaken whereupon the existing approved open-cut mining operations were assessed together with the proposed underground mine.

4.3.9 Model limitations

The groundwater flow model was a simplification of a real system, so it is subject to limitations. Limitations result from the simplification of the conceptual model upon which the numerical model is based, the grid scale, the inaccuracies of measurement data, and the incomplete knowledge of the spatial variability of input parameters.

The best data available is the hydraulic conductivity values from aquifer tests, core tests, and the spatial distribution with depth identified in Table 16. The groundwater model was calibrated to capture the regional groundwater flow trend identified from groundwater levels with the objective of obtaining an acceptable starting condition that represented the regional trend for the predictive simulation and reasonable parameter ranges. Verification of reliability of the model was conducted by undertaking uncertainty analysis for the predictive model.

5.0 Description of environmental values

5.1 Physical setting

5.1.1 Location

The Project is located approximately 170 km south-west of Mackay and 30 km north of Dysart in the Isaac Region of central Queensland (Figure 1). The Project is located immediately east of the approved existing open-cut Saraji Mine.

5.1.2 Land use

The Project is located on land which includes both freehold land and a number of utility and access easements. Activities associated with the existing mining have markedly altered the surface profile west of the Project.

Adjacent land uses surrounding the Project are predominantly for coal mining and cattle grazing.

5.1.3 Topography and drainage

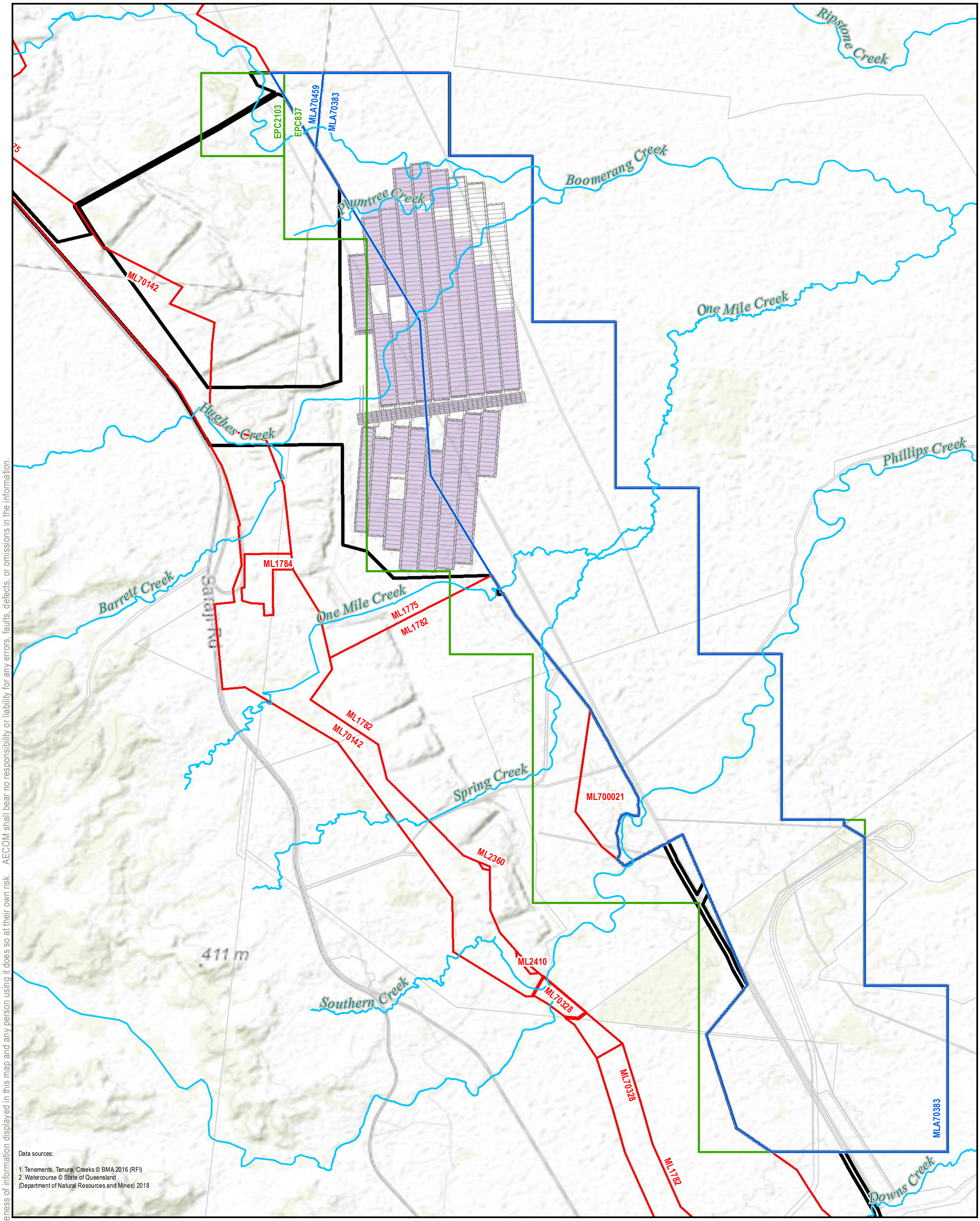
A review of contour data (Department of Natural Resources and Mines 2016) indicates that the majority of the Project Site[2] is flat, with elevations ranging from 180 metres (m) Australian Height Datum (AHD) to 200 m AHD. This changes abruptly at the eastern side of the Project Site, where existing mining operations have created artificial elevations ranging from 90 m AHD to 270 m AHD.

The generally flat terrain continues to the north, south and east of the Project Site; however, some three kilometres (km) to the west of the Project Site are the Harrow, Denham and Peak Ranges, with peaks reaching over 680 m AHD.

Eleven intermittent watercourses cross the Project Site, making their way from the ranges in the west to the downs in the east (Department of Natural Resources and Mines 2015) (Figure 21). These include the fourth order Boomerang Creek in the north, into which runs the third order Plumtree Creek. A small oxbow lake has formed just to the south of this confluence. South of this is a section of the former Hughes Creek, a third order watercourse that has been diverted by the existing mines. Further south is the fourth order One Mile Creek and, at the southern end of the Project Site, the fourth order Phillips Creek. All of these watercourses ultimately drain into the sixth order Isaac River, which is 15 km east of the Project Site, and the major watercourse in the catchment area.

These ephemeral creeks are considered to have limited flow, typically only after high intensity rainfall events.

[2] For the purposes of this groundwater technical report the Project Site is bound by Exploration Permit for Coal (EPC) 837, EPC 2103, MLA 70383, MLA 70459, ML 1775, ML 70142 and ML 1782 (see Figure 1).



LEGEND

- Project Site
- Exploration Permit Coal (EPC)
- Mining Lease (ML)
- Mining Lease Application (MLA)
- Watercourse
- Cadastre
- Underground layout (optimised)
- Underground layout (maximised)

N

Figure 21
Topography and Surface Water Features

Groundwater Technical Report
Saraji East Mining Lease Project

0 0.75 1.5 3
Kilometres

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

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

BHP

DATE: 4/12/2020 VERSION: 1

Filename: \\aubne1fp003\Projects\605X\60507031\4. Tech Work Area\4.99 GIS\02_MXDs\06 Environmental Impact Statement\F-1 Groundwater Technical Report\60507031_G183_v1_A4P.mxd GISWR-25

5.1.4 Climate

The nearest operating climate weather station is the Bureau of Meteorology (BoM) Station 034035 at Moranbah Airport, which is located approximately 48 km north of the Project. This weather station has only been operational since 2012, which is considered too short of a timeframe to comprehensively assess climate trends within the area. Data from BoM Station 035019, which is located at the Clermont Post Office, which is approximately 85 km south-west of the Project, has been operational since 1870 and was used to assess long term rainfall (1870 to 2018), temperature (1910 to 2011) and evaporation (1979 to 2011).

A summary of climate data for BoM Station 035019 is presented in Table 11; the climate data is assumed to be representative of the Project Area.

The data in Table 11 shows that the mean annual rainfall is approximately 666 mm/year and the average annual evaporation is approximately 2,070 mm/year. Evaporation is recognised to exceed rainfall every month indicating a negative climate budget.

Overall, the climate for the Project Area is sub-tropical characterised by high variability in rainfall, temperature and evaporation, typical of Central Queensland.

Table 11 Climate summary

Month	Average Temperature (ºC)	Average Rainfall (mm)	Average Daily Pan Evaporation (mm)	Average Monthly Pan Evaporation (mm)
January	34.3	117.0	7.5	232.5
February	33.0	114.4	6.8	190.4
March	32.0	74.9	6.4	198.4
April	29.5	38.4	5.1	153.0
May	26.1	34.1	3.7	114.7
June	23.1	33.5	3.0	90.0
July	23.1	25.3	3.2	99.2
August	25.3	18.7	4.2	130.2
September	28.8	20.1	5.7	171.0
October	31.9	35.2	7.0	217.0
November	33.9	57.0	7.4	222.0
December	34.8	91.5	8.1	251.1
Annual Total	**29.7**	**665.6**	**5.7**	**2,069.5**

Source: BoM Station 035019

5.1.4.1 Cumulative rainfall departure

The Cumulative Rainfall Departure (CRD) method (Weber and Stewart, 2014) depicts monthly rainfall trends compared against long-term average monthly rainfall. A rising trend in the CRD indicates periods of above average rainfall (and possibly increased groundwater recharge to unconfined aquifers), whilst a falling slope indicates periods of below average rainfall.

The CRD for the period 1900 to 2018 is shown in Figure 22 and can be summarised as follows:

- The area has experienced several climatic fluctuations of above average and below average rainfall since 1900.
- The area experienced a period of below average rainfall between 2001 and 2007 followed by a period of above average rainfall between 2010 and 2013.
- More recently, the Project Area has experienced below average rainfall since 2013.

Groundwater levels in unconfined aquifers that receive direct rainfall recharge could be expected to show a trend which mirrors that of the CRD.

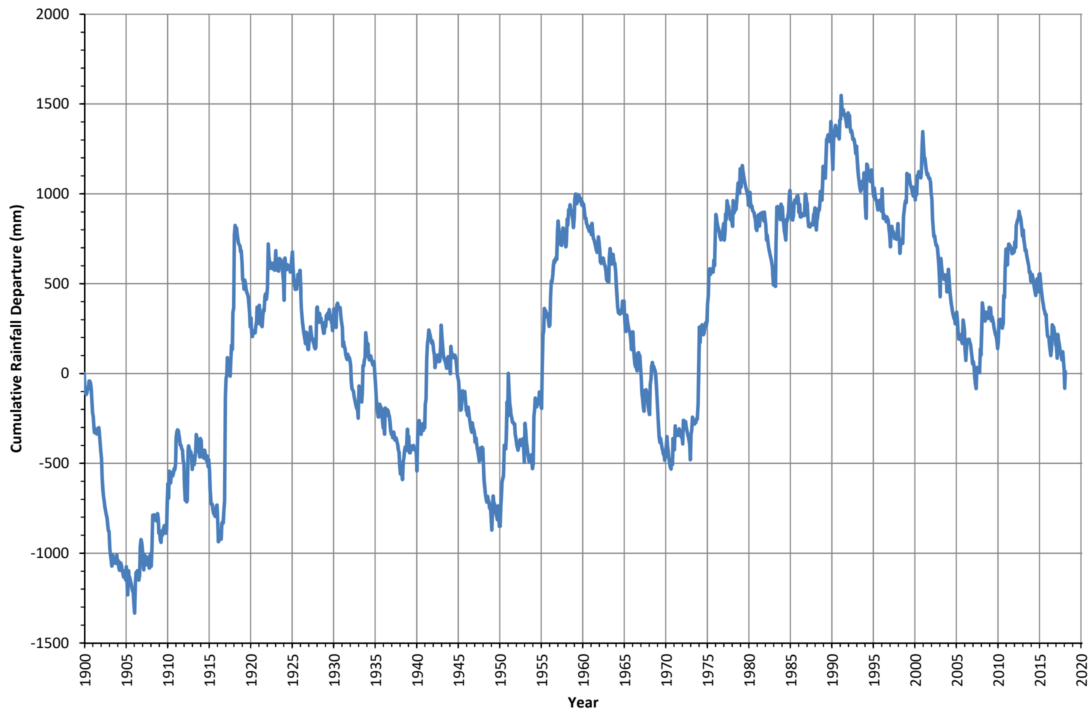


Figure 22 CRD Plot

5.2 Geology

The sections below detail the geological setting of the Project. Data used to describe the geology has been obtained from the following sources:

- historical investigations included in published reports
- published surface and basement geological maps.
- exploration and resource drilling across the underground mining footprint.

5.2.1 Bowen Basin

The Project is located on the western limb of the northern Bowen Basin; a north-south trending Early Permian to Middle Triassic geological basin.

The Bowen Basin is divided into a number of tectonic structures which comprise north north-west to south south-west trending platforms or shelves, separated by sedimentary troughs. The major regional structural feature surrounding the Project area is the Collinsville Shelf. The Nebo Synclinorium, a major axis of deposition, occurs to the east of the Project area (Dickins et al, 1973).

Folds within the basin are generally gentle and mostly related to drag on thrust faults at the eastern margin of the basin. The boundary between the Collinsville Shelf and adjoining Nebo Synclinorium is marked by a major thrust fault, the Jellinbah Thrust Fault (URS, 2012).

The regional stratigraphic sequence is presented in Section 5.2.3. Summarised, the stratigraphic sequence in the Project Area comprises the following:

- Middle Permian Back Creek Group (basement)
- Late Permian Blackwater Group sediments (and coal measures)
- Tertiary sediments

- Unconsolidated Quaternary alluvium sediments.

The surface geology for the Project Area is shown in Figure 23 and the basement geology in Figure 24.

5.2.2 Structural geology

The location of mapped faults and structures within and surrounding the Project are shown in Figure 24.

Figure 24 shows that faults in the Project Area comprise both normal and thrust faults with mapped trends which describe two dominant structural domains: one trends north north-west, the second trends north-south.

The Isaac Fault, which is located to the east of the Project, separates relatively undisturbed sediments towards the west from a complex zone of folded and faulted sediments to the east.

No known faults are mapped within the footprint of the underground mine workings.

5.2.2.1 Local geological cross-sections

To further assess possible structural features within the underground mining footprint, such as faults and folding, three east-west trending geological cross-sections and one north-south trending geological cross-section were generated from exploration data (BMA geological model) to show the lateral extent (dip and strike) of the target coal seam. Exploration holes located within the vicinity of the proposed underground mine are included in Appendix C.

The locations of the four cross-sections are included in Figure 24.

The resultant geological cross-sections and exploration bores are shown in Figures 25 to 28 and indicate the following:

- Sediments dip gently towards the east within the MLAs, with an average dip of approximately 8 degrees.
- There is no indication of any marked disruption of coal seams or sediments because of faulting.

LEGEND

Underground layout (optimised)
Underground layout (maximised)
Existing Open-Cut Extent

Mining Tenement

Exploration Permit Coal (EPC)
Mineral Development Licence
Mining Lease (ML)
Mining Lease Application (MLA)

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)

N

Figure 23
Surface Geology
(1:100,000)

Groundwater Technical Report
Saraji East Mining Lease Project

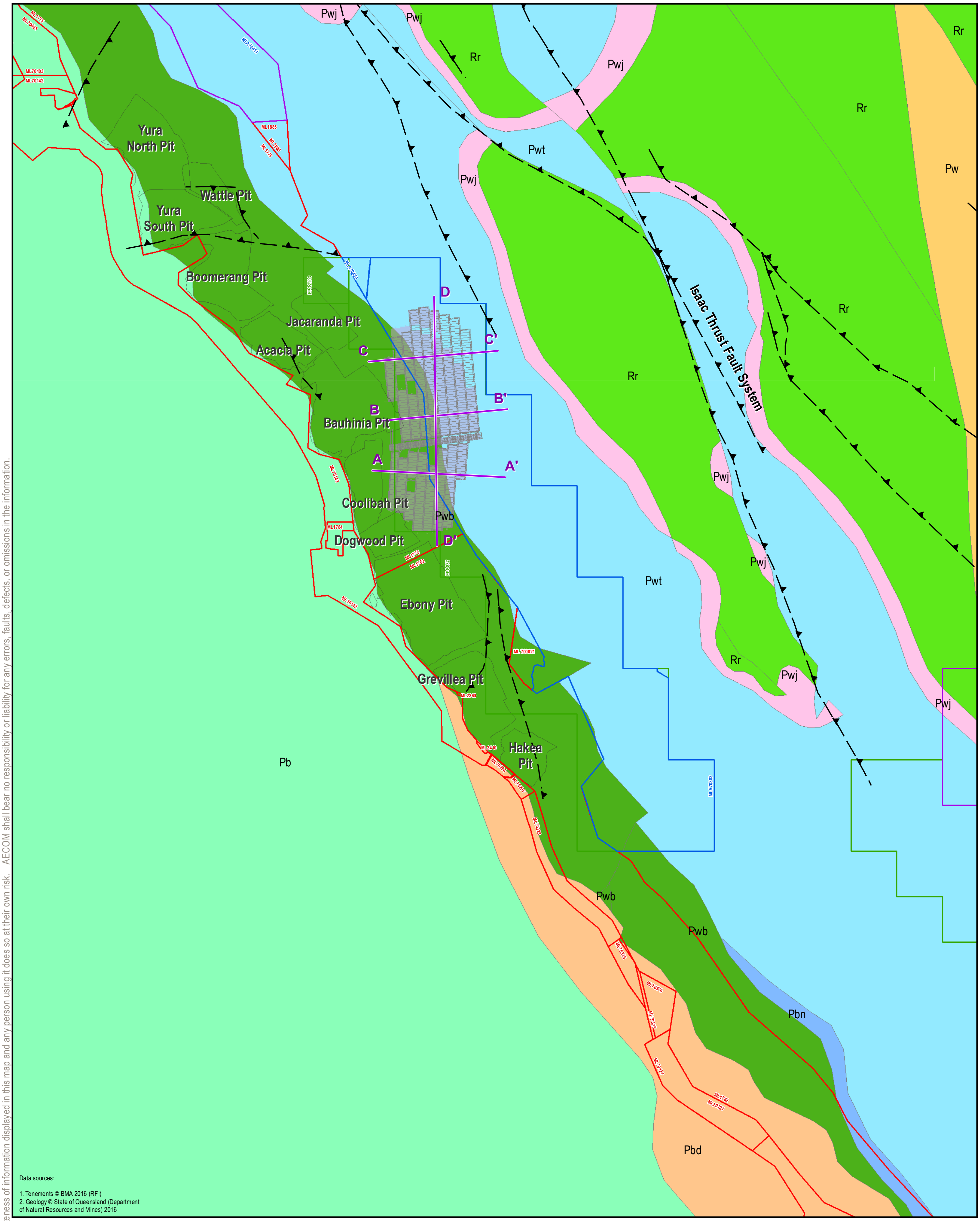
0 1 2 4
Kilometres

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

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

BHP

DATE: 21/02/2019 VERSION: 1



LEGEND

- Cross Section
- Fault
- Underground layout (optimised)
- Underground layout (maximised)
- Existing Open-Cut Extent

Mining Tenement

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

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
- Rr - Triassic Rewan Group

N

Figure 24
Basement Geology
(1:500,000)

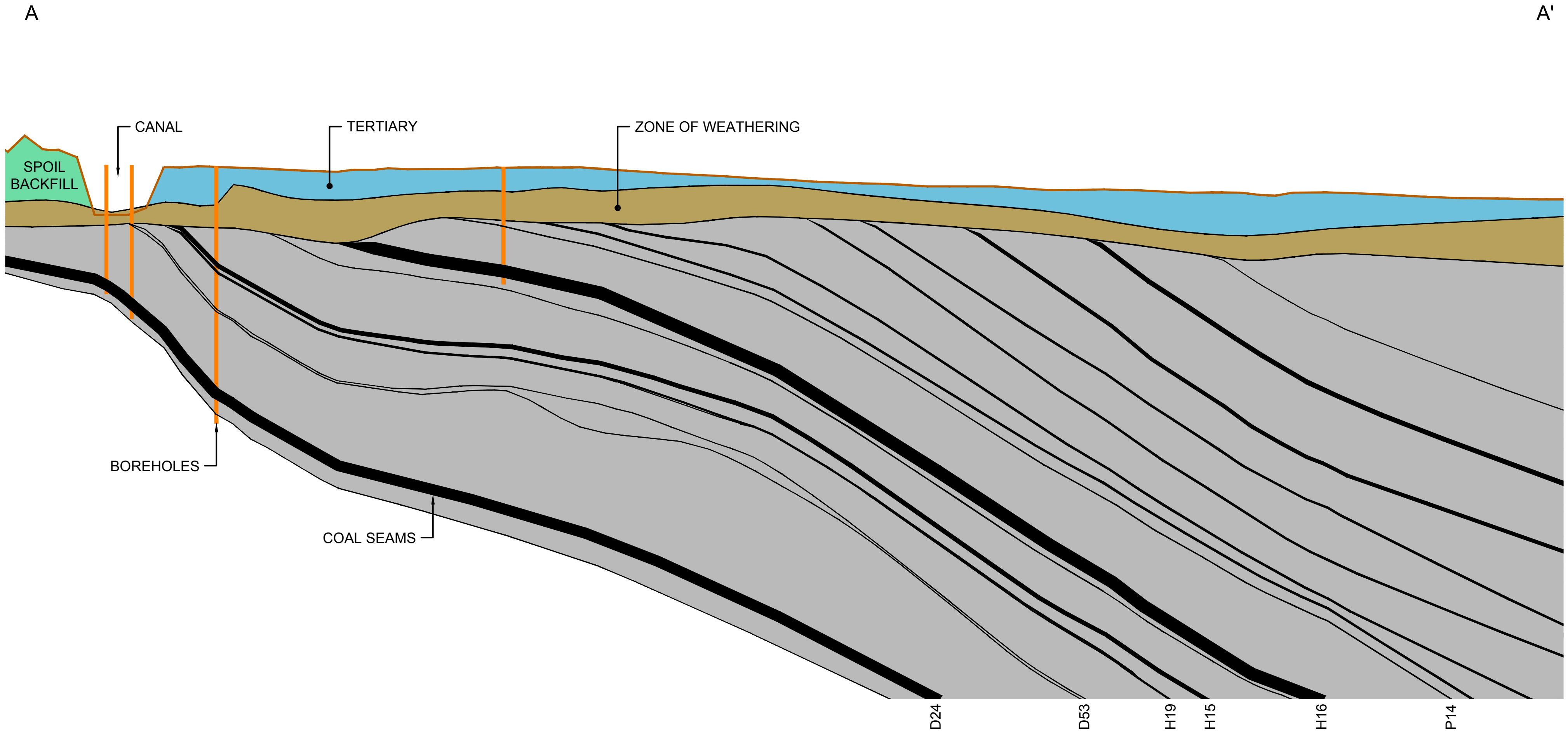
Groundwater Technical Report
Saraji East Mining Lease Project

0 1 2 4
Kilometres

Scale: 1:200,000 (when printed at A4)
Projection: Map Grid of Australia - Zone 55 (GDA94)

BHP

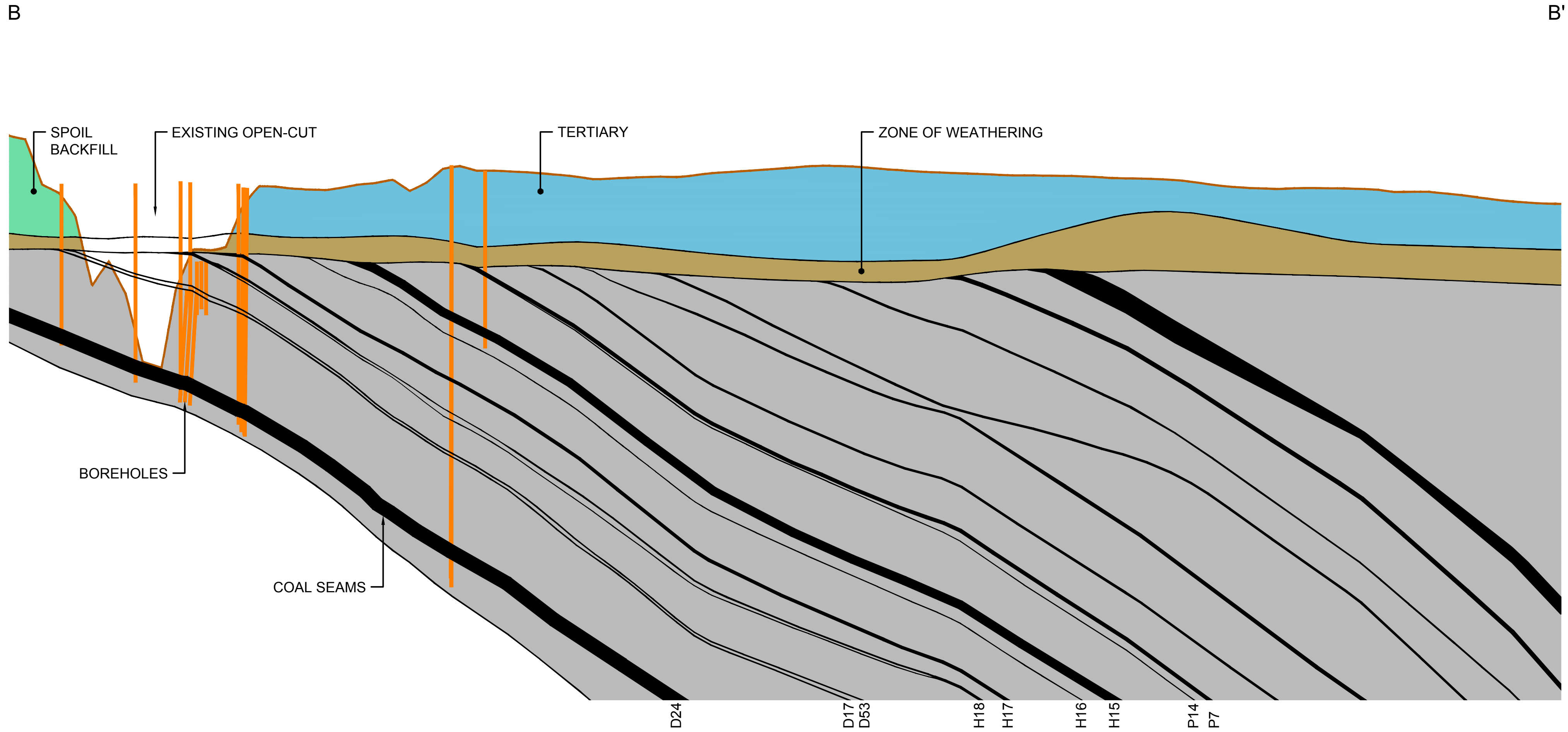
DATE: 21/02/2019 VERSION: 0



NOT TO SCALE

SARAJI APPROVALS
SECTION A-A'

FIGURE 25



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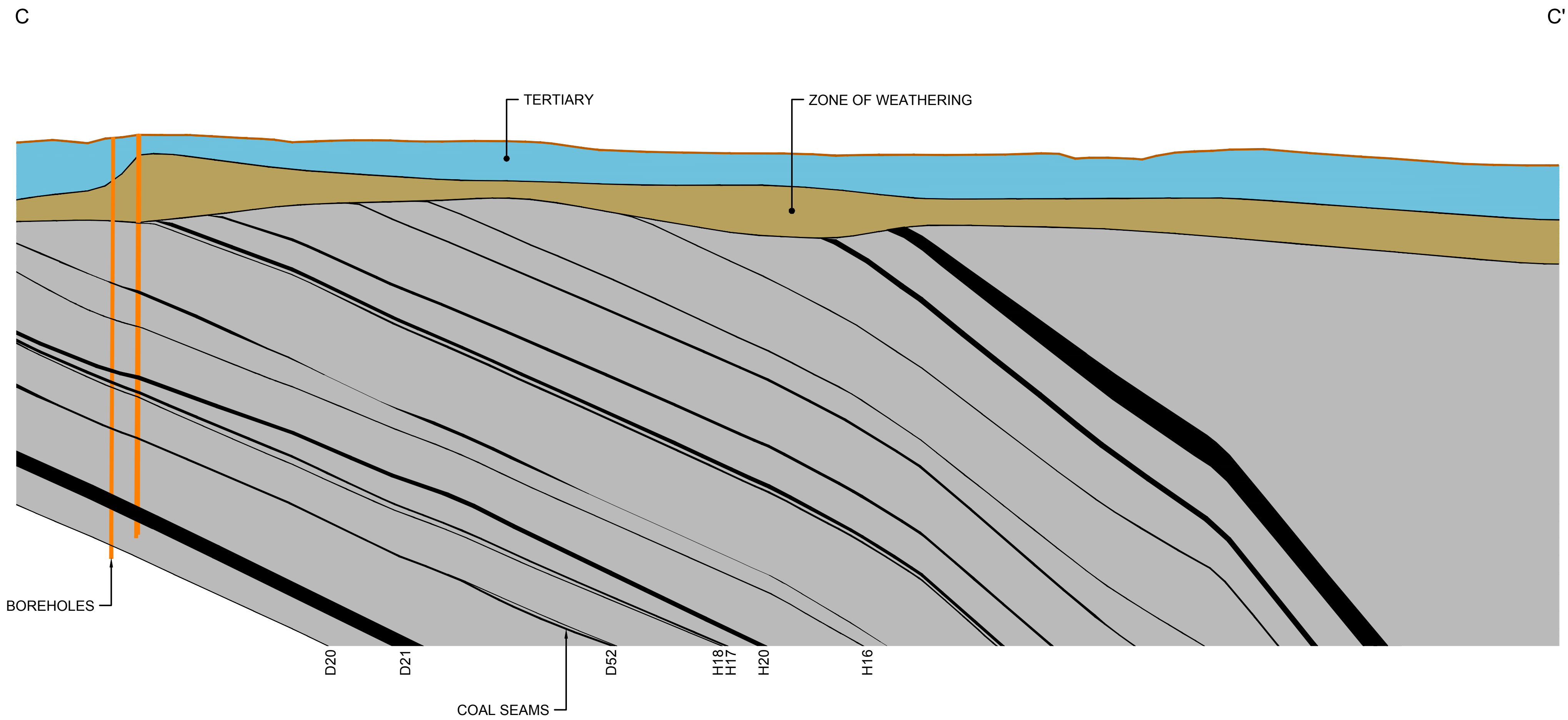
SARAJI APPROVALS
SECTION B-B'

FIGURE 26



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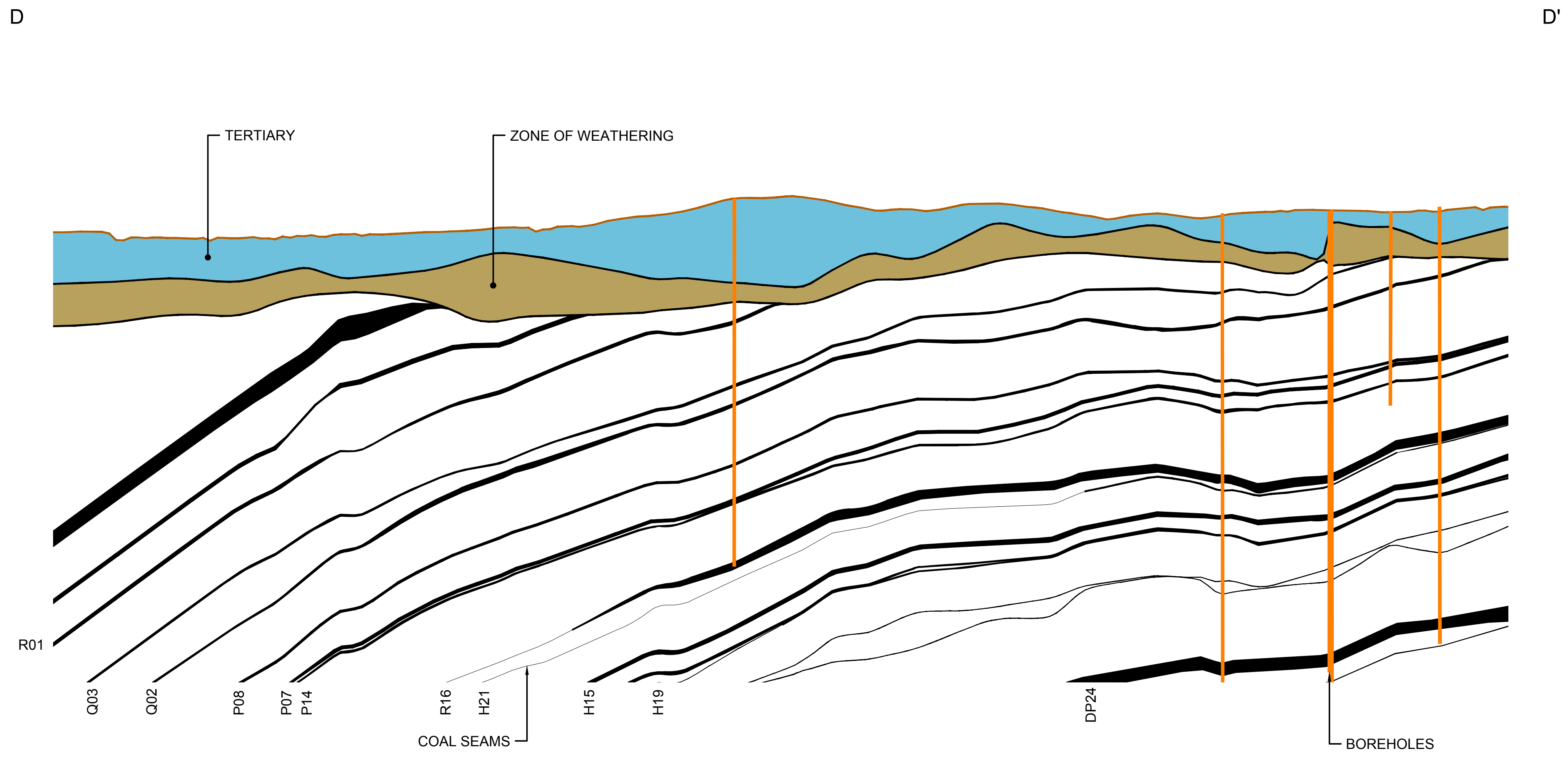
SARAJI APPROVALS
SECTION C-C'

FIGURE 27



NOT TO SCALE

SARAJI APPROVALS
SECTION D-D'

FIGURE 28

5.2.3 Stratigraphy

Figure 23 presents the surface geology for the Project Area based on the 1:100,000 scale Grosvenor Downs (Sheet 8553) geological map sheet. The basement geology based on the 1:500,000 scale Bowen Basin basement geology map is shown in Figure 24.

The mapped geology indicates that the stratigraphy typically comprises Permian coal measures overlain by a variable thickness of unconsolidated to poorly consolidated Tertiary and Quaternary sediments. Figure 23 shows that Tertiary sediments outcrop throughout the Project Area whilst Quaternary sediments are associated with the present day channels of the Isaac River and Phillips Creek. It is noted that little or no alluvium is mapped within or adjacent to the Hughes Creek, which drains across the underground mining footprint (Section 5.1.3).

Figures 25 to 28 show that the Permian sediments form a regular layered dipping sedimentary sequence while the overlying Tertiary materials are more complex and irregular with a maximum thickness of approximately 45 m across the underground mine footprint. Table 12 summarises the stratigraphy of the Project and surrounds.

Table 12 Stratigraphy

Age	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 and Isaac River.
Tertiary	Clay		Clay, clayey sand, sandy clay, sand.	4 - 45	Covers Project area with regular distribution; individual lenses are discontinuous and lensoidal.
	Basal Sand/Gravel		Sand.	0 - 3	Irregular distribution, generally observed where Tertiary sediments are thickest. Not reported within underground mining footprint.
	Duaringa Formation		Mudstone, sandstone, conglomerate, siltstone.	~ 20	Extensive outside of the underground mining footprint to the southeast.
Permian	Fort Cooper Coal Measures (FCCM)	Burngrove Formation	Sandstone, siltstone, mudstone, carbonaceous shale and coal.	Up to 400	Present beneath eastern portion of underground mining footprint.
		Fairhill Formation			
	Moranbah Coal Measures (MCM)	MacMillan Formation	Sandstone, conglomerate, claystone, siltstone, coal. Contains target coal seam – D14/24.	250 – 350	Present beneath entire underground mining footprint.
		German Creek Formation			
Early to Middle Permian	Back Creek Group		Sandstone, siltstone, carbonaceous shale, minor coal.	-	Underlies entire Project area. Outcrops west of Saraji Mine and extends under mined areas to the east.

The stratigraphic units are described in more detail below.

5.2.3.1 Quaternary sediments

The 1:100,000 surface geology map (Figure 23) indicates that Quaternary sediments are confined to the present day channels of Phillips Creek and the Isaac River. The Quaternary sediments comprise irregular sequences of unconsolidated clay, silt, sand, and gravel which are variable in thickness.

Quaternary sediments surrounding the Project Area have been reported to have a maximum thickness of 25 m at Phillips Creek (AGE, 2007).

5.2.3.2 Tertiary sediments

Tertiary sediments within the Project Area comprise dominantly of ‘tight’ clay overlying an irregular / discontinuous basal unit comprising sand and gravel.

Geological cross-sections (Figures 25 to 28) indicate that the Tertiary sediments reach a maximum thickness of approximately 45 m across the underground mine footprint whilst AGE (2011) indicates that the Tertiary sediments are up to 57 m thick in the western portion of the Saraji Mine.

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

Clay unit

The Tertiary clay unit comprises a predominantly clay matrix with intercalation of clay and sand lithologies and is the dominant Tertiary lithology present across the Project Area.

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).

Basal sand/gravel unit

A basal sand and gravel sequence is associated with the base of the Tertiary sediments.

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

JBT (2014) suggests that the basal sand and gravels represent the presence of a laterally discontinuous paleo-channel system assumed to be related to a proto-Phillips Creek system.

Duaringa formation

The Duaringa Formation, which is mapped towards the south and north of the underground mining footprint (Figure 23), contains mudstone and siltstone (i.e. low permeability argillaceous strata).

The Duaringa Formation has not been logged within the underground mining footprint.

5.2.3.3 Permian strata

The Permian coal bearing strata within the Project Area comprise the Fort Cooper Coal Measures (FCCM) and the underlying Moranbah Coal Measures (MCM).

The coal measures comprise sandstone, siltstone, claystone, mudstone and coal. Coal seams of interest within the MCM include the P seam, Harrow Creek Upper (H16) seam, Harrow Creek Lower (H15 and H19) seams, Dysart Upper (D52) seam and Dysart Lower (D14, D24) seam. Other seams are present but are generally too thin or discontinuous to be of economic value within the Project area. The target coal seam of the underground workings is the Dysart Lower (D14 / D24) seam.

The Dysart Lower seam (D24 and D14) is located 17 m to 35 m below the Dysart Upper seam (D52). The D24 seam depth of cover ranges from 120 m at western to maximum of 780 m at eastern limit of MLA 70838 and the seam is typically seven metres thick where coalesced towards the northern end of the MLA 70383. The seam thins to the north and progressively splits to the south into the D14/D142/D291 plys with thicknesses ranging from 2 m to 5.8 m.

Figure 29 outlines the Saraji seam correlation present across the Project Area.

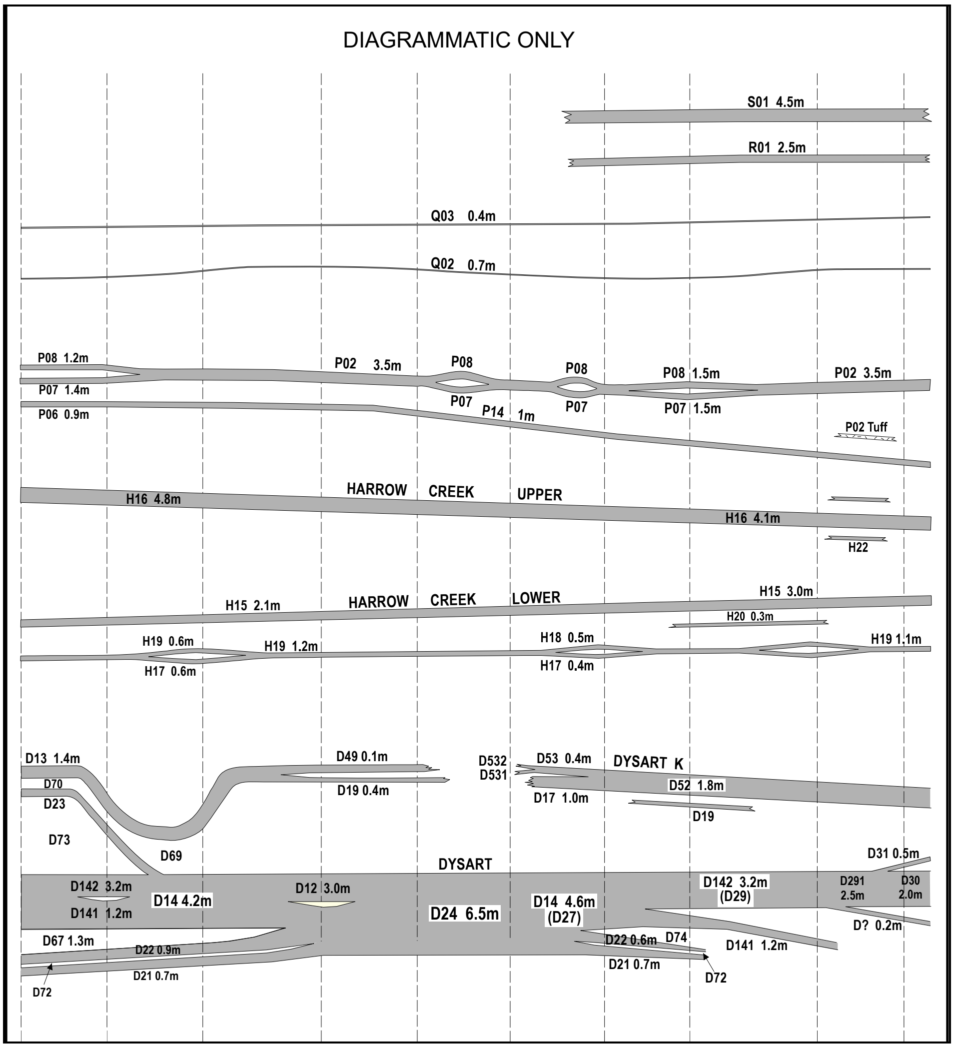


Figure 29 Saraji seam correlation

5.3 Groundwater resources

5.3.1 Groundwater monitoring network

The existing Saraji Mine groundwater monitoring network, at the time of report compilation, comprised two landholder bores, five single pipe monitoring bores, five monitoring locations comprising three nested groundwater piezometers (i.e. 15 monitoring points in total), and eight vibrating wire piezometers (VWPs) located within three holes. These bores provide detailed groundwater resource data for the Project.

The monitoring bore locations are shown in Figure 30 and construction details are summarised in Table 13.

With the exception of the landholder monitoring bores (MB31 and MB32); all monitoring locations were drilled and constructed between 2011 and 2012.

The two landholder monitoring bores (MB31 and MB32) and single (stand) pipe monitoring bores (MB33, MB34, MB35, MB36 and MB37) are required to be monitored as part of the Saraji Mine EA conditions. Groundwater levels and water quality have been measured on a quarterly basis within all seven of these EA bores since July 2011. It is noted that MB31 and MB32 also contain additional monitoring data which dates back to 2008.

The monitoring records for the nested (individual standpipe bores constructed adjacent to one another, screened in different hydrostratigraphic units) groundwater monitoring bores and VWPs are variable and can be summarised as follows:

Nested groundwater monitoring bores PZ09A and PZ10A were drilled ‘dry’ into Tertiary sediments and have not been monitored since 2012.

All other nested groundwater monitoring bores contain sporadic monitoring data (water levels and quality) measured between November 2011 and March 2012.

Records of VWP are available for the period June 2011 to December 2011.

Table 13 Groundwater Monitoring Bores

Registration Number	Latitude	Longitude	Depth (m)	Geology	Water Level (mbGL)	Yield (L/s)	Type / Name
Single Pipe Groundwater Monitoring Bores							
158010	-22.4192	148.3859	34.5	Fair Hill Formation	18.41 (166.87 mAHD)	-	MB35
158011	-22.4720	148.3622	32	Fair Hill Formation	17.96 (178.97 mAHD)	0.09	MB36
158012	-22.4610	148.2867	41.4	Back Creek Group	12.80 (221.86 mAHD)	0.02	MB37
158013	-22.43625	148.3402	107	Moranbah Coal Measures	23.10 (172.51 mAHD)	0.05	MB34
158014	-22.4189	148.32761	37.5	Moranbah Coal Measures	21.28 (172.83 mAHD)	0.08	MB33
Landholder Monitoring Bores							
(unregistered)	-22.40	148.224	44.23	Coal	7.85 (217.19 mAHD)	-	MB31 (SJ1)
(unregistered)	-22.506	148.336	19.52	Alluvium	10.4 (197.73 mAHD)	-	MB32 (TG2)
Nested Groundwater Monitoring Bores							
PZ02A	-22.3246	148.2818	26	Tertiary - Regolith	-	-	MB
PZ02B	-22.3246	148.281	170	Sandstone	-	-	MB
PZ02C	-22.3246	148.2818	278	Dysart D24	-	-	MB
PZ04A	-22.3223	148.2645	30	Tertiary - Regolith	-	-	MB
PZ04B	-22.3223	148.2645	66	Harrow Creek H16	-	-	MB
PZ04C	-22.3223	148.2645	180	Coal D47	-	-	MB
PZ07A	-22.4419	148.3399	14	Tertiary - Claystone	-	-	MB
PZ07B	-22.4419	148.3399	198	Sandstone	-	-	MB
PZ07C	-22.4419	148.3399	303	Harrow	-	-	MB

Registration Number	Latitude	Longitude	Depth (m)	Geology	Water Level (mbGL)	Yield (L/s)	Type / Name
				Creek H16			
PZ09A	-22.3507	148.2907	-	Tertiary - Clay	-	-	MB (drilled dry)
PZ09B	-22.3507	148.2907	75	Harrow Creek H16	-	-	MB
PZ09C	-22.35075	148.29076	195	Dysart D24	-	-	MB
PZ10A	-22.3833	148.3039	-	Tertiary - Regolith	-	-	MB (drilled dry)
PZ10B	-22.3833	148.3039	70	Harrow Creek H16	-	-	MB
PZ10C	-22.3833	148.30392	184	Dysart D24	-	-	MB
Vibrating Wire Piezometers							
PZ05A	-22.5176	148.3838	203	Harrow Creek H16	168.8 mAHD	-	VWP
PZ05B	-22.5176	148.3838	239	Coal D52	166.3 mAHD	-	VWP
PZ06A	-22.4807	148.3537	40.5	Sandstone	185.9 mAHD	-	VWP
PZ06B	-22.4807	148.3537	78.5	Harrow Creek H16	179.6 mAHD	-	VWP
PZ06C	-22.4807	148.3537	167	Coal D142	183.4 mAHD	-	VWP
PZ08A	-22.3931	148.3080	38.5	Coal P07	177.6 mAHD	-	VWP
PZ08B	-22.3931	148.308	65	Harrow Creek H16	173.6 mAHD	-	VWP
PZ08C	-22.3931	148.3080	180	Dysart D24	-	-	VWP

Notes: VWP – Vibrating Wire Piezometer MB – Monitoring Bore – No data

5.3.2 Registered groundwater bores

A search of the Department of Natural Resources, Mines and Energy (DNRME) Groundwater Database (GWDB) was undertaken during May 2018 to identify registered groundwater bores within and adjacent to the underground mining footprint. The search identified 42 registered groundwater bores within a 15 km radius of the underground mine footprint (Figure 30).

Of the 42 registered bores identified within 15 km of the underground mine footprint:

- five (43639, 90475, 165162, 165326 and 13040179) are described as being abandoned or destroyed
- five (158010, 158011, 158012, 158013 and 158014) are groundwater monitoring bores identified in Table 13 and located on BMA owned land.

For the purposes of this report, those five bores described as being abandoned and destroyed were excluded from any further discussion in this report as they are not considered to be potential useable/impacted bores.

Registered bore details as recorded in the DNRME GWDB are summarised in Table 14. It is noted that details for the five BMA owned registered groundwater monitoring bores are not included in Table 14 as they are already summarised in Table 13.

Table 14 Registered groundwater bores

Registered Number (RN)	Latitude	Longitude	Depth (m)	Geology	Water Level (mbGL)	Yield (L/s)	Type / Name
Registered Groundwater Bores							
43305	-22.4500	148.4281	91.4	Moranbah Coal Measures	45.7	0.39	Utah Bore
43639	-22.5015	148.3507	43.9	Blackwater Group	29.49	0.75	Abandoned
44336	-22.5174	148.3123	54.86	No data	36.6	2.5	
57747	-22.5157	148.3650	126.5	Back Creek Group Basalt	-	4.42	
57748	-22.5309	148.2872	55.0	Back Creek Group	18.0	1.00	
84538	-22.4498	148.3737	109.7	No strata data	18.3	0.07	
90475	-22.4805	148.4139	76.2	Blackwater Group	-	0.01	Abandoned
100248	-22.4325	148.3763	-	No data	-	-	
100252	-22.2578	148.2994	-	-	-	-	No bore details
122458	-22.3588	148.4080	50.5	Permian overburden	26 (149.11 mAHD)	-	
132627	-22.3742	148.4527	70	Duaringa Formation	30 (141.29 mAHD)	0.95	
132628	-22.3831	148.4397	120	Duaringa Formation	77 (95.61 mAHD)	0.8	
132631	-22.3469	148.3152	328	Back Creek Group Sandstone	31 (156.88 mAHD)	15?	
136092	-22.4914	148.2969	22	Back Creek Group	12	1.1	
136689	-22.3464	148.3194	328	Back Creek Group	157.13 mAHD	-	
158480	-22.4010	148.4552	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	-	
158481	-22.4025	148.3905	38	Rangal Coal Measures	VWP4 162.5	-	LV2226 VWP

Registered Number (RN)	Latitude	Longitude	Depth (m)	Geology	Water Level (mbGL)	Yield (L/s)	Type / Name
					mAHD		
			56		VWP3 157.9 mAHD	-	
			74		VWP2 154.5 mAHD	-	
			94		VWP1 153.6 mAHD	-	
158482	-22.3951	148.4136	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	-22.3951	148.4136	20	Quaternary	Dry	-	LV2369W
158484	-22.3847	148.4379	19	Quaternary	157.7 mAHD	-	LV2370W
158485	-22.4026	148.3905	22	Quaternary clay	Dry	-	LV2371W
158686	-22.5221	148.3952	210	Moranbah Coal Measures	60 (141.15 mAHD)	0.13	MW9P
162506	-22.2892	148.1765	42	Sandstone	5	1.89	
162681	-22.2216	148.3518	10	Isaac River Alluvium	-	-	IF3835P
162685	-22.2408	148.4100	13	Isaac River Alluvium	-	-	VP3833P
165122	-22.4168	148.3997	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	-	
165123	-22.3655	148.4327	136	Rangal Coal Measures	-	-	VWP

Registered Number (RN)	Latitude	Longitude	Depth (m)	Geology	Water Level (mbGL)	Yield (L/s)	Type / Name
165124	-22.3848	148.4379	82	Rangal Coal Measures	-	-	LV2375W VWP
165162	-22.4824	148.2588	100	No data	-	-	Abandoned
165163	-22.5024	148.2490	72	Back Creek Group	15.0	1.26	
165323	-22.4649	148.3375	15	Alluvial sand	-	-	Piezometer
165324	-22.4733	148.3460	15	Alluvial clay	-	-	Piezometer
165325	-22.4574	148.3635	18.5	Quaternary clay	-	-	Piezometer
165326	-22.4574	148.3635	35	Unknown	-	-	Abandoned
165374	-22.3048	148.3736	42	Duaringa Formation	20.0	0.14	VE3831P
13040179	-22.2836	148.4523	14.32	Alluvial sand	-	-	Abandoned
13040283	-22.3547	148.2414	68.5	Coal	40.56 (178.29 mAHD)	-	DNRME

5.3.3 Bore census

A bore census was undertaken in the Project Area in 2007 which identified 12 unregistered landholder bores which are not listed on the DNRME GWDB. Two of the identified landholder bores (MB31 and MB32) were subsequently monitored as part of the Saraji EA conditions (Section 5.4).

A summary of available information for each of the bores identified during the bore census is presented in Table 15.

Table 15 Unregistered groundwater bores

Registered Number	Latitude	Longitude	Depth (m)	Geology	Water Level (mbGL)	Yield (L/s)	Type / Name
(unregistered)	-22.4000	148.2224	44.23	Coal	7.85 (217.19 mAHD)	-	MB31 (SJ1)
(unregistered)	-22.5061	148.3366	19.52	Alluvium	10.4 (197.73 mAHD)	-	MB32 (TG2)
(unregistered)	-22.4131	148.37133		Unknown		-	MB29 (MB5)
(unregistered)	-22.4278	148.3846	>100	Coal	23.77	-	MB30 (LV1)
(unregistered)	-22.3434	148.4127	79.4	Unknown	20.63	-	MB1
(unregistered)	-22.3490	148.3200	60.94	Unknown	22.86	-	MB2
(unregistered)	-22.3490	148.3201	50	Unknown	23.82	-	MB3
(unregistered)	-22.3491	148.3200	27.1	Unknown	23.53	-	MB4
(unregistered)	-22.3486	148.3142	-	Unknown	-	-	MB6
(unregistered)	-22.5040	148.3361	-	Unknown	-	-	LV2
(unregistered)	-22.4802	148.2641	-	Unknown	-	-	SJ2
(unregistered)	-22.52105	148.3147	15.06	Unknown	9.42	-	TG1

5.3.4 Existing hydrogeological understanding

The following description of the existing groundwater regime(s) for the Project Area is based on a review of previous groundwater investigations (Section 4.1) and data obtained from the following sources:

- DNRME GWDB
- Exploration drilling across the Project Area
- Data from the Saraji Mine groundwater monitoring network including groundwater level measurements and groundwater quality sampling.

An aquifer is defined as a groundwater bearing formation permeable to transmit and yield water in useable quantities.

There are three aquifer systems and one aquitard within the Project Area. These aquifers and aquitard are likely to be in hydraulic connection to the Project and are therefore sensitive to the Project's groundwater-affecting activities. The aquitard is formed by the Permian overburden and interburden (i.e. shale, mudstone, siltstone and sandstone).

The three aquifers are associated with the following geological strata:

- Quaternary alluvium
- Tertiary sediments
- Coal seams contained within the Permian coal measures.

This section details the physical and chemical characteristics of these aquifers within the context of the prevailing regional hydrogeological regime.

5.3.5 Quaternary alluvium

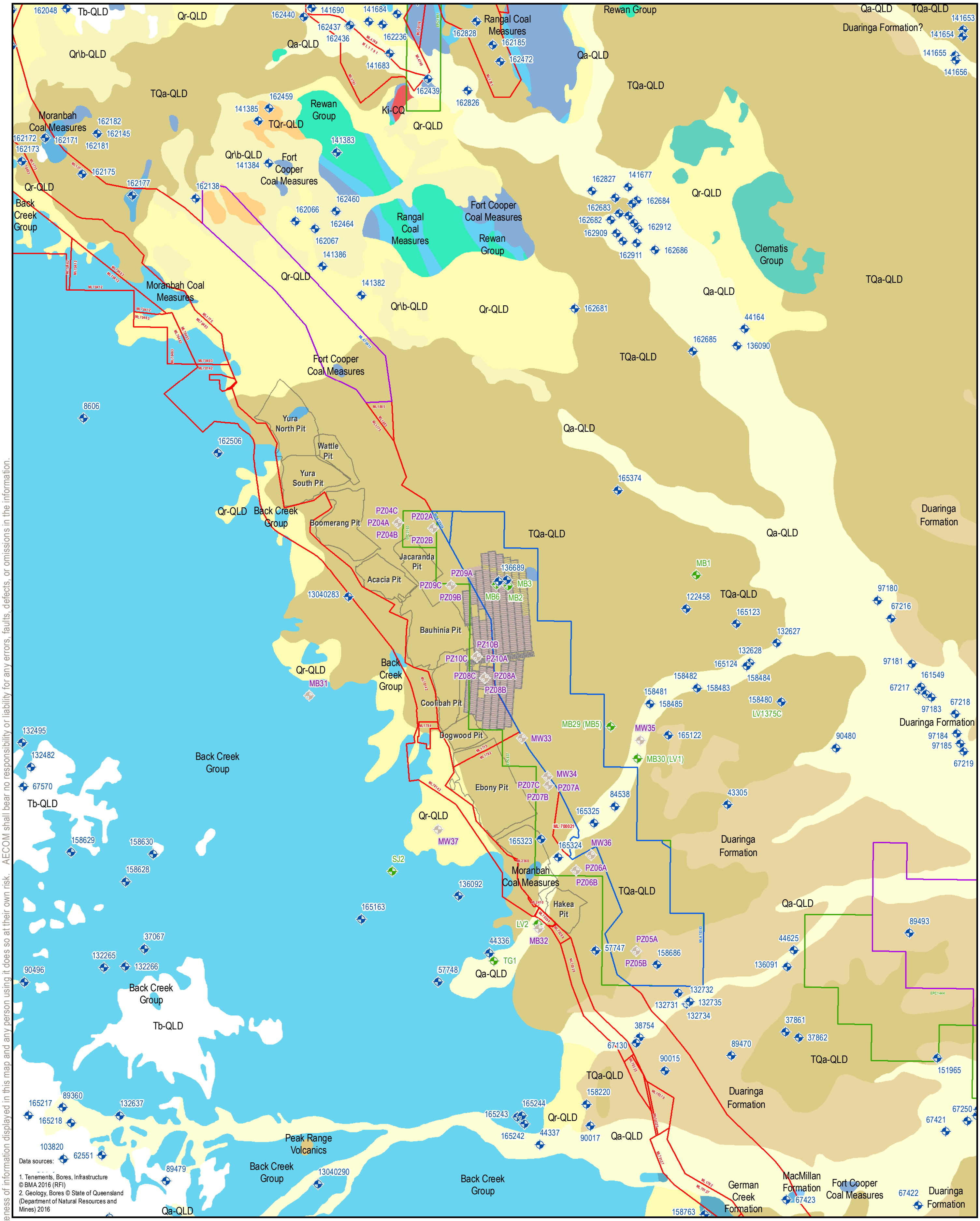
5.3.5.1 Occurrence

Quaternary alluvium is not mapped within the footprint of the proposed underground mine (Figure 23). Quaternary alluvium is recognised to occur as paleo-channels associated with the present-day course of Phillips Creek. The alluvial aquifer is unconfined with a maximum thickness of 25 m adjacent to Phillips Creek. No alluvium is mapped in association with Hughes Creek, which drains across the underground mining footprint.

The Quaternary alluvium associated with Phillips Creek is considered to have limited potential as a groundwater resource for the following reasons:

- A review of DNRME and site data indicates that several bores have been drilled near Phillips Creek and most of these bores did not intersect groundwater i.e. the drilling results indicate limited or no sustainable groundwater resources associated with the alluvium.
- Phillips Creek is ephemeral and does not provide a permanent recharge source to the alluvium.

Only one bore (MB32) which was constructed in the alluvial sediments of Phillips Creek located to the west of the Saraji Mine (Figure 30**)**, has been reported to contain water during groundwater monitoring events.



LEGEND

- Saraji Monitoring Bores
- Registered Bore
- Census Bore
- Underground layout (optimised)
- Underground layout (maximised)
- Existing Open-Cut Extent

Mining Tenement

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

Surface Geology

- Back Creek Group (Pb)
- Clematis Group (Re)
- Duaringa Formation (Tu)
- Duaringa Formation? (Tu?)
- Fort Cooper Coal Measures (Pwt)
- German Creek Formation (Pbd)
- Ki-CQ (Ki)
- MacMillan Formation (Pbn)
- Moranbah Coal Measures (Pwb)
- Peak Range Volcanics (Tp)
- Qa-QLD (Qa)
- Qr-QLD (Qr)
- Qr\b-QLD (Qr\b)
- Rangal Coal Measures (Pwj)
- Rewan Group (Rr)
- TQa-QLD (TQa)
- TQr-QLD (TQr)

N

Figure 30
Groundwater Bores

Groundwater Technical Report
Saraji East Mining Lease Project

0 2 4 8
Kilometres

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

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

BHP

DATE: 21/02/2019 VERSION: 1

Filename: P:\605X\60507031\4. Tech Work Area\4.99 GIS\02_MXDs\06 Environmental Impact Statement\F-1 Groundwater Technical Report\60507031_G186_v1_A4P.mxd

5.3.5.2 Groundwater recharge, discharge and flow

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

- recharge from surface water flow or flooding
- surface infiltration of direct rainfall and overland flow where permeable alluvial deposits are 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 occur at the surface. It is conceptualised that the Quaternary alluvium will not contain permanent groundwater as recharge to the alluvium seeps downwards into the underlying sediments or downgradient due to low effective storage.

Discharge from the alluvium is likely to include the following mechanisms:

- Infiltration and recharge to the underlying formations where Phillips Creek intersects more permeable areas within these units.
- Discharge to Phillips 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.
- Evapotranspiration from vegetation growing in the creek beds and along the banks.

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

5.3.5.3 Hydraulic parameters

As the alluvial aquifer is seasonal (recharged only during ephemeral flow periods), hydraulic parameters have not been determined in the Project Area.

More extensive alluvial systems occur outside the Project Area, associated with ephemeral water courses such as the Isaac River (approximately 15 km to the east of the underground mining footprint – Figure 21).

No site-specific aquifer data was obtained during previous groundwater investigations for the Saraji Mine due to the dry nature of the alluvium. Based on available information from the nearby Caval Ridge Mine, Quaternary alluvium deposits associated with creeks and main river tributaries could be expected to have a bulk hydraulic conductivity of approximately 0.1 m/day (URS, 2009).

5.3.6 Tertiary sediments

5.3.6.1 Occurrence

The Tertiary sediments maintain permanent groundwater resources particularly within the deeper sequences and the basal unit. The primary groundwater bearing strata of this unit is the basal sand/gravel unit, where it is locally extensive. The basal sand/gravel unit is however recognised to be discontinuous.

Observations from the open-cut pits at Saraji Mine indicate that groundwater discharges slowly from the Tertiary sediments and at the boundary (unconformable contact) between the Tertiary sediments and the underlying Permian strata. Based on these observations, the Tertiary sediments are considered to contain a series of poorly connected water-bearing horizons of low to moderate permeability, with drainage from the upper to lower horizons delayed by lower permeability horizons. Groundwater ingress rates to the Saraji pits 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.

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). 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 groundwater within the Tertiary sediments is considered variable and dependent 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 that the aquifer is confined to semi-confined because of the clayey sediments in the upper Tertiary sequence.

5.3.6.2 Groundwater recharge, discharge and flow

Recharge to the Tertiary aquifers is considered to be the result of the following:

- direct infiltration of rainfall and/or surface water runoff where the sediments subcrop or outcrop at the surface
- leakage from overlying alluvium, where present.

Primary discharge mechanisms in the Tertiary aquifers are likely to include the following:

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

Direction of groundwater flow within the Tertiary aquifer is expected to reflect topography, from elevated areas in the west towards lower areas towards the east.

5.3.6.3 Hydraulic parameters

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

Rising head permeability tests were undertaken by AGE (2011) at groundwater monitoring bores PZ02A, PZ04A, and PZ07A. These tests were conducted to assess the permeability of the Tertiary sediments at each location. The tests allowed for groundwater to be removed from each bore via airlift techniques; the rate of water level recovery for each well was then measured via groundwater level loggers installed in each well. Additionally, manual water level readings were measured prior to, and at regular intervals, for each test.

Results of these tests indicated a permeability range for the Tertiary aquifer between 1×10^{-2} m/day and 2×10^{-3} m/day (2 to 3 orders of magnitude lower than the alluvium).

5.3.7 Permian sediments

5.3.7.1 Occurrence

Permian sediments in the Project Area include the FCCM and MCM. While the Permian sediments do not outcrop in the underground mining footprint, they subcrop under the Tertiary sediments. Figure 24 depicts the extent of mapped Permian sediments (i.e. basement geology).

As is the case throughout much of the Bowen Basin, the individual coal seams are typically regarded as the main water bearing units within the Permian coal measures. Groundwater movement and storage occurs within the coal seam cleats and fissures and within open fractures that intersect the seams. The coal seams are often the first unit where useable volumes of groundwater are encountered during drilling along the western edge of the Bowen Basin and therefore the coal seams may provide locally sufficient groundwater supplies where yields and quality are sufficient (typically for cattle stock watering or industrial purposes as included in Section 5.4).

Other sediments in the coal overburden and interburden are relatively impermeable and generally form aquitards, except where fractured or faulted. It is recognised from the 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 leaky aquitard would result in all bores having the same/similar piezometeric levels).

Permian sediments may therefore be categorised into the following hydrogeological units:

Hydraulically ‘tight’ and hence very low yielding sandstone, siltstone, mudstone, carbonaceous shale and claystone that comprise most of the Permian overburden and interburden sediments.

Low to moderately permeable coal seams which are the main water bearing strata within the Permian coal measures.

5.3.7.2 Groundwater recharge, discharge and flow

Groundwater monitoring bores constructed to intersect the Permian sediments have water levels which are higher in elevation than the horizon at which the water was first intersected, which indicates that groundwater within the Permian sediments is confined.

Groundwater recharge to the Permian sediments is likely to occur via the following mechanisms:

- Direct infiltration from overland flow and rainfall in areas where the Permian sediments subcrop or outcrop at the surface.
- Downward seepage and/or through flow from adjacent or overlying Tertiary/Quaternary sediments in places where no substantial clay unit is present.

Discharge mechanisms of the Permian sediments are likely to include the following:

- Through flow into adjacent coal seams or seepage into underlying aquifers (via structural discontinuities).
- Downgradient Permian strata outcrop areas.
- Groundwater extraction from regional / local mine dewatering activities.
- Groundwater flow within the Permian deposits is expected to generally be down-dip.

The geological cross-section in Figures 25 to 28 suggest that the Permian sediments are relatively undisturbed and groundwater within the sediments is therefore unlikely to be influenced by faulting (i.e. mounding or lows in the groundwater flow patterns are not expected or identified, which can result from alteration of sediments due to fault throws).

5.3.7.3 Hydraulic parameters

Hydraulic parameters for the Permian sediments were derived from the following three sources:

- Rising head permeability tests were undertaken by AGE (2011) at groundwater monitoring bores PZ02B&C, PZ04B&C, PZ07B, PZ09B, and PZ10B&C using the same methodology as described in Section 5.3.6.3.
- Packer tests which were undertaken on eight geotechnical boreholes by Mining One (2011).
- Stress and permeability testing which was undertaken by Multiphase Technologies (2011).

The results of the permeability testing is summarised in Table 16.

Table 16 Permeability Test Results

Geological Unit	Test Method	Hydraulic Conductivity (m/day)		
		Minimum	Maximum	Average
Harrow Creek	Slug	4.3×10^{-5}	2.6×10^{-2}	7.0×10^{-3}
	Packer	-	-	1.6×10^{-2}
	Stress & perm	5.8×10^{-5}	3.2×10^{-1}	3.9×10^{-2}
Dysart	Slug	4.3×10^{-5}	4.6×10^{-3}	2.3×10^{-3}
	Packer	-	-	9.5×10^{-3}
	Stress & perm	5.8×10^{-4}	1.0×10^{-1}	1.2×10^{-2}
Permian Interburden	Slug	-	-	-
	Packer	-	-	1.6×10^{-1}
	Stress & perm	-	-	-

Notes: "-" not tested or no result provided

Source: AGE (2011).

Table 16 shows that the coal seam aquifers within the Project Area generally exhibit low to moderate hydraulic conductivity. Overall, results show that the deeper Dysart seam is slightly less permeable (less than one order of magnitude) than the overlying Harrow Creek seam.

The hydraulic conductivity data, as determined during the field tests, indicates a reducing hydraulic conductivity of the coal with depth. Based on the decrease in permeability with depth, the following 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) = $0.006499 \times e^{-0.0104 \times depth}$

It is recognised from Table 16 that packer tests performed across Permian interburden yielded hydraulic conductivity values comparable to the coal seams which contrasts with the conceptual understanding that the Permian interburden is typically tight and less permeable than the coal seams. The higher hydraulic conductivity results for the packer tests across the Permian interburden suggest that the interburden material can be locally permeable but are not expected to be laterally continuous (AGE, 2011).

5.3.8 Groundwater level data

Groundwater level data was compiled from the various bores identified in Sections 5.3.1, 5.3.2 and 0.

5.3.8.1 Quaternary groundwater levels

Ten (10) bores were reported to intersect Quaternary alluvium. Groundwater level data is limited due to the seasonal nature of the alluvium. For this unit available data includes:

- six bores (162681, 162685, 165323, 165324, 165325, 165326) with no water level data
- two bores (158483, 158485) which were drilled dry
- one bore (158484) with a single recorded water level measurement
- one bore (MB32) with transient water level data.

Bore MB32 is a historic stock watering bore (used for stock watering until 2007) identified during a bore census. This bore is located upstream of the Saraji Mine on Phillips Creek (Figure 30).

The available groundwater level data for MB32 shows fluctuations over an approximately 7 m range (Figure 31). Groundwater levels within MB32 do not correlate with the CRD indicating possible semi-confining conditions (i.e. not unconfined at this location), alteration due to limited effective storage (i.e. drainage under gravity) or possible abstraction.

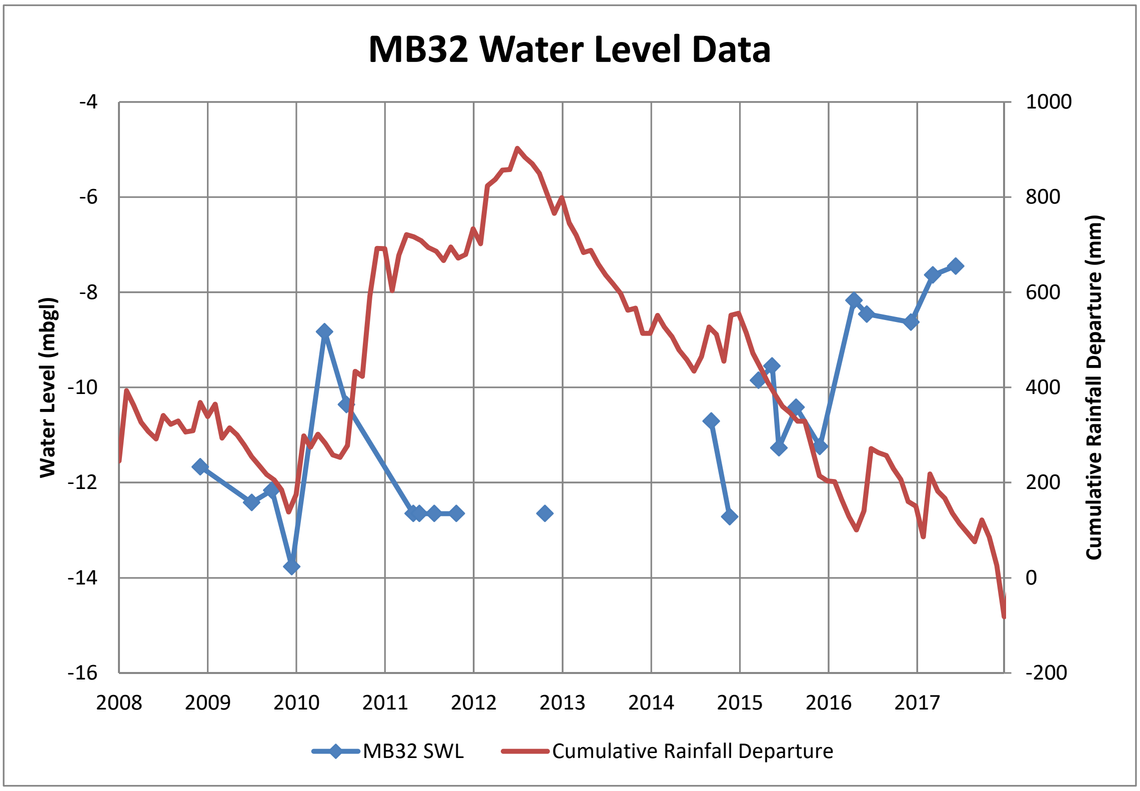


Figure 31 MB32 Groundwater level data

5.3.8.2 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 also drilled to intersect Tertiary sediments but both were drilled dry.

Groundwater level measurements, compiled during 2011 and 2012, indicate variable groundwater levels across the Project Area (Figure 32). Tertiary monitoring bores generally became dry during the monitoring period as a result of sampling, indicating limited sustainable yields.

Tertiary groundwater levels measured in PZ02A and PZ04A (IESA, 2012) indicate that groundwater levels are generally greater than 20 m below ground level (Figure 32).

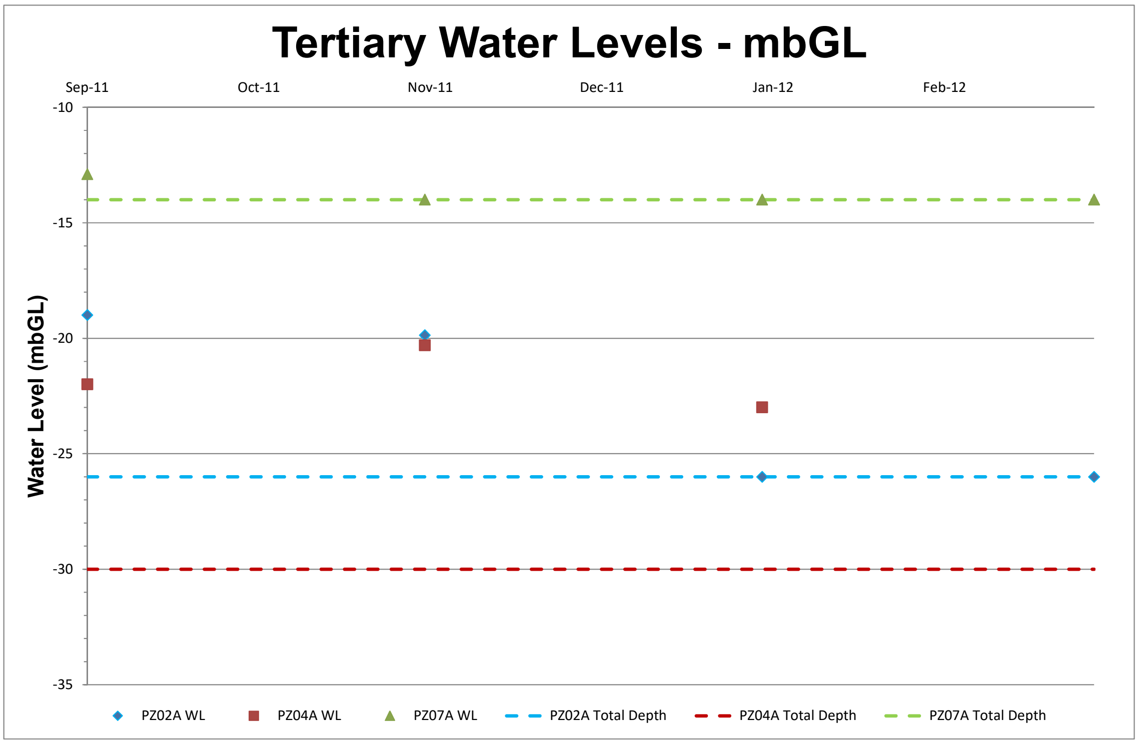


Figure 32 Tertiary groundwater level data

Groundwater flow contours in the Tertiary sediments are expected to mimic topography with flow from west to east towards the Isaac River.

5.3.8.3 Permian groundwater levels

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

Harrow Creek – PZ02B, PZ04B, PZ05A, PZ06B, PZ07C, PZ08B, PZ09B, and PZ10B

Dysart – PZ02C, PZ04C, PZ05B, PZ06C, PZ07B, PZ08C, PZ09C, and PZ10C.

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

The potentiometric surface of the Permian sequences indicates a gradient from around 185 mAHD in the north-west to around 170 mAHD in the south-east across the Project Area. This is similar to the regional groundwater contours generated for the Permian coal seams across the entire Bowen Basin, Figure 33 (Arrow, 2012).

The regional groundwater flow pattern across the Project area 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 a result of abstraction or faulting.

Groundwater levels for the Permian coal seam bores are shown in Figure 34 and Permian interburden/overburden sediments in Figure 35. Overall, Permian groundwater levels indicate no marked 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).

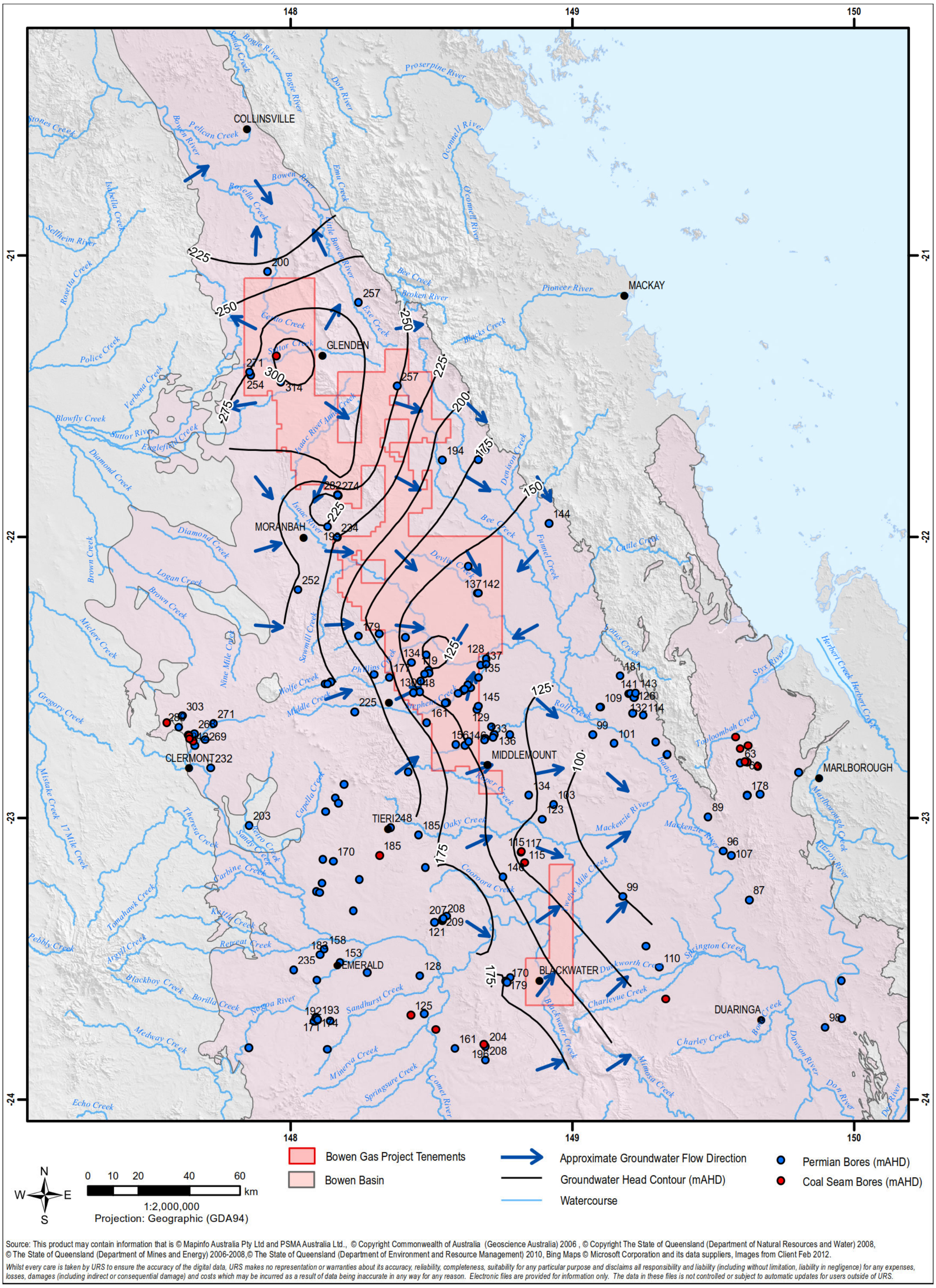
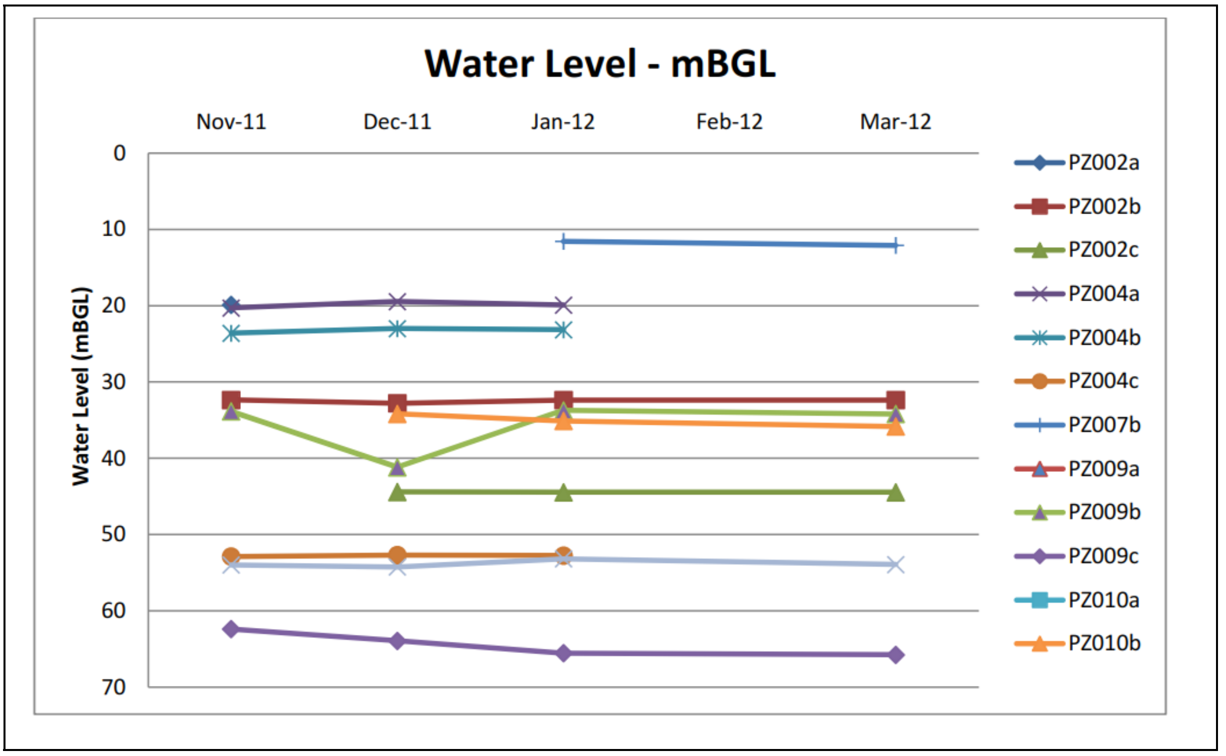
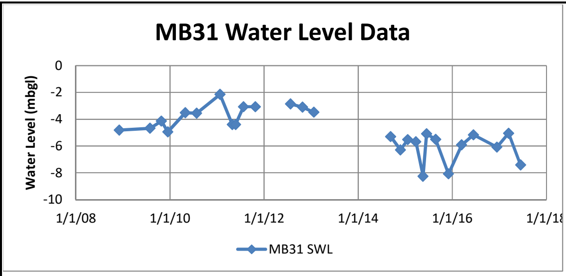


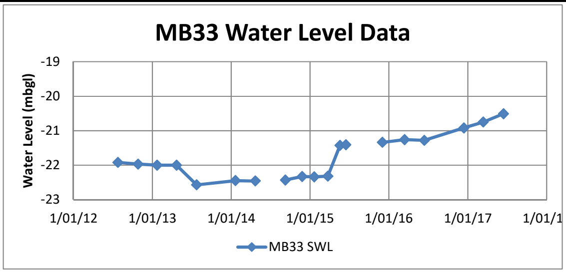
Figure 33 Average groundwater level contours across the Bowen Basin. Source: Arrow (2012)

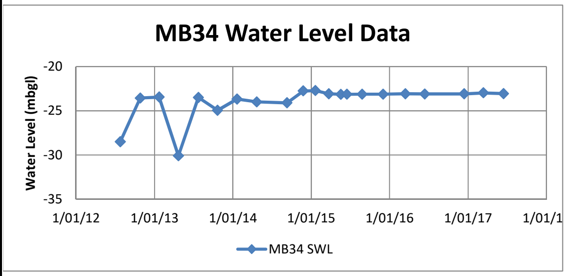


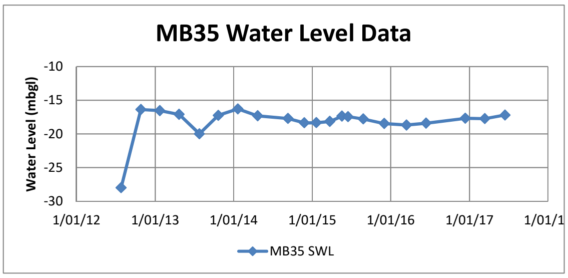
Note: PZ002a, PZ004a, PZ009a and PZ010a are screened across Tertiary sediments.

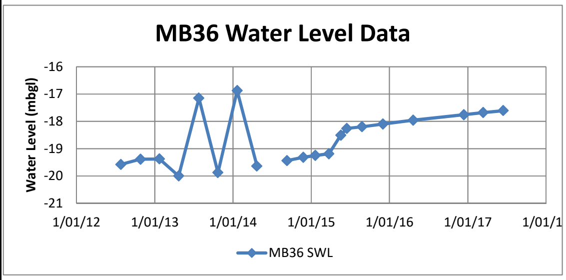
Figure 34 Permian coal seam monitoring bore groundwater level data











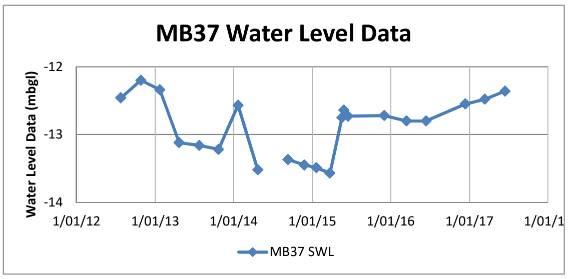


Table 4: SARAJI MINE MONITORING BORE DETAILS

Bore Name	Property	Easting	Northing	Diameter mm	Total Depth (mbgl)	Surface Elevation (mRL)	Screened Interval		Screened Lithology	Use	Status
							From	To			
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

Figure 35 Permian Interburden/Overburden Monitoring Bore Groundwater Level Data

5.3.8.4 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 Project Area. Representative groundwater data and nested bore details are included in Table 17.

Table 17 Vertical groundwater level assessment (Aug /Sept 2011 Groundwater monitoring data; AGE)

Bore	Monitoring Point	Depth (mbGL)	Unit	Water Level (mAHD)	Comment
PZ02	PZ02A	26	Tertiary	181.78	Downwards gradient. Marked water level separation between units.
	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. Minor water level separation between coal seams.
	PZ05B	239	Dysart (D52)	166.43	
PZ06	PZ06A	40.5	Permian overburden	184.39	Downwards gradient between overburden and H16 seam. Upwards gradient between H16 seam and D142 seam. Marked water level separation between units.
	PZ06B	78.5	H16	179.08	
	PZ06C	167	Dysart (D142)	182.62	
PZ08	PZ08A	38.5	P07 coal	177.70	Downwards gradient. Marked water level separation between coal seams.
	PZ08B	65	H16	173.25	
	PZ08C	180	Dysart (D24)	No Data	
PZ09	PZ09A		Tertiary	Dry	Downward gradient. Marked water level separation between coal seams.
	PZ09B	75	H16	165.69	
	PZ09C	195	Dysart (D24)	133.02	
PZ10	PZ10A		Tertiary	Dry	Downwards gradient. Marked water level separation between coal seams.
	PZ10B	70	H16	177.52	
	PZ10C	184	Dysart (D24)	159.33	

Overall, the groundwater level data shows that there are distinct differences in groundwater levels between the Tertiary sediments and Permian sediments, and between the Permian interburden/overburden sediments and Permian coal seams.

The vertical hydraulic gradient is predominantly downwards.

5.3.8.5 Dewatering as a result of existing mining

Those monitoring bores which contain several years of monitoring data (i.e. MB31 to MB37) do not indicate any decline / downward trend in groundwater levels despite some bores being located within close vicinity (and down dip) to existing open-cut pits, i.e. MB32 is located approximately 600 m from existing pits whilst MB33 and MB34 are located some 1,500 m away. The lack of a groundwater level decline trends within these monitoring bores suggests that these bores have not yet been impacted by mine dewatering.

Given that Saraji Mine has been operating since 1974, the absence of a downwards water level trend indicates that the zone of influence has not yet extended to those bores and is considered restricted to the immediate vicinity of the pits due to the low permeability of the sediments.

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

5.3.9 Groundwater quality

5.3.9.1 Quaternary deposits

Groundwater quality of alluvial sediments associated with creeks and river systems within the Isaac-Connors sub-catchment are considered to be moderately to highly variable, ranging from fresh to very saline (URS, 2012).

The groundwater monitoring bores across the area reported to be screened through the alluvium are dry, except for bore MB32. Available water quality data for MB32 was compiled by Gauge (2016) to provide an indication of the groundwater quality associated with saturated alluvium adjacent to the Project Area (Table 18).

Table 18 shows that groundwater associated with the alluvium is generally brackish and bicarbonate dominant.

The concentration of total dissolved solids indicates that the water is not suitable for drinking but can be used for livestock watering.

Table 18 Alluvium groundwater quality - MB32 (Gauge, 2016)

Site	Date	Insitu pH	Insitu EC	SWL		TDS	CO3	HC03	SO4	Cl-	Ca	Mg	Na	K	Al	Sb	As	Fe	Hg	NO3	P	C6-C9	C10-C36
											(diss)	(diss)	(diss)	(diss)	(Total)	(Total)	(Total)	(Total)	(Total)		react.		(sum)
		pH units	µ S/cm	(mBGL)	(mRL)	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	µg/l	µg/l	µg/l	µg/l	µg/l
Guidelines (Fitzroy)																							
Zone 34	Shallow 80th	7.1-8.1	8910			-	-	878	318	3185	215	389	1500	-	-	-	-	246	-	5.3	-	-	-
Zone 34	Deep 80th	7.1-8.03	16000			-	-	650	398	5905	442	491	2565	-	-	-	-	140	-	14.92	-	-	-
ANZECC stock		6.0-9.0	5970			4000			1000		1000				5000	-	500	-	2				
NHMR drinking water		6.5-8.5	*895*			600			500	250			180		200	3	10	300	1	11.3			
MB32	2/12/2008			11.67	196.33																		
MB32	1/07/2009			12.42	195.58																		
MB32	23/09/2009			12.16	195.84																		
MB32	14/12/2009	6.98	1440	13.77	194.23	649	< 1	422	21	51	73	74	47	< 1			< 1					< 20	< 50
MB32	29/04/2010	7.34	996	8.83	199.17	552	< 1	423	26	40	80	65	41	< 1			1					< 20	< 50
MB32	27/07/2010	7.06	1098	10.36	197.64	637	< 1	497	24	55	71	78	61	< 1			< 1			< 0.01	0.06	< 20	< 50
MB32	24/01/2011																						
MB32	29/04/2011	7.28	1080	12.65	195.35	606	< 1	471	21	42	87	64	38	1			< 1			< 0.01	0.37	< 20	< 50
MB32	25/05/2011	7.28	1080	12.65	195.35	606	< 1	471	21	42	87	64	38	1			< 1			< 0.01	0.06	< 20	< 50
MB32	25/07/2011	7.48	867	12.65	195.35	606	< 1	471	21	42	87	64	38	1						< 0.01		< 20	< 50
MB32	24/10/2011	6.95	997	12.65	195.35	609	< 1	517	23	50	83	70	48	< 1			< 1			< 0.01	0.05	< 20	< 50
MB32	20/06/2012	7.67	773			3000	< 5	940	500	780	69	89	910	51			1			< 0.005	4.4	< 10	< 100
MB32	25/07/2012	6.8	1690			690	< 5	500	32	83	95	82	56	1.1			< 1			< 0.005	0.44	< 10	< 100
MB32	24/10/2012	7.57	1401	12.65	195.35	790	< 5	540	32	91	80	72	53	1			< 1			< 0.005	0.067	< 10	< 100
MB32	22/01/2013	7.15	2276			860	< 5	650	59	140	86	94	90	1			< 1			< 0.005	0.065	< 10	< 100
MB32	22/04/203																						
MB32	24/07/2013	6.65	2437			1100	< 5	560	42	140	110	97	77	1.3			< 1			< 0.005	0.24	< 10	< 100
MB32	22/10/2013	7.37	1713			930	< 1	488	67	202	105	111	75	1	50	< 1	< 1	390	< 1			< 20	< 50
MB32	21/01/2014	8.18	1672			1100	29	436	82	219	79	113	107	1	100	< 1	< 1	1070	< 0.1			< 20	< 50
MB32	22/04/2014		1622			940	< 1	586	91	218	117	111	106	1	70	< 1	< 1	690	< 0.1			< 20	< 20
MB32	29/07/2014					856	< 1	563	62	182	91	102	94	1	150	< 1	< 1	1160	< 0.1			< 20	< 50
MB32	10/09/2014	7.518	1562	10.71	197.29	797	18	485	52	193	104	104	83	2	<10	< 1	< 1	390	< 0.1			< 20	< 50
MB32	25/11/2014	7.518	1611	12.72	195.28	882	< 1	646	59	182	98	106	108	2	30	< 1	< 1	320	< 0.1			< 20	< 50
MB32	20/01/2015																						
MB32	24/03/2015	7.504	1695	9.82	198.15	961	< 1	611	91	212	110	101	119	1	90	< 1	< 1	1100	< 0.1			< 20	< 50
MB32	19/05/2015	7.63	1946	10.65	197.35	1100	< 1	661	136	263	119	118	154	1	10.00	< 1	< 1	0.85	< 0.1			< 20	< 50
MB32	16/06/2015	7.77	1655	12.37	195.63	918	< 1	596	68	221	108	103	101	1	50.00	< 1	< 1	0.11	< 0.1			< 20	< 50
MB32	26/08/2015	7.16	1638	10.42	197.58	660	< 1	482	49	101	89	80	81	3	20	< 1	< 1	80	< 0.1	0.23		< 20	< 50
MB32	2/12/2015	7.04	1833	11.42	196.76	16800	< 1	829	2580	7920	352	525	4330	87	920	< 1	2	2970	< 0.1			< 20	< 50
MB32	21/04/2016	7.65	1380	8.17	199.83	18300	10	16	280	9720	801	131	4670	40	< 50	< 5	< 5	< 0.26	< 0.1			< 50	< 20
MB32	13/06/2016	7.29	1396	8.46	199.54	940	< 1	586	91	218	117	111	106	1	70	< 1	< 1	690	< 0.1			< 50	< 20
MB32	19/09/2016	7.28	1223	8.29	199.71	6150	< 1	465	506	3220	386	295	1260	6	560	< 1	3	1980	< 0.1			< 20	< 50

5.3.9.2 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 19 summarises the groundwater quality of samples from the Tertiary sediments as collected from bores PZ02A and PZ04A.

Table 19 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
Alkalinity (total)	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 N	-	< 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 (2011)

Table 19 indicates 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 livestock guideline 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.

5.3.9.3 Coal seam aquifers

Representative samples of the Permian coal seam aquifers were collected from bores PZ02B, PZ04B, and PZ09B for the Harrow Creek Upper (H16) Coal Seam and from PZ04C, PZ09C, and PZ10C for the Dysart Lower Coal Seam (Figure 30), Table 20 and Table 21 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 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 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 20 Harrow coal seam groundwater quality (AGE, 2011)

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	14000	27000	20000	-
Total Dissolved Solids	mg/L	5	***9600***	***20000***	***15000***	4000
Major Irons						
Total Alkalinity	mg/L	1	35	590	420	-
Sulphate	mg/L	1	49	1900	1500	1000-2000
Chloride	mg/L	1	4900	9100	6700	-
Fluoride	mg/L	0.1	0.14	0.44	0.2	1000
Calcium	mg/L	0.5	310	400	320	
Magnesium	mg/L	0.5	120	740	500	-
Sodium	mg/L	0.5	2900	5200	4700	-
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_{36} 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

Table 21 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	23000	8122	5500	-
Total Dissolved Solids	mg/L	5	***18000***	3420	3300	4000
Major Irons						
Total Alkalinity	mg/L	1	270	201	220	-
Sulphate	mg/L	1	1200	52	60	1000-2000
Chloride	mg/L	1	7900	7880	1600	-
Fluoride	mg/L	0.1	0.18	0.44	0.4	1000
Calcium	mg/L	0.5	350	32	29	
Magnesium	mg/L	0.5	520	27	25	-
Sodium	mg/L	0.5	4400	0.45	1200	-
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	0.034/0.040	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_{36} Fraction	µg/L	100	<100	-	1100	-
C_{29} - C_{36} Fraction	µg/L	100	<100	-	490	-
BTEX[1]	µg/L	1-2	<LOR	-	2 (Toluene)	1-25

Saraji EA monitoring bores

Seven monitoring bores, MB31 to MB37, form part of the existing groundwater monitoring network. All these bores, except MB32 (alluvium), provide ongoing hydrochemistry data for the Permian interburden/overburden strata across and adjacent to the Saraji Mine. Available hydrochemical data for these Permian bores was compiled by Gauge (2016) and shown in Appendix A.

The latest annual groundwater monitoring report (Gauge, 2016) indicates the following:

- Groundwater quality parameters monitored include; pH, electrical conductivity (EC), total dissolved solids (TDS), calcium (Ca), magnesium (Mg), sodium (Na), potassium (K), carbonate (CO_3), Bicarbonate (HCO_3), chloride (Cl), sulphate (SO_4), reactive phosphorus (P), nitrate (NO_3), aluminium (Al), iron (Fe), arsenic (As), mercury (Hg), antimony (Sb), and petroleum hydrocarbons.
- Bores MB33 and MB34 have the highest salinities, EC 23,000 µS/cm to 35,000 µS/cm associated with deeper Permian interburden indicating increased salinity with depth due to slow movement and interaction with Permian sediments.
- The lowest salinities occur within the Phillips Creek bores MB32 (alluvium) and MB35 (Fairhill Formation directly below alluvium) with EC concentrations less than 2,500 µS/cm. The salinity values in MB35 suggest this bore is likely to receive recharge from the overlying alluvium.
- All bores have TDS concentrations greater than 500 mg/L which exceeds the drinking water guideline.
- Sulphate concentrations in MB31, MB33, and MB37 are greater than the cattle 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 all 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 and indicate little or no measurable impact due to mine operations.

5.3.9.4 Summary

The groundwater quality data across the site 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 TDS and saline water for prolonged periods. For beef cattle, this TDS limit is the range of 5,000 mg/L to 10,000 mg/L.

Given that total dissolved solids for the Tertiary and Permian sediments are generally above 5,000 mg/L, the regional groundwater would generally not be considered suitable for livestock.

5.3.10 Groundwater dependent ecosystems

Groundwater dependent ecosystems (GDEs) are defined as ecosystems that require access to groundwater on a permanent or intermittent basis to meet all or some of their water requirements so as to maintain their communities of plants and animals, ecological processes and ecosystem services (Richardson et al, 2011).

GDEs can be grouped into three categories in Queensland, based on their type of groundwater reliance:

- aquatic GDEs
- terrestrial GDEs
- subterranean GDEs.

Aquatic GDEs are dependent on the surface expression of groundwater and rely on groundwater after it has been discharged to the surface i.e. groundwater-fed wetland systems (swamps, lakes and rivers).

Terrestrial GDEs are dependent on the subsurface expression of groundwater and access subsurface groundwater to meet all or some of its water requirements i.e. terrestrial vegetation with typically deep-rooted trees.

Subterranean GDEs occur within caves and aquifers. Cave GDEs occur in caves which have some degree of groundwater connectivity. Aquifer GDEs typically occur within the intergranular void space, rock fractures and solution cavities. Aquatic animals that live in groundwater are referred to as stygofauna.

5.3.10.1 Identification of GDEs

The National Atlas of groundwater dependent ecosystems (GDE Atlas) was consulted to identify whether GDEs have been mapped within the area. GDE Atlas comprises maps that show the location of both known and potential GDEs across Australia, as well as ecological and hydrogeological information for each GDE. The database containing the GDE mapping is hosted by BoM and accessible through the BoM website (http:\\www.bom.gov.au).

Where no known aquatic or terrestrial GDEs were mapped within the GDE Atlas, the potential for aquatic or terrestrial GDEs were further assessed by using the Stage 1 assessment approach recommended within the *Australian groundwater-dependent ecosystem toolbox part 1: assessment framework* (GDE Toolbox) (Richardson et al, 2011). The GDE Toolbox Stage 1 assessment relies heavily on the methodology outlined by Eamus et al (2006) for identifying aquatic and terrestrial GDEs. Eamus et al (2006) pose a series of questions to help determine the likelihood of whether an ecosystem is potentially dependent on groundwater. They suggest that an affirmative answer to one or more of these questions means there is potentially a GDE present. The questions are reproduced in Table 22 and Table 23. Where no known subterranean GDEs were mapped within the GDE Atlas; the potential for subterranean GDEs was assessed from a literature review and site specific sampling results.

5.3.10.2 Aquatic GDEs

Aquatic GDEs, as mapped within the GDE Atlas, are shown in Figure 36 and can be summarised as follows:

No known aquatic GDEs are mapped within the Project Area.

There is moderate to high potential for aquatic GDEs to exist within those areas of the Saraji Mine which contain open water i.e. tailings dams, evaporation dams and levees.

There is moderate to high potential for aquatic GDEs to exist along reaches of Phillips Creek to the south of the proposed underground mine and Hughes Creek/Boomerang Creek which overlies the northern portion of the underground mining footprint.

To further assess the likelihood of aquatic GDEs within the Project Area, using project specific data and observations, a series of five questions posed by Eamus et al (2006) were answered as shown in Table 22.

Table 22 Questions to determine likelihood of aquatic GDEs

Question	Comment
Does a stream/river continue to flow all year, or a floodplain waterhole remains wet all year in dry periods?	No. All creeks in the Project Area are ephemeral with only intermittent flow. As discussed in Section 5.3.5, it is conceptualised that the alluvial sediments will not contain permanent groundwater as recharge to the alluvium seeps downwards into the underlying sediments. None of the creeks in the Project Area have permanent groundwater baseflow that contributes to surface flows (Hydrobiology, 2016).
For estuarine systems, does the salinity drop below that of seawater in the absence of surface water inputs?	Not applicable to the Project.
Does the volume of flow in a stream/river increase downstream in the absence of inflow from a tributary?	No. Creeks flow throughout their length following flood events, water then quickly retreats due to the sandy nature of the creek bed. During retreat, water becomes ponded in areas where clay is present and/or areas which have low elevation. None of the creeks in the Project area are identified as gaining streams (SKM, 2009).
Is the level of water in a wetland/swamp maintained during dry periods?	No. Water levels in tailing dams, evaporation dams and levees (areas identified as moderate to high potential for aquatic GDEs within the GDE Atlas) do maintain permanence throughout the year but are artificial mining features and permanence is related to mining activities.
Is groundwater discharged to the surface for significant periods of time each year at critical times during the lifetime of the dominant vegetation type?	No. There are no springs which have been mapped in the area or which are known to exist within the area. There are no known points where groundwater can be seen naturally discharging to the surface.

Given that the answers to all of the questions in Table 22 are either 'no' or 'not applicable', those areas mapped as having moderate to high potential for aquatic GDEs in the GDE Atlas, are considered to have low potential for aquatic GDEs when assessed using site specific data for the following reasons: Those areas of the mine which contain open water i.e. tailings dam, evaporation pits and levees only have permanence of water due to them being artificial mining features.

The creeks in the area are ephemeral with only intermittent flows and it is conceptualised that the alluvial sediments associated with the creeks do not contain permanent groundwater.

5.3.10.3 Terrestrial GDEs

Terrestrial GDEs, as mapped within the GDE Atlas, are shown in Figure 37 and can be summarised as follows:

No known terrestrial GDEs occur within the Project Area.

There is low to moderate potential for terrestrial GDEs to exist within the footprint of the proposed underground mine workings and surrounds.

To further assess the likelihood of terrestrial GDEs within the Project area, using project specific data and observations, a series of three questions posed by Eamus et al (2006) were answered as shown in Table 23.

Table 23 Questions to determine likelihood of Terrestrial GDEs

Question	Comment
Is groundwater or the capillary fringe above the water table present within the rooting depth of any vegetation?	Unlikely in alluvial sediments. Sections 5.3.5.2 and 5.3.8.1 shows that groundwater is not permanently present in alluvial deposits with the exception of MB32 located to the west of Saraji Mine. Groundwater levels in MB32 vary between 7 mbGL and 14 mbGL. No in Tertiary sediments. Section 5.3.8.2 shows that water levels in Tertiary sediments are greater than 15 mbGL. Froend and Loomes (2004) suggest that groundwater is of reduced importance to vegetation when the water table is at depths greater than 10 m.
Does a proportion of the vegetation remain green and physiologically active (principally, transpiring and fixing carbon, although stem-diameter growth or leaf growth are also good indicators) during extended dry periods?	Not applicable. Previous studies have shown that the majority of floral assemblages within the area are characterised by drought tolerant species with low physiological sensitivity to water availability and are not considered groundwater dependent. No EPBC Act listed GDEs identified.
Is the level of water in a wetland/swamp maintained during extended dry periods?	No. Water levels in tailing dams, evaporation dams and levees (areas identified as moderate to high potential for terrestrial GDEs within the GDE Atlas) do maintain permanence throughout the year but are artificial mining features and permanence is related to mining activities.

Given the answers to the questions in Table 23, those areas mapped as having moderate potential for terrestrial GDEs in the GDE Atlas, are considered to have low potential for terrestrial GDEs when assessed using site specific data for the following reasons:
Groundwater levels in Tertiary sediments are generally deeper than 15 mbGL which is at a depth where groundwater has a reduced importance to vegetation (Froend and Loomes, 2004). This depth is also outside the accessible reach for Eucalypt vegetation (Zolfagher et al, 2014).

Groundwater is generally not permanently present within alluvial sediments and is therefore unlikely to provide a source of water for terrestrial species.

The majority of floral assemblages within the area are drought tolerant with low sensitivity to water availability.

5.3.10.4 Subterranean GDEs

No known or potential subterranean GDEs have been identified within the GDE Atlas for the Project area and surrounds.

5.3.10.5 Desktop review

Several previous investigations have been undertaken to assess the suitability of sediments within the Bowen Basin for stygofauna.

4T Consultants (2012) conducted a desktop review to assess the potential for stygofauna within the Bowen Basin. The main findings of the desktop review are summarised below:

- Aquifer type and associated hydraulic conductivity and pore space are the primary determinants for the presence or absence of stygofauna.

- Available information indicated that no stygofauna have been detected in coal seams within the Bowen Basin.
- Most stygofauna identified in the Bowen Basin were found within shallow (<29 mbGL) unconsolidated sediments, such as alluvium, at salinity levels less than 2,000 µS/cm and pH between 6.5 and 8.5.
- For unconsolidated sediment aquifers, stygofauna are more likely to be located where the depth to water is less than 20 m. In fractured rock aquifers, the majority of stygofauna have been located where the depth to water is less than 30 m.
- ALS (2012) suggested that salinity values of less than 5,000 µS/cm were most preferable for stygofauna with the highest number of taxa present where the water table was less than 10 mbGL.

5.3.10.6 Site-specific investigations

Stygofauna sampling was undertaken in seven groundwater monitoring bores screened across Tertiary and Permian sediments during September 2011 (IESA, 2011a) and December 2011 (IESA, 2011b). The details of the monitoring bores are summarised in Table 24 and the location of the bores in Figure 38.

Table 24 Monitoring bores sampled for stygofauna

Hole ID	Sediments Sampled	Latitude	Longitude	Total Depth (mbGL)	Water Level (mbGL)
SEGT02	Triassic and Permian	-22.3872	148.3002	149.62	28.61
SEGT04	Triassic and Permian	-22.4004	148.3001	138.01	22.40
SEGT10	Triassic and Permian	-22.4062	148.3053	162.30	45.77
PZ002-1	Tertiary	-22.3229	148.2828	26.00	17.44
PZ002-2	Triassic and Permian	-22.3229	148.2828	170.00	34.29
PZ009-1	Tertiary	-22.3492	148.2917	20.00	16.98
PZ00902	Triassic and Permian	-22.34927	148.2917	170.00	33.60

Note: Bores SEGT02, SEGT04, and SEGT10 were temporary bores, constructed for the stygofauna assessments.

Sampling was undertaken in accordance with *Draft Guidance No. 54A - Sampling methods and survey considerations for subterranean fauna in Western Australia* (WA EPA, 2007). It is noted that this guideline has since been updated.

No stygofauna species were detected during the September 2011 and December 2011 sampling events.

5.3.10.7 Potential for subterranean GDEs

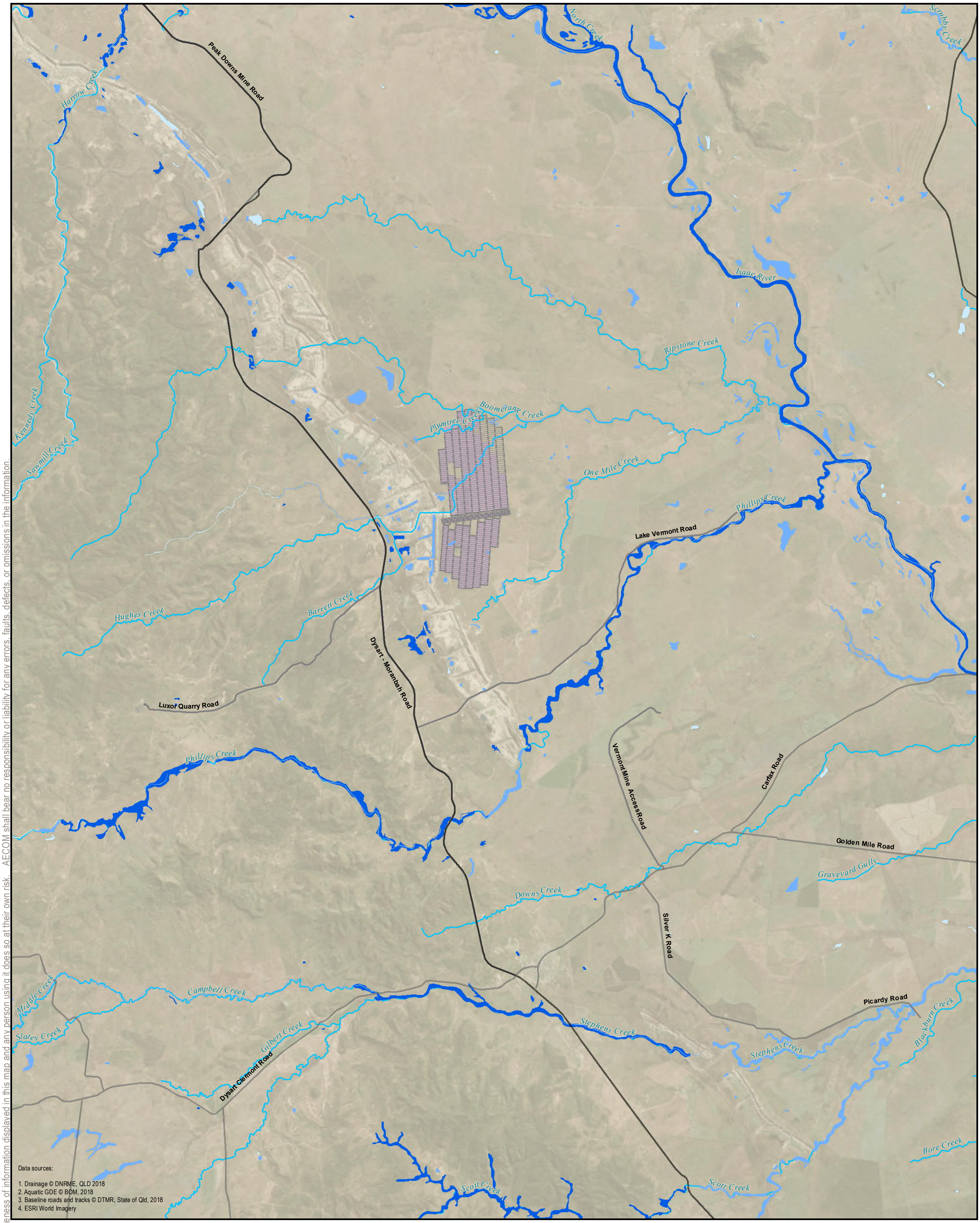
As the alluvium in and adjacent to the Project area is ephemeral, discontinuous, and can be saline it is considered that the alluvium is unlikely to contain sufficient permanent suitable groundwater to support stygofauna populations.

The potential for subterranean GDEs to exist within the Tertiary and Permian sediments is considered to be low for the following reasons:

- The saline nature of the Tertiary and Permian sediments (>5,000 µS/cm) and depth to groundwater (>17 m) are likely to preclude the presence of stygofauna.
- Site specific sampling of the Tertiary and Permian sediments did not detect any stygofauna taxa.

5.3.11 Springs

No known springs are present within the Project Area. A review of registered springs indicates that the closest springs are greater than 150 km from Saraji Mine (Figure 39).



LEGEND

- Watercourse
- Major Road
- Other Road
- Underground layout (optimised)
- Underground layout (maximised)

Aquatic Groundwater Dependent Ecosystems

- High potential GDE (national assessment)
- Moderate potential GDE (national assessment)
- Low potential GDE (national assessment)

N

Figure 36
Aquatic Groundwater Dependent Ecosystems

Groundwater Technical Report
Saraji East Mining Lease Project

0 1 2 4
Kilometres

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

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

BHP

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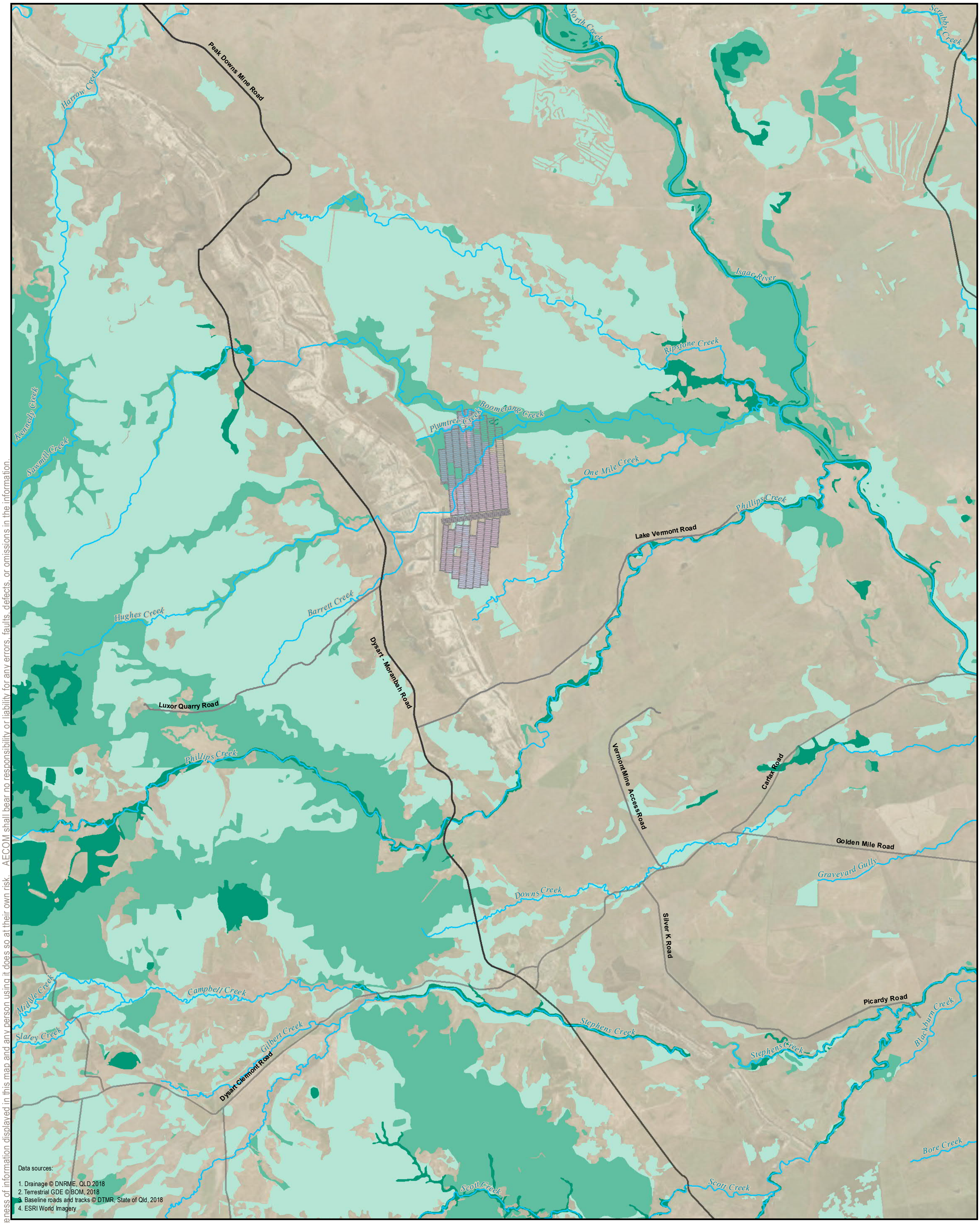

LEGEND

- Watercourse
- Major Road
- Other Road
- Underground layout (optimised)
- Underground layout (maximised)

Terrestrial Groundwater Dependent Ecosystems

- High potential GDE (national assessment)
- Moderate potential GDE (national assessment)
- Low potential GDE (national assessment)

N

Figure 37
Terrestrial Groundwater Dependent Ecosystems

Groundwater Technical Report
Saraji East Mining Lease Project

0 1 2 4
Kilometres

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

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

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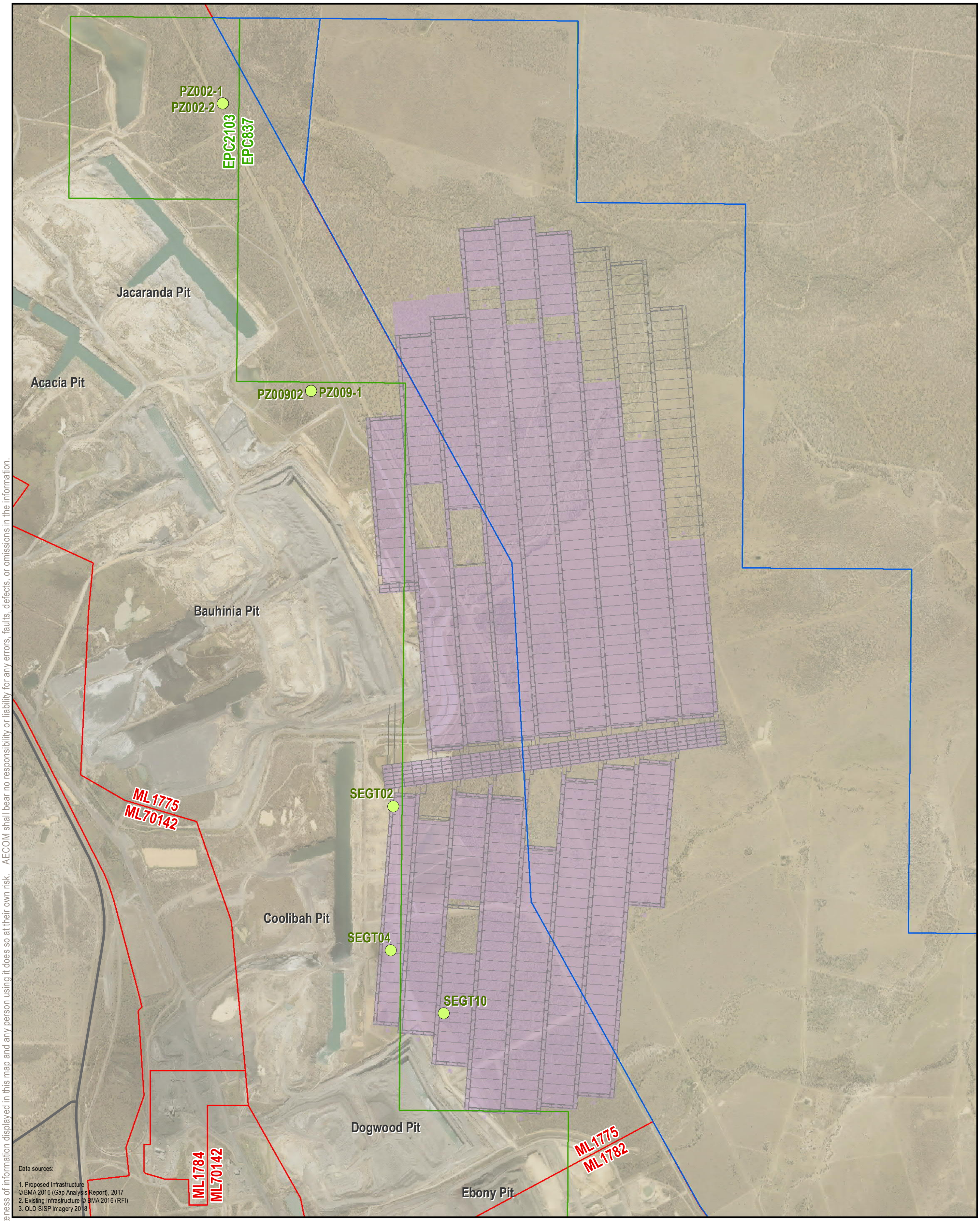

LEGEND

- Stygofauna Sampling Bore
- Public Road
- Underground layout (optimised)
- Underground layout (maximised)

Mining Tenement

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

N

Figure 38
Stygofauna Sampling Bores

Groundwater Technical Report
Saraji East Mining Lease Project

0 0.275 0.55 1.1
Kilometres

Scale: 1:50,000 (when printed at A4)

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

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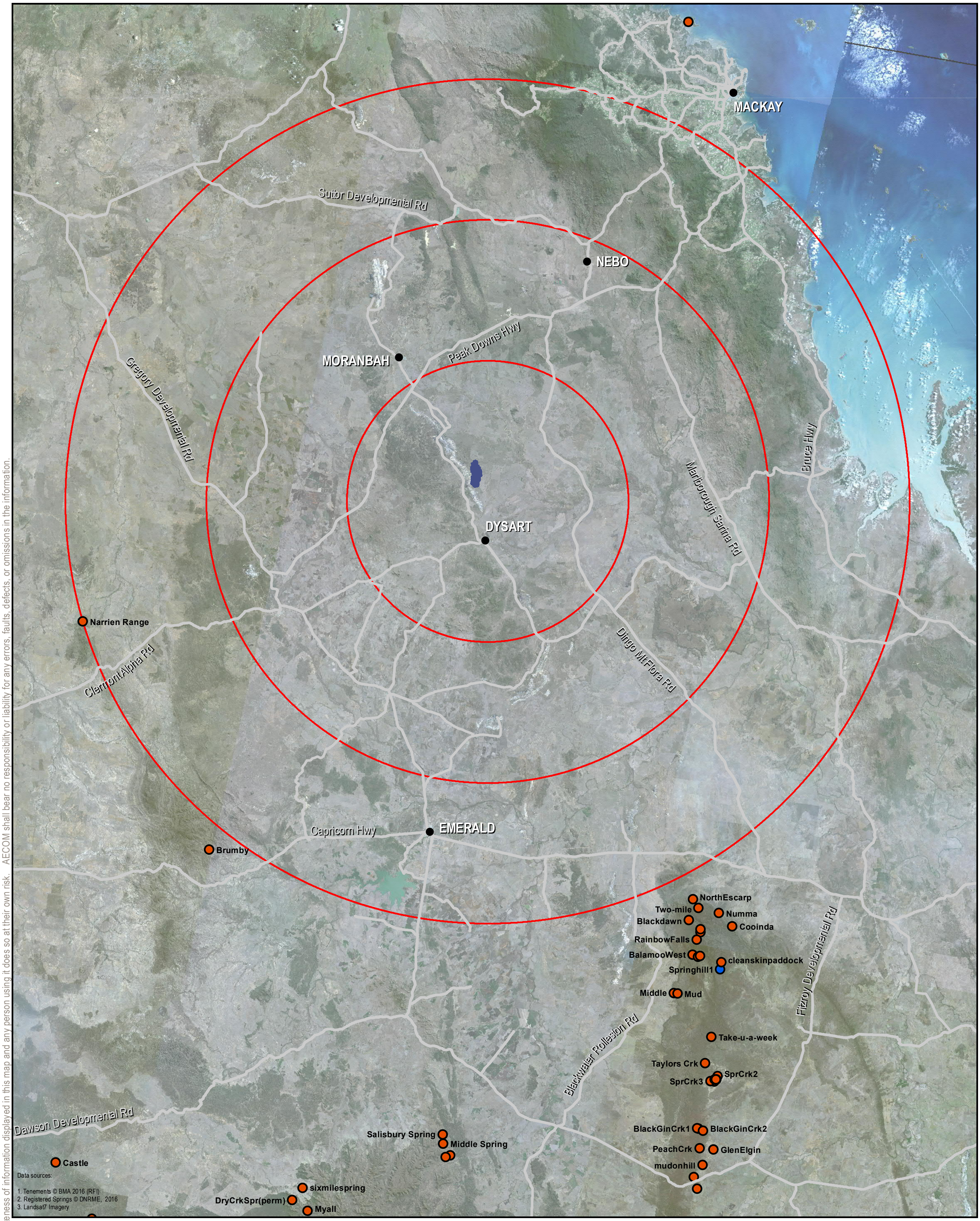

LEGEND

- Locality
- Major Road
- Underground layout (optimised)
- 50km concentric circles from Saraji Mine

Registered Springs

- Palustrine
- Riverine

N

Figure 39
Registered Springs

Groundwater Technical Report
Saraji East Mining Lease Project

0 5 10 20
Kilometres

Scale: 1:1,750,000 (when printed at A4)

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

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5.4 Groundwater use

A bore census was undertaken by AGE (2007). The bore census identified 12 bores within 15 km of Saraji Mine which did not correlate with the registered bore database and as such were unregistered bores. Table 25 presents a summary of information available for each bore.

Table 25 2007 Bore Census Data

Bore ID	Property	Location		Standing Water Level (m)	Bore Depth (m)	Water quality		Status
		Latitude	Longitude			pH	EC	
MB1	Meadowbrook	-22.3434	148.4127	20.63	79.4	7.62	2760	Pump removed
MB2	Meadowbrook	-22.3491	148.3200	22.86	60.94	-	-	Not equipped
MB3	Meadowbrook	-22.3490	148.320	23.82	50	6.67	6990	Not equipped
MB4	Meadowbrook	-22.3491	148.3200	23.53	27.1	-	-	Not equipped
MB5	Meadowbrook	-22.4131	148.3713	-	-	7.11	7270	Equipped
MB6	Meadowbrook	-22.3486	148.3142	-	-	8.23	5880	Equipped
LV1	Lake Vermont	-22.4278	148.3846	23.77	>100	7.32	916	New unequipped bore
LV2	Lake Vermont	-22.5040	148.3361	-	-	7.87	758	Equipped
SJ1	Saraji Station	-22.4000	148.2224	7.85	-	7.74	8250	Equipped
SJ2	Saraji Station	-22.4802	148.2641	-	-	-	-	Equipped – not operational
TG1	Tayglen	-22.5210	148.3147	9.42	15.06	8.23	1940	Not equipped
TG2	Tayglen	-22.5061	148.3366	-	-	7.88	754	Equipped

Source: AGE (2007)

Of the 12 bores identified during the bore census, four bores (MB2, MB3, MB4 and MB6) were identified adjacent to two registered bores; RN132631 and RN136689. The location of all registered and non-registered bores is shown on Figure 30**.** Registered bore details are summarised in Table 14.

Of the non-registered groundwater bores:

- Bores MB2 to MB4 are between 27 m and 60 m deep and not equipped with any pumps.
- Bore MB6 is equipped with a pump but its depth is unknown.
- 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.

A search of the Queensland Water Entitlement Database showed that none of the registered groundwater bores located within 15 km of Saraji Mine had water licences.

5.5 Groundwater environmental values

This section identifies and describes groundwater related environmental values in the Project Area as described in the EPP (Water).

The enhancement of groundwater environmental values and the protection of groundwater are required in the EPP (Water) (Section 3.2.2). 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 Project is located within the Isaac River sub-basin of the Fitzroy Basin as described in Schedule 1 of the EPP (Water). Environmental values and water quality objectives for groundwater within the Isaac River sub-basin are provided in '*Isaac River Sub-basin Environmental Values and Water Quality Objectives* (EHP, 2011)'. The environmental values for groundwater to be enhanced or protected in the Project Area are listed Table 26.

Table 26 Environmental values for groundwater

Environmental Value	Definition
Aquatic ecosystems	'A community of organisms living within or adjacent to water, including riparian or foreshore area' (EPP (Water), schedule 2). The intrinsic value of aquatic ecosystems, habitat and wildlife in waterways and riparian areas. For example, biodiversity, ecological interactions, plants, animals, key species (such as turtles, platypus, seagrass and dugongs) and their habitat, food and drinking water. Waterways include perennial and intermittent surface waters, groundwaters, tidal and non-tidal waters, lakes, storages, reservoirs, dams, wetlands, swamps, marshes, lagoons, canals, natural and artificial channels and the bed and banks of waterways.
Irrigation	Suitability of water supply for irrigation. For example, irrigation of crops, pastures, parks, gardens and recreational areas.
Farm water supply/use	Suitability of domestic farm water supply, other than drinking water. For example, water used for laundry and produce preparation.
Stock watering	Suitability of water supply for production of healthy livestock.
Primary recreation	Health of humans during recreation which involves direct contact and a high probability of water being swallowed, for example, swimming, surfing, windsurfing, diving and water-skiing. Primary recreational use, of water, means full body contact with the water, including, for example, diving, swimming, surfing, water-skiing and windsurfing (EPP (Water), s. 6).
Drinking water supply	Suitability of raw drinking water supply. This assumes minimal treatment of water is required, for example, coarse screening and/or disinfection.
Cultural and spiritual values	Indigenous and non-indigenous cultural heritage, for example: • custodial, spiritual, cultural and traditional heritage, hunting, gathering and ritual responsibilities • symbols, landmarks and icons (such as waterways, turtles and frogs) • lifestyles (such as agriculture and fishing). Cultural and spiritual values of water, means its aesthetic, historical, scientific, social or other significance, to the present generation or past or future generations (EPP (Water), s. 6).

5.5.1 Aquatic ecosystems

Section 5.3.10 shows that there are no known aquatic, terrestrial or subterranean GDEs that have been identified within the Project Area, and that there is a low potential for GDEs to be present. Aquatic ecosystems are therefore not expected to be impacted by dewatering or changes in groundwater quality.

5.5.2 Irrigation

Section 4.2.4 of the ANZECC guidelines (2000) states that the threshold salinity tolerances for plants grown in loamy to clayey soils are 600 µS/cm to 7,200 µS/cm. Given that groundwater salinity within Tertiary and Permian sediments is generally greater than 5,000 µS/cm, groundwater would not be considered suitable for irrigation.

A lack of licensed groundwater bores within 15 km of the Project Area also suggests that groundwater is not useable as a source of irrigation water.

5.5.3 Farm water supply/use

The high salinity of the groundwater generally precludes it from being suitable for farm supply uses such as laundry or produce preparation.

5.5.4 Stock watering

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

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.

5.5.5 Primary recreation

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 Project Area.

5.5.6 Drinking water

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 5.3.9, indicates that groundwater is unsuitable for human consumption before treatment due to elevated levels of salinity (Appendix A).

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

The availability of rainwater tanks 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.

It is noted, however, that alluvium bores LV2 and TG2, located to the west of the Saraji Mine have electrical conductivity concentrations below the Australian Drinking Water Guidelines EC (895 µS/cm or 600 mg/L TDS). These shallow groundwater resource could be suitable for drinking based on salinity off lease. It is noted in Section 5.5.6, however, that the groundwater resources associated with alluvium deposits in the Project area are limited and seasonal.

5.5.7 Cultural and spiritual values

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

5.5.8 Summary

In summary, the evaluation of groundwater environmental values in the area enveloping the Project indicates that groundwater associated with the Tertiary and Permian sediments are of limited value for most uses.

Groundwater associated with the alluvium, which has recorded good quality groundwater quality, is sporadic and seasonal and is not considered to provide sufficient (sustainable supply) in the Project area to allow for evaluation.

Based on available groundwater resources (potential and chemistry) the only recognised groundwater environmental value to be enhanced or protected within the Project area is stock watering.

5.6 Sustainable and efficient use of groundwater

Based on an assessment of existing water quality data (Section 5.3.9), extracted water is expected to be of poor quality and have high salinity. As a result, extracted water will not be discharged and will instead be used in the CHPP with losses through evaporation.

6.0 Potential impacts

6.1 Overview of potential impacts

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

6.1.1 Construction phase

As the proposed mining activities will start within the existing open-cut pits (high wall), the construction phase activities are thus considered to include the start of the portal to facilitate access to the longwall mining panels.

It is considered that this construction would occur in the dewatered sediments immediately adjacent to the high wall, thus no additional groundwater impacts are envisaged during construction.

6.1.2 Operational phase

The principal activities during the operational phase of the underground workings, which may impact groundwater resources, include:

- dewatering of workings
- alteration of geology, and associated aquifer hydraulic properties, due to goaf
- the cumulative drawdown of open-cut mining along strike, with the extended down-dip underground mining (portal construction and dewatering).

6.1.3 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 underground mining. 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 footprint (Figure 45), have been considered.

6.1.3.1 Indirect impacts

The longwall 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 above the longwall panels
- additional leakage from the overlying altered (due to goaf) Permian units to the dewatered and depressurised target coal seams.

6.1.3.2 Creek flow impacts

Mine dewatering can result in drawdown of the coal seam potentiometric surface, which can extend beneath Hughes 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 frequency or duration of no flow in the creek.

6.1.4 Post closure

It is considered that on completion of the proposed underground workings, the approved Saraji Mine open-cut final voids will be in place.

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 (final voids), such that groundwater levels are considered to recover within the underground workings up into the final voids. Principally the reduced groundwater levels and alterations to the groundwater regime are 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.

Thus the long term predictions are for the groundwater to recover within the Project area but not to pre-mining levels across the Project area due to final voids.

6.2 Conceptual model

The data used to develop the conceptualisation indicates two separate groundwater systems occur within the Project Area; these aquifer systems are associated with the following geological units:

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

Key understandings from the conceptualisation as discussed in Section 4.3.5 include the following:

- 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-cut 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 indicates lower groundwater levels to the east even though the permeability decreases with depth (Section 5.3.7.3). It is considered that faulting facilitates more complex groundwater movement to the east of the Project area.

6.2.1 End of mining drawdown contours

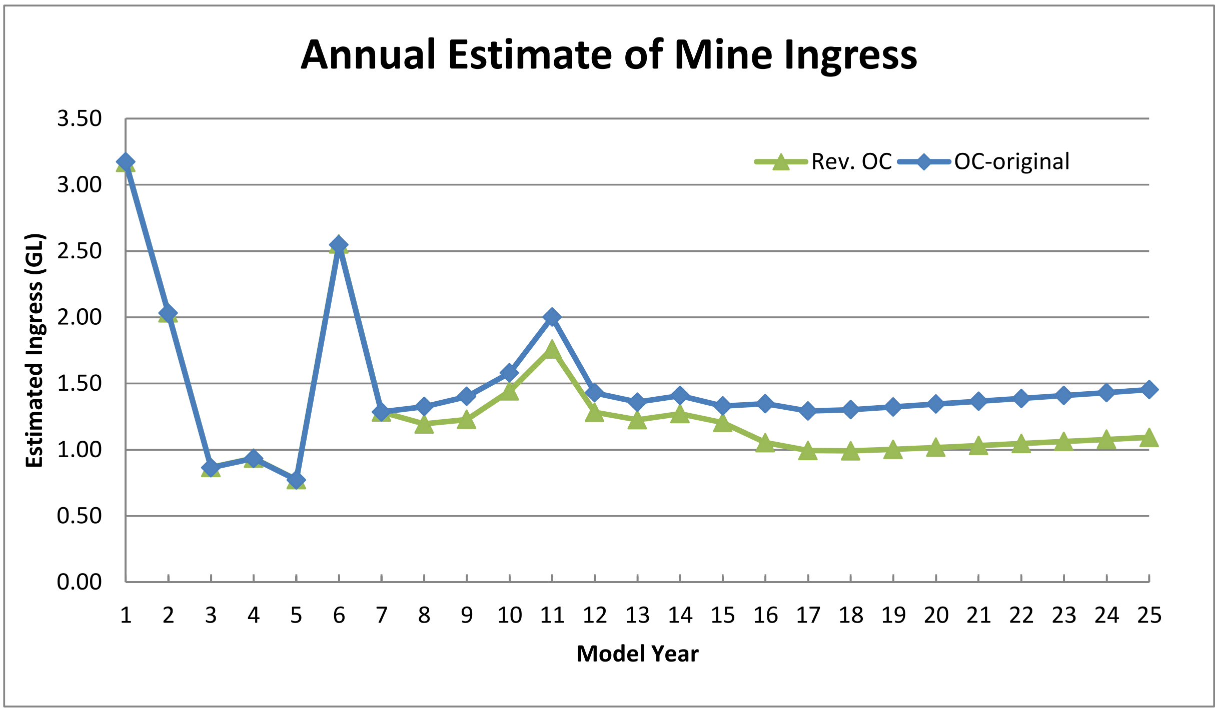
Groundwater drawdown contours were generated for the end of underground mining for the following model layers:

- Layer 1 - Quaternary/Tertiary, which is shown in Figure 41
- Layer 6 - Harrow Creek (H16) seam, which is shown in Figure 42
- Layer 10 - Dysart Lower (D14, D24) coal seam, which is shown in Figure 43.

The modelled drawdown contours provide a conservative representation of the LTAA (as defined in the Water Act) due to water extraction from mining activities.

Drawdown contours for end of approved open-cut mining, including the Grevillea Pit extension and excluding underground mining impacts, are also shown in Figures 41, 42 and 43 to allow for comparison to the drawdown predicted when including an assessment of the impacts from the underground mining.

In assessing proposed underground mining drawdown contours versus approved open-cut (excluding underground mining) drawdown contours, it is noted that the modelling that includes the Project activities uses the modified open-cut mine plan (Section 6.2). For comparison it is considered that the difference in the simulation of the open-cut mining has minimal influence on model predictions, thus allowing for the comparison and assessment of the underground workings (the Project). An example of the groundwater ingress for the approved open-cut workings versus the revised open-cut workings is included in Figure 40.



Note: OC-original = Original Open-Cut, Rev.OC = Revised Open-Cut (to remove overlap with underground panels)

Figure 40 Annual groundwater ingress estimates for approved versus revised open-cut Saraji Mine

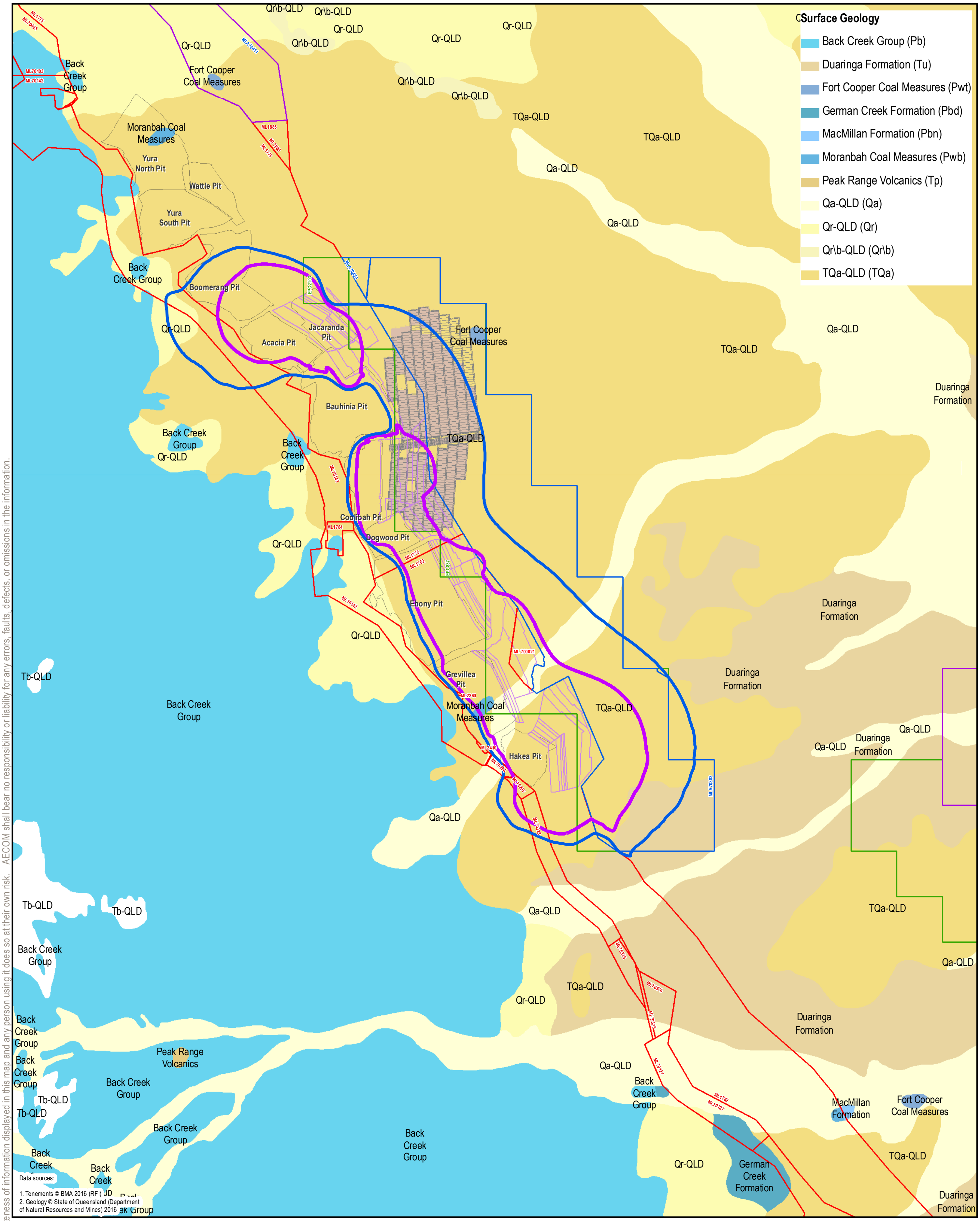
The reduction of the open-cut footprint of Coolibah and Dogwood Pits (Figure 5), has a reduction in groundwater ingress predictions (< 0.5 GL per year after mining open-cut mining ceases) as these pits will no longer reach the final depths and extent of the approved open-cut pits. Groundwater predictions during mining indicate limited differences in ingress (and consequently drawdown).

A summary of the predicted end of underground mining drawdown contours, for each of the three modelled layers, is summarised in Table 27.

Table 27 Summary of predicted drawdown

Model Layer	Cumulative Drawdown (Revised Open-Cut and Underground Mining)	Additional Drawdown as a result of Underground Mining (compared to approved open-cut mining)
Model Layer 1 - Tertiary and Quaternary cover (Figure 41)	• two metre drawdown contours not predicted to extend any further than five kilometres to the east from mining operations. • two metre drawdown contour extends approximately 28.5 km in a north-south direction adjacent to the mining operations.	• two metre drawdown contours outside the underground mining footprint extends up to two kilometres further towards the east. • two metre drawdown contours predicted to extend into the underground mining footprint. • two metre drawdown contours, which previously consisted of two distinct zones, now consists of one continuous zone.
Model Layer 6 - H16 coal seam (Figure 42)	• five metre drawdown contour extends approximately seven kilometres to the east of open-cut operations and two kilometres east of underground operations. • five metre drawdown contour extends approximately 28 km in a north-south direction adjacent to the mining operations.	• five metre drawdown contours outside the underground mining footprint extends up to three kilometres further towards the east. • five metre drawdown contours predicted to extend into the underground mining footprint and up to three kilometres beyond the footprint towards the east and north. • five metre drawdown contours, which previously consisted of two distinct zones, now consists of one continuous zone.
Model Layer 10 - Dysart Lower (D14 / D24) coal seam (Figure 43)	• five metre drawdown contour extends approximately seven kilometres to the east of open-cut operations and two kilometres east of underground operations. • five metre drawdown contour extends approximately 30 km in a north-south direction adjacent to the mining operations.	• five metre drawdown contour extends up to two kilometres further towards the east. • five metre drawdown contours extend into the underground mining footprint and up to three kilometres beyond the footprint towards the east and north. • five metre drawdown contours, which previously consisted of two distinct zones, now consists of one continuous zone.

Overall, proposed underground mining of the Lower Dysart (D14 / D24) seam will result in extension of the drawdown contours towards the east and north. Additional impacts towards the west and south of the mining operations are predicted to be minimal.



LEGEND

- Quaternary/Tertiary (Layer 1) - 2 m drawdown contour (Underground and Open-Cut Mining)
- Quaternary/Tertiary (Layer 1) - 2 m drawdown contour (Open-Cut Mining only)
- Conceptual Surface Water Mine Plan
- Underground layout (optimised)
- Underground layout (maximised)
- Existing Open-Cut Extent

Mining Tenement

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

Figure 41
End of Mining Drawdown Contours - Quaternary/ Tertiary (Layer1)

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0 1 2 4
Kilometres

Scale: 1:200,000 (when printed at A4)
Projection: Map Grid of Australia - Zone 55 (GDA94)

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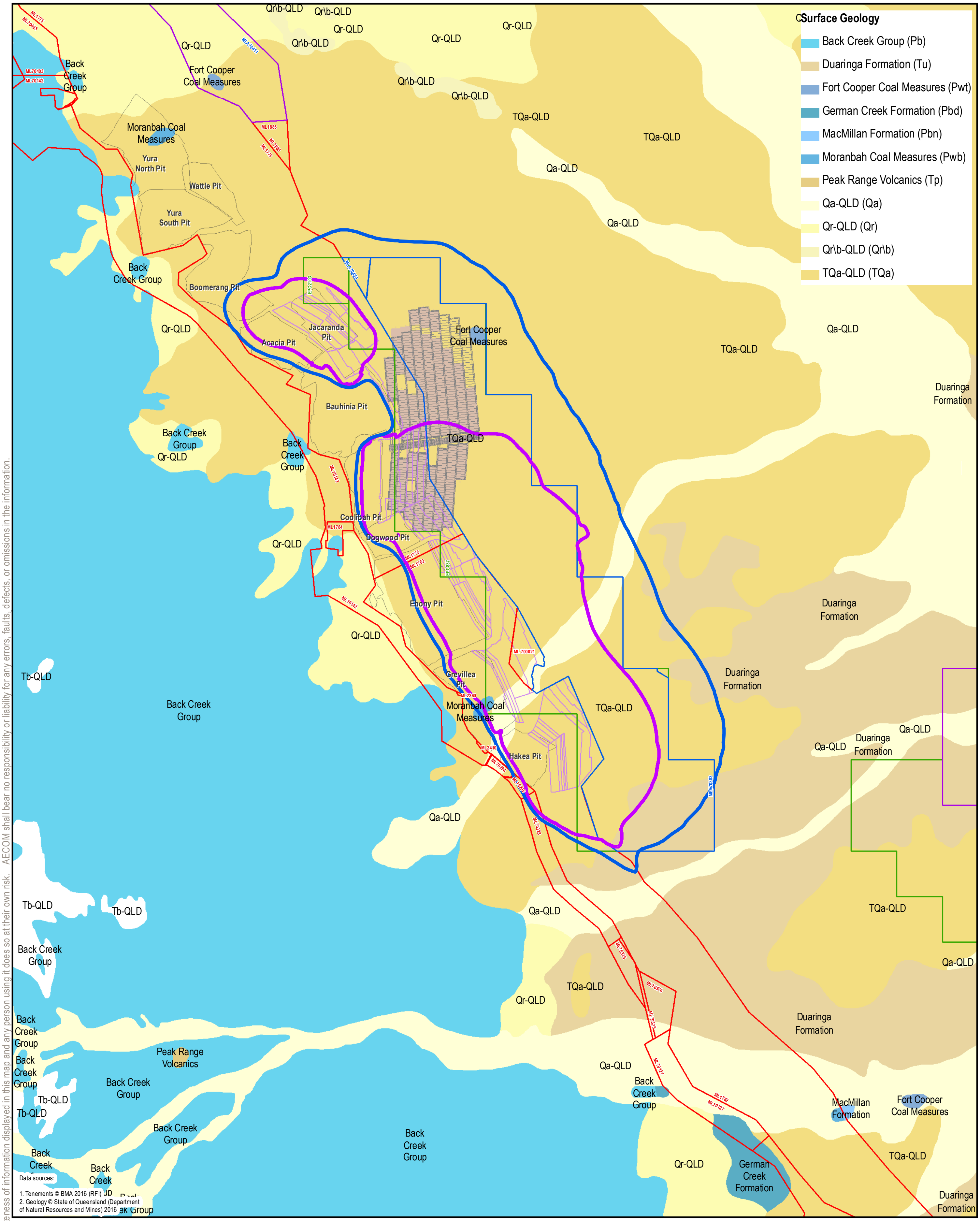

LEGEND

- Harrow Creek (H16) seam (Layer 6) - 5 m drawdown contour (Underground and Open-Cut Mining)
- Harrow Creek (Layer 6) - 5 m drawdown contour (Open-Cut Mining only)
- Conceptual Surface Water Mine Plan
- Underground layout (optimised)
- Underground layout (maximised)
- Existing Open-Cut Extent

Mining Tenement

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

Figure 42
End of Mining Drawdown Contours Harrow Creek (H16) Seam (Layer6)

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Saraji East Mining Lease Project

Scale: 0 1 2 4 Kilometres

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

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

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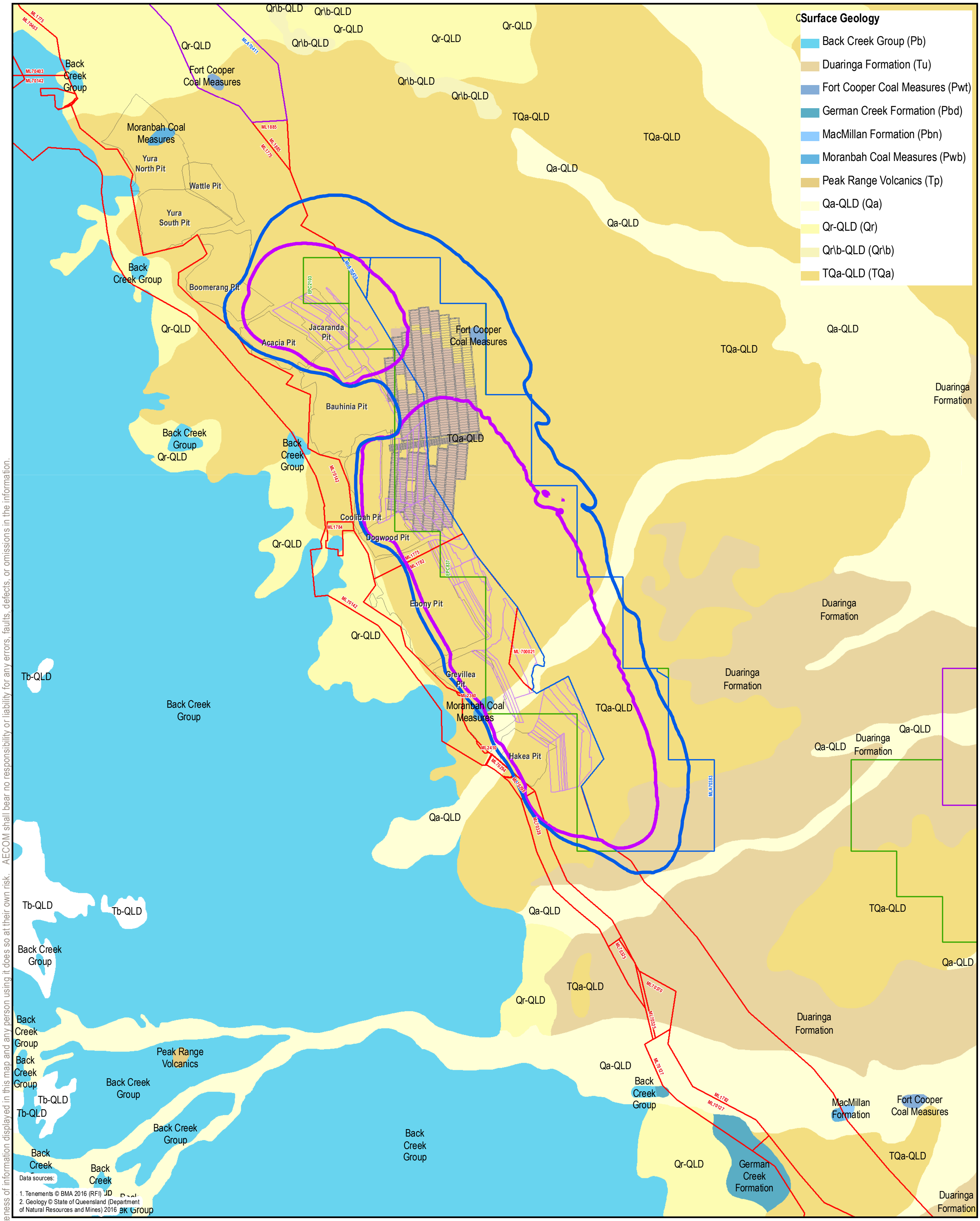

LEGEND

- Dysart Lower (D14, D24) seam (Layer 10) - 5 m drawdown contour (Underground and Open-Cut Mining)
- Dysart Lower (D14, D24) seam (Layer 10) - 5 m drawdown contour (Open-Cut Mining only)
- Conceptual Surface Water Mine Plan
- Underground layout (maximised)
- Underground layout (optimised)
- Existing Open-Cut Extent

Mining Tenement

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

N

Figure 43
End of Mining Drawdown Contours Dysart Lower (D14, D24) seam (Layer10)

Groundwater Technical Report
Saraji East Mining Lease Project

0 1 2 4
Kilometres

Scale: 1:200,000 (when printed at A4)
Projection: Map Grid of Australia - Zone 55 (GDA94)

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6.2.2 Groundwater ingress estimates

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

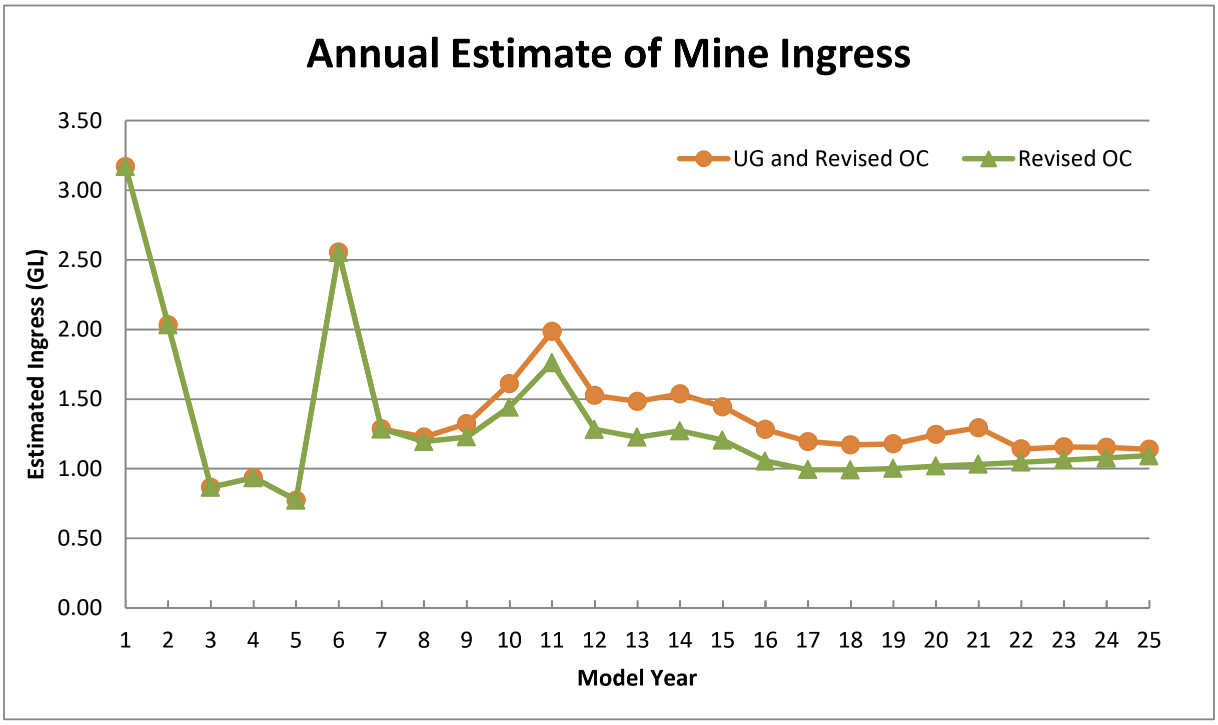
Table 28 presents the estimates of groundwater ingress.

Table 28 Groundwater ingress estimate (in m^3)

Model Year	Modified OC (No UG) (m^3/year)	Modified OC and UG (m^3/year)	Ingress Into UG Only (m^3/year)	Comments
1	3.17E+06	3.17E+06		
2	2.03E+06	2.03E+06		
3	8.67E+05	8.67E+05		
4	9.36E+05	9.36E+05		
5	7.74E+05	7.75E+05		
6	2.55E+06	2.55E+06	1.04E+03	Gas drainage commences
7	1.28E+06	1.29E+06	1.86E+03	Underground mining commences
8	1.19E+06	1.23E+06	3.18E+04	
9	1.23E+06	1.32E+06	9.59E+04	
10	1.44E+06	1.61E+06	1.68E+05	
11	1.76E+06	1.99E+06	2.24E+05	
12	1.28E+06	1.53E+06	2.43E+05	
13	1.23E+06	1.48E+06	2.58E+05	
14	1.27E+06	1.54E+06	2.63E+05	
15	1.21E+06	1.45E+06	2.40E+05	Open-cut mining ceases
16	1.05E+06	1.28E+06	2.28E+05	
17	9.93E+05	1.19E+06	2.01E+05	
18	9.92E+05	1.17E+06	1.79E+05	
19	1.00E+06	1.18E+06	1.77E+05	
20	1.02E+06	1.25E+06	2.27E+05	
21	1.03E+06	1.29E+06	2.62E+05	
22	1.05E+06	1.14E+06	9.51E+04	
23	1.06E+06	1.16E+06	9.56E+04	
24	1.08E+06	1.15E+06	7.56E+04	
25	1.09E+06	1.14E+06	4.69E+04	Underground mining ceases
TOTALS (Year 1 - 15)	**2.22E+07**	**2.38E+07**	**1,527,725**	
TOTALS (Year 1 - 25)	**3.26+E07**	**3.57+E07**	**3,113,800**	

Note: OC = Open-Cut, UG = Underground

The estimate of groundwater ingress, as included in Table 28, is presented in Figure 44.



Note: OC = Open-Cut, UG = Underground

Figure 44 Annual groundwater ingress estimates

The ingress estimates between the open-cut only scenario and the open-cut with underground mining scenario, were estimated for the life of open-cut to determine the component of ingress that can be attributed to the underground operations. Table 28, shows that the total amount of ingress as a result of underground mining is predicted to be 1,527,725 cubic metres (m^3) which is on average 152.77 mega litres per annum (ML/a) for the ten year period from gas drainage commencement until end of open cut mining.

A sensitivity analysis was also undertaken by varying the recharge rate by ± 10 percent. The sensitivity results, presented in Appendix D, suggest that mine ingress is not markedly affected by the recharge rate.

Total groundwater ingress estimates resulting from open-cut and underground mining over 25 years is estimated at 3.57 GL, which equates to approximately 45 L/s. Considering the mining operations extend over a strike length of over 22.5 km, this equates to approximately 1 L/s over 500 linear metres.

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. Groundwater intersected in the underground workings will be removed in the Incidental Mine Gas extraction, wet coal, and mine dewatering (from the lowest point in the workings).

6.3 Impact assessment

6.3.1 Impacts on groundwater levels and existing groundwater users

Figure 45 shows the location of existing registered bores plus additional bores identified during the bore census in relation to the predicted extent of groundwater drawdown at the end of underground mining in FY 2042.

The drawdown contours, associated with the approved Saraji Mine open-cut mining and the underground mine layout (maximised), results in drawdown of groundwater levels in several bores in several hydrostratigraphic units. The bore thresholds as defined in the Water Act were considered when assessing potential impacts on neighbouring groundwater bores.

Figure 45 shows that there are 18 groundwater bores within the end of underground mining drawdown thresholds comprising 17 registered bores and one unregistered bore. Bore details are provided in Table 29.

Of the 18 bores predicted to be impacted, none are identified as potential 'make-good' bores for a combination of the following reasons:

- they are located on BMA owned land
- they are identified as being abandoned or destroyed
- they are screened within the Back Creek Formation which is located below the Lower Dysart (D14 / D24) seam, which is not predicted to be impacted.

As BMA is unlikely to require any 'make-good' agreements, it is unlikely that any significant impacts will occur upon groundwater levels and existing groundwater users.

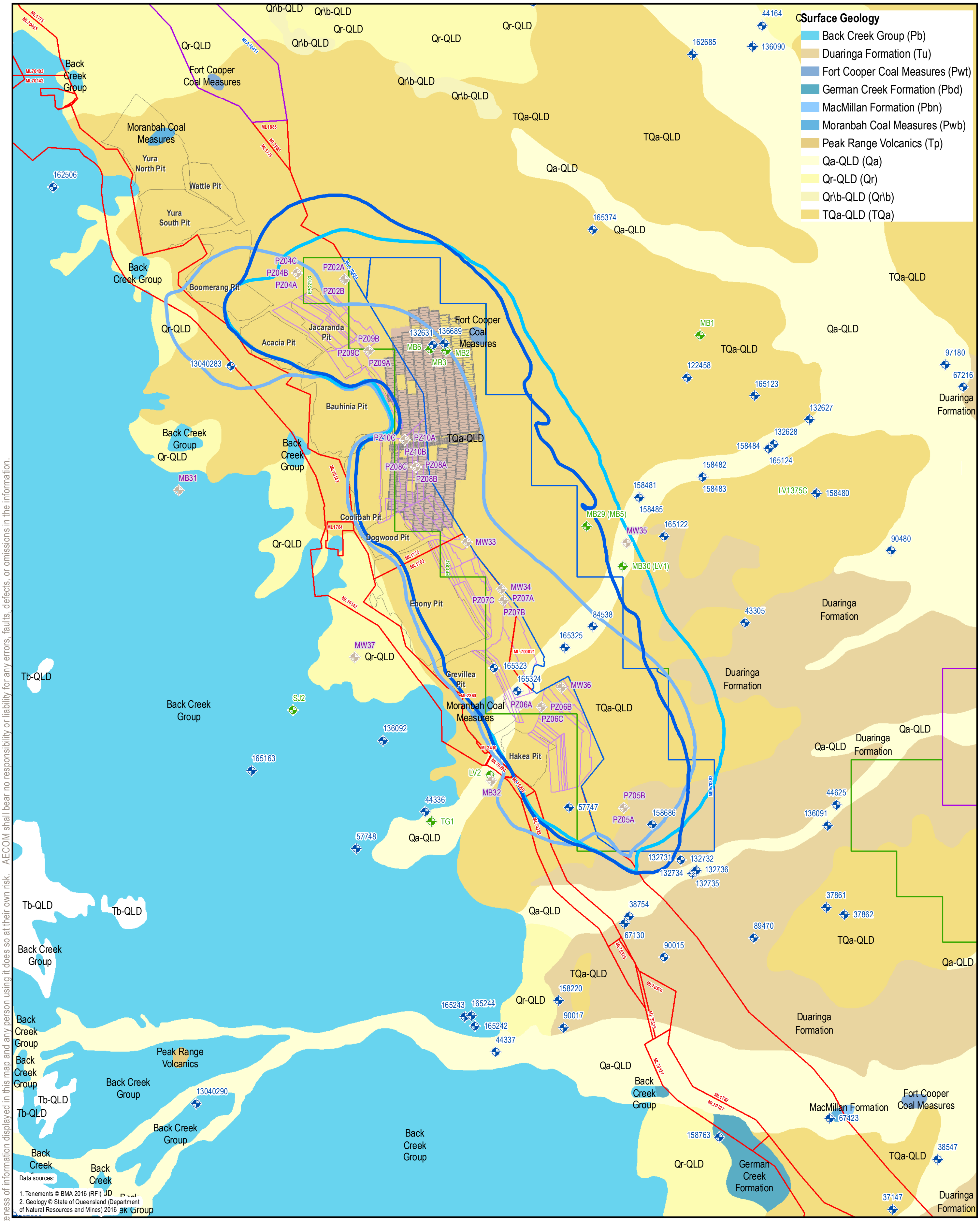
Table 29 Potentially impacted bores located within end of underground mining (2042) drawdown contours

Bore RN	Latitude	Longitude	Lot/Plan	Owner	Depth (mbGL)	Geology /Aquifer	Model Layer	Use	Comment
43639	-22.5015	148.3507	4/SP235303	BMA	43.9	Blackwater Group	-	-	Abandoned and destroyed
57747	-22.5157	148.3650	1/SP235303	BMA	126.5	Back Creek Group	11	Unknown	Existing. Screened in Layer 11 (Back Creek Group) which is located below MCM and not predicted to be impacted.
84538	-22.4498	148.3737	1/SP260662	BMA	109.7	Unknown	-	Unknown	Existing
90475	-22.4805	148.4139	5/SP190749	Private Landholder	76.2	Blackwater Group	-	-	Abandoned and destroyed
100248	-22.4325	148.3763	1/SP260662	BMA	-	Unknown	-	Unknown	Existing.
132631	-22.3469	148.3152	10/CNS93	Private Landholder	328	Back Creek Group	11	Unknown	Existing. Screened in Layer 11 (Back Creek Group) which is located below MCM and not predicted to be impacted.
136689[#]	-22.3464	148.3194	10/CNS93	Private Landholder	328	Back Creek Group	11	Unknown	Existing. Screened in Layer 11 (Back Creek Group) which is located below MCM and not predicted to be impacted.
158010	-22.4192	148.3859	2/SP260662	BMA	34.5	Fair Hill Formation	2	Monitoring	Existing.
158011	-22.4720	148.3622	1/SP260662	BMA	32	Fair Hill Formation	2	Monitoring	Existing.
158013	-22.4362	148.3402	1/SP260662	BMA	107	MCM	3	Monitoring	Existing.
158014	-22.4189	148.3276	14/CNS382	BMA	37.5	MCM	2	Monitoring	Existing.

Bore RN	Latitude	Longitude	Lot/Plan	Owner	Depth (mbGL)	Geology /Aquifer	Model Layer	Use	Comment
158686	-22.5221	148.3952	1/SP235303	BMA	210	MCM	2	Unknown	Existing.
165323	-22.4649	148.3375	1/SP260662	BMA	15	Alluvial sand	1	Monitoring	Existing.
165324	-22.4733	148.3460	1/SP260662	BMA	12.0	Alluvial Clay	1	Monitoring	Existing.
165325	-22.4574	148.3635	1/SP260662	BMA	18.5	Quaternary Clay	1	Monitoring	Existing.
165326	-22.4574	148.3635	1/SP260662	BMA	35	Unknown	-	-	Abandoned and destroyed
13040283	-22.3547	148.2414	-	Road Reserve	68.5	Back Creek Group	11	DNRME Monitoring	Existing. Screened in Layer 11 (Back Creek Group) which is located below MCM and not predicted to be impacted.
MB6*	-22.3486	148.3142	10/CNS93	BMA	-	Unknown	-	Equipped	Identified during Bore Census

Note: # Formation determined from geological log from adjacent bore RN132631

* Bore has no registered number



LEGEND

- Saraji Monitoring Bores
- Registered Bore
- Census Bore
- Conceptual Surface Water Mine Plan
- Underground layout (optimised)
- Underground layout (maximised)
- Existing Open-Cut Extent

- Dysart Lower (D14, D24) seam (Layer 10) - 5 m drawdown contour (Underground and Open-Cut Mining)
- Harrow Creek (H16) seam (Layer 6) - 5 m drawdown contour (Underground and Open-Cut Mining)
- Quaternary/Tertiary (Layer 1) - 2 m drawdown contour (Underground and Open-Cut Mining)

Mining Tenement

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

N

Figure 45

Bores Located within End of Underground Mining (FY42) Predicted Groundwater Drawdown Contours

Groundwater Technical Report
Saraji East Mining Lease Project

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Kilometres

Scale: 1:200,000 (when printed at A4)
Projection: Map Grid of Australia - Zone 55 (GDA94)

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6.3.2 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.

The results of the predictive modelling show the following:

- Additional ingress because of proposed underground operations is 152.77 ML/a (Section 6.2.2).
- Groundwater drawdown contours will extend further to the east and north (Section 6.2.1).

6.3.2.1 Distributions of ecosystems around the Project

No known GDEs are reported within the Project area (Section 5.3.10) and the groundwater, due to depth and salinity, has limited environmental values with regards to ecosystems.

Impacts of the mine dewatering associated with the proposed underground workings, considered in connection with the approved Saraji open-cut operations, are considered low for the following reasons:

- Surface water creeks in the area are ephemeral and groundwater levels (more than 17 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 and are not expected to impact surface ecosystems.

Due to the limited environmental values in the Project Area, it is unlikely a significant impact will be caused by the Project.

6.3.2.2 Catchment-scale groundwater levels

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

6.3.3 Impacts on groundwater quality

During mining, a cone of depression will develop around the underground mining footprint due to incidental mine gas management (coal seam groundwater extraction) and development of goaf above the longwall panels. This will result in localised groundwater flow into the underground panels. The risk of water contained in the underground panels (a blend of groundwater from different strata) impacting on groundwater quality, away from the underground workings is therefore considered limited.

Due to the limited groundwater quality within the Project Area, there is unlikely to be a significant impact upon any existing values.

6.3.4 Potential environmental impacts

The potential environmental impacts of the maximised footprint are considered low as:

- 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 often have insufficient yield/low recharge potential indicating low permeability and low potential for usage

- the largest predicted drawdown extends within the target coal seam, which is understood not to discharge into the down gradient Isaac River; in addition, the drawdown cones do not extend 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 underground mine is predicted to have long term locally contained impacts on the quantity and quality of groundwater resources on the Project area. These impacts include:

- localised drawdown due to mining of underground panels and final voids
- blending (mixing of groundwater from the different aquifers) within the underground mine footprint.

To protect against unexpected impacts and ensure ongoing validation of the predictive modelling in the vicinity of the proposed underground workings, 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 7.0.

7.0 Mitigation measures

7.1 Groundwater monitoring bore network

In summary, the impacts that require ongoing monitoring include:

- shallow Quaternary and Tertiary aquifer groundwater levels and quality
- Permian coal seam (Harrow Creek and Dysart seam) groundwater levels and quality
- potential contamination sources including tailings disposal areas.

A Groundwater Monitoring Program will be developed to ensure an appropriate level of detail and scale. The purpose of the program will be to monitor the magnitude and distribution of actual changes to groundwater conditions in response to mining and to provide early detection of any unforeseen impacts to groundwater levels, groundwater flows or groundwater quality.

The objective of the groundwater monitoring network is to monitor potential effects of the proposed mining on overlying and underlying hydrostratigraphic units (aquifers), so that informed management decisions can be made.

The fundamental components of the groundwater plan are as follows:

- The monitoring network and subsequent monitoring program will be developed established prior to the commencement of mining. Baseline seasonal trends for groundwater levels and quality will need to be sufficiently rigorous to allow comparison with mining-related trends.
- If appropriate, existing VWPs and monitoring bores will be incorporated into the final monitoring network. As some drawdown impacts are predicted for registered bores, representative private bores (or new sentinel sites) are likely to also be incorporated into the monitoring program.
- Site-specific and regional groundwater quality will be monitored to establish baseline trigger levels, evaluate spatial and temporal trends, and gauge whether water quality objectives are being protected or enhanced for specified environmental values, being stock watering. An objective of the program will be to detect a significant change to water quality values (consistent with the current suitability of the groundwater for domestic and agricultural use) due to activities that are part of the Project.
- There are no local springs or GDEs to monitor.

7.1.1 Existing monitoring bores

A summary of the current groundwater monitoring network is presented for each monitoring unit in Table 13. Figure 30 shows the bore locations.

7.1.2 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 programmed 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.

7.2 Additional groundwater monitoring requirements

The existing groundwater monitoring network will be augmented near the proposed underground mine (and over time) to ensure the following:

- The determination of groundwater level responses to mine activities within the Project Area. The comparison of water level decline will allow for the identification of groundwater resources which may be unduly affected by mine dewatering; unduly affected is where drawdown is projected to be greater than the model predictions.
- The extent and magnitude of drawdown in each aquifer near the proposed underground workings is adequately monitored for comparison to modelled projections over time.
- The identification and management of any potential impacts on surface water.
- The groundwater monitoring network will, during operations, act as an early warning system for potential drawdown impacts. 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).

7.2.1 Recommended new groundwater monitoring bores

To ensure the collection of representative groundwater monitoring data, allow for the assessment of the potential predicted impacts of the Project on local groundwater resources, and consider the existing groundwater monitoring bore network (Figure 30), additional monitoring bores are recommended prior to the Project mining activities, these are detailed in Table 30 and in Figure 46.

Table 30 Recommended project monitoring bores

Recommended bore	Latitude	Longitude	Target
SEMLPMB1	-22.3543	148.3193	Standpipe bore in Hughes Creek Alluvium Standpipe bore in underlying Tertiary
SEMLPMB2	-22.32438	148.3114	VWP in coal seams and Standpipe bore in coal
SEMLPMB3	-22.3647	148.3450	VWP in coal seams and Standpipe bore in coal
SEMLPMB4	-22.3915	148.3410	VWP in coal seams and Standpipe bore in coal

7.2.2 Bore design and drilling

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

Consideration must be given to casing and annular seal requirements to ensure that no pathway is provided for the movement of water between aquifers (i.e. the bore does not act as a connecting pathway).

7.3 Groundwater monitoring and sampling program

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.

7.3.1 Parameters

It is important that a rigorous sampling protocol is followed to ensure that representative parameters are measured, and that due diligence is maintained in tracking of the samples and the results. Appropriate quality assurance and quality control (QA/QC) of samples and procedures will be implemented. All groundwater monitoring, water level measurements and sample collection, storage and transportation is to be undertaken in accordance with the procedures outlined by the DES Monitoring and Sampling Manual (2018), EPP Water and the Murray Darling Basin Commission (1997).

The parameter suite for analysis for each groundwater sample is likely to include, but not limited to the following:

- pH, Electrical Conductivity, (field and laboratory determinations)
- Total Dissolved Solids (laboratory analysis)
- Anions - carbonate, bicarbonate, chloride, sulphate, (laboratory analysis)
- Cations - calcium, magnesium, sodium, potassium (laboratory analysis)
- Dissolved metals - aluminium, antimony, arsenic, iron, manganese, molybdenum, selenium, silver, mercury (laboratory analysis)
- Nutrients - nitrate, nitrite, phosphorus, ammonia
- Total petroleum hydrocarbons (TPH).

LEGEND

- Existing Bores
- Proposed Bore
- Underground layout (optimised)
- Underground layout (maximised)
- Existing Open-Cut Extent

Mining Tenement

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

Figure 46
Existing and Proposed Monitoring Bores

Groundwater Technical Report
Saraji East Mining Lease Project

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Kilometres

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

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7.3.2 Groundwater level monitoring

Groundwater level monitoring is the key parameter for assessing changes to the groundwater regime, particularly as the 'make good' agreements with landholders are typically predicated on a water level change.

7.3.2.1 Frequency and duration

At a minimum, groundwater levels within the groundwater monitoring network are reviewed annually. Most of the groundwater monitoring bores will have permanent groundwater level monitoring devices (either VWP pressure sensors or automated water level loggers) installed. These data loggers 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).

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 31.

Table 31 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 30
Post closure	Automated loggers	Weekly	Every 6 months	For first 10 years after closure	To be determined

7.3.2.2 Instrumentation and control

Groundwater levels will be measured manually with an electronic water level probe each time a bore is visited. The probe is to be 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 data loggers for recording the measurements.

7.3.2.3 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 the 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.

7.3.3 Groundwater quality monitoring

Groundwater samples have and will be obtained from the representative groundwater monitoring points which have 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, include:

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

7.3.3.1 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 32.

Table 32 Field parameter stabilisation criteria prior to sampling

Measurement	Variability[1]	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	± 5%	
Dissolved oxygen	± 10 %	
Redox potential (Eh)	± 10 mV	

[1] EPA Guidelines: Regulatory Monitoring and Testing - Groundwater Sampling June 2007 (Johnston, 2007).

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

Groundwater samples are to be analysed for the parameters listed in Section 7.3.1.

7.3.3.2 Quality assurance / quality control sampling

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

QA/QC laboratory samples are to be collected at one 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; all external laboratories will be National Association of Testing Authorities (NATA) accredited for the analytical procedures they are performing. 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.

7.4 Data analysis

7.4.1 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.

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

7.4.1.1 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 in 7.3.1 for each geological unit, possibly impacted by mine operations, as detailed in Section 7.3.3.

Trends can be identified, and follow-up investigations initiated per the established approach outlined in Section 7.4.2. 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).

7.4.1.2 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.

To identify potential drawdown impacts the monitoring points will act as early warning and model prediction validation points, when assessing underground mine drawdown impacts.

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

7.4.2 Investigation and response processes

7.4.2.1 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 the Project EA
- 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 will 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.

7.4.2.2 Water levels

If groundwater levels decline in excess of the levels defined through predictive modelling is identified, 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 the Project EA
- 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.

7.5 Data reporting

All documentation and information related to groundwater level and groundwater quality monitoring will be kept in a secure archive, and readily available to scrutinise against regulatory criteria and trigger levels. All calibration records, laboratory chain-of-custody forms, photographs, laboratory certificates, and laboratory reports should be up-to-date and archived. A dedicated groundwater monitoring database will be developed and maintained on at least a monthly basis to ensure compliance conditions are met and any impacts are detected as soon as practicably possible.

The groundwater monitoring program will be reviewed annually by a suitably qualified hydrogeologist to identify unforeseen potential impacts, update the monitoring schedule, and factor in any changes to the mine plan that could influence groundwater impacts.

7.6 Post-mining period

A post-mining monitoring program will be developed by a suitably qualified hydrogeologist towards the end of mining operations (e.g. within two years of mine closure). The program will be customised to address recovery of actual groundwater drawdown impacts observed during operation of the underground mine.

8.0 Residual impacts

Potential impacts to groundwater because of the Project have been considered in detail as part of this groundwater assessment. Recognised and proven actions to manage likely impacts have been proposed. Residual impacts are anticipated in the short to medium term. These concern groundwater flow and height and are relative to the duration of dewatering. Beyond closure, groundwater aquifers will continue to flow into the final voids until a steady state is achieved. During this period the loss of water from the alluvium/Tertiary and Permian aquifers are not expected to have a significant impact on beneficial use or natural ecosystem values.

8.1 Simulated drawdown hydrographs

The groundwater model was used to provide a prediction of long-term groundwater level rebound after 50 years of recovery. For this long-term prediction, it was assumed that all Saraji Mine open-cut operations will cease at the end of 2031 (when the open-cut pits reach the ML boundaries) and all underground mining will cease at the end of 2042; this in line with the current open-cut approvals and the proposed Project life of mine.

Groundwater recovery was predicted in the model, using select bores, such that groundwater level time series hydrographs were generated to show groundwater rebound. The post-mining modelling, included for increased permeability in the underground goaf and open-cut backfill, natural low recharge across the model domain and evaporative losses from the final open-cut voids.

It is predicted that there will be little or no recovery of groundwater levels 50 years following cessation of underground mining outside of the underground mining footprint due to:

- drawdown in all model layers because of on-going extraction (through evaporation) from the open-cut final voids
- the only marked groundwater rebound is considered to occur within the goaf and underground workings until water reaches the open-cut final voids
- limited rainfall recharge over the region
- 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 (due to large final void areas) is expected to remain after 2031 (across the approximately 22.5 km strike length of the open-cut mine)
- low permeability within the sediments surrounding the open-cut pits.

A hydrograph showing the typical recovery pattern for coal seams within the underground mining footprint are shown in Figure 47. Groundwater is predicted to rebound following cessation of mining, but only to the level of the final voids in the Saraji Mine open-cut pits. A new pseudo-steady state pit water level will occur post-mining which is dependent on ingress/evaporation discharge from the final voids.

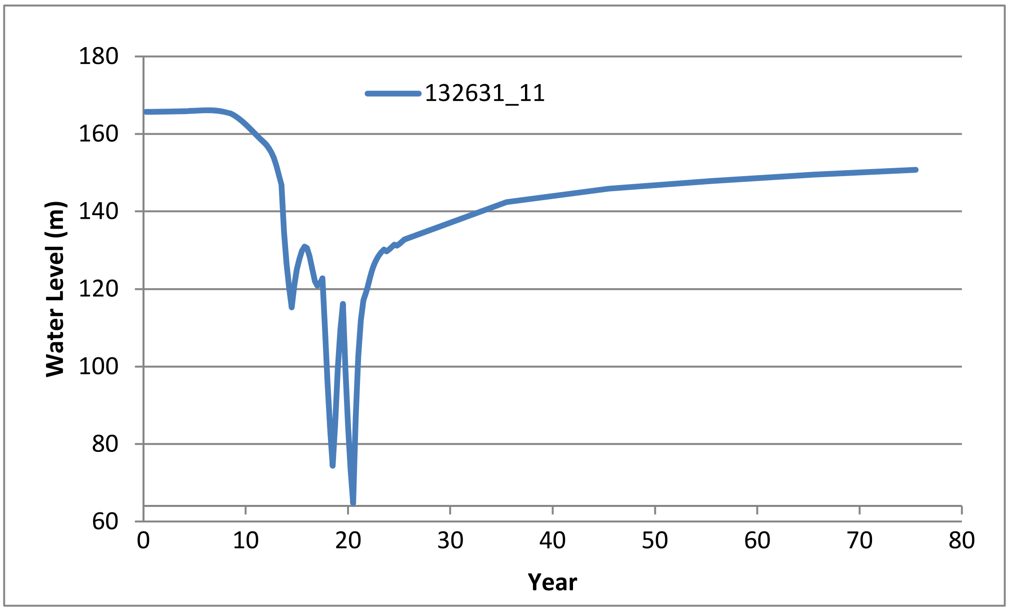

Figure 47 Simulated hydrograph for RN132631 (Layer 11 – Dysart Lower Coal Seam)

Predicted drawdown time-series hydrographs for potentially impacted registered bores and monitoring locations are provided in Appendix A[3].

The hydrographs include drawdown predictions until the end of 2092 i.e. 50 years of recovery following cessation of underground mining.

These time-series projected groundwater level graphs allow for an assessment of potential impacts on local groundwater resources.

[3] The number following the underscore refers to the model layer in which the bore is screened (i.e. 43639_10 is screened across model layer 10)

9.0 Summary and conclusion

Introduction and methodology

A groundwater environmental assessment has been compiled to evaluate potential impacts associated with the proposed underground mining associated with the Project.

The groundwater study includes predictive groundwater modelling to evaluate the potential impacts of the proposed underground mining activities on groundwater resources. This groundwater technical report was compiled for inclusion in the EIS submission.

Predictive groundwater modelling was conducted to assess the potential impacts of the proposed longwall mining. The modelling looked at mine dewatering impacts (groundwater ingress and groundwater level drawdown) considering the approved Saraji Mine open-cut workings 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.

Geology

The Project is located on the western limb of the geological Bowen Basin and is underlain by Quaternary and Tertiary sediments which overly the Permian strata, which hosts the target coal seam. The sediments across the Project are generally undisturbed and gently dip approximately 8 degrees 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 sediments.

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 as evidenced in the bedrock outcrop within the creeks. The alluvial aquifer is not a permanent source of groundwater as bores drilled in close proximity to creeks on the MLA and the Saraji Mine 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),do not store groundwater) and are non-continuous (the coarse grained more permeable sediments are not continuous down the length of the creeks). Groundwater quality of the alluvium is variable, ranging from fresh to saline and is typically slightly saline.

The Tertiary aged sediment sequence in the Project Area consists 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 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 TDS more than 6,000 mg/L. This means the water is brackish to saline and exceeds the recommended level for cattle.

The Permian overburden/interburden sediments comprise sandstone, siltstone, and shale. The Permian coal seams comprise 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 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.

Environmental values

The Project is situated within the Isaac River sub-basin of the Fitzroy Basin. The land use surrounding the Project is predominantly coal mining and cattle grazing.

The groundwater quality data across the site 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 TDS and saline water for prolonged periods. For beef cattle, this TDS limit is in range the range of 5,000 mg/L to 10,000 mg/L.

Given that TDS for the Tertiary and Permian sediments are generally above 5,000 mg/L, the regional groundwater would generally not be considered suitable for livestock.

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).

There are no known aquatic or terrestrial GDEs. No known springs are present within the Project Area.

Potential impacts

Groundwater level drawdown in the Tertiary and Quaternary cover as well as the target coal seam indicated that the Project would result in extension of drawdown into the underground mining footprint and up to three kilometres further towards the east and north when compared to previously approved open-cut mining drawdown predictions.

Groundwater ingress estimates show that the total amount of ingress because of underground mining for the life of open-cut is predicted to be 1,527,725 m^3, which is on average 152.77 ML/a. Total groundwater ingress resulting from open-cut and underground mining over 25 years is estimated to be 3.57 Gigalitres (GL). This impact is not considered to be significant due to the absence of privately owned bores in the drawdown areas.

Impacts of the mine dewatering associated with the proposed underground workings, considered in connection with the approved Saraji open-cut operations, are considered low for the following reasons:

- Surface water creeks in the area are ephemeral and groundwater levels (more than 17 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 and are not expected to impact surface ecosystems.

It is unlikely that a significant impact will occur on alluvial/sediment or surface waters.

The potential environmental impacts of the maximised footprint are considered low as:

- 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 often have insufficient yield/low recharge potential indicating low permeability and low potential for usage
- the largest predicted drawdown extends within the target coal seam, which is understood not 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.

Management measures

A Groundwater Monitoring Program will be developed for the Project, 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. To ensure the collection of representative groundwater monitoring data, allow for the assessment of the potential predicted impacts of the Project on local groundwater resources, and consider the existing groundwater monitoring bore network (Figure 30), additional monitoring bores are recommended prior to the Project mining activities, these are detailed in Table 30 and in Figure 46.

The assessment indicates significant, long term impacts would not result from the Project.

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Appendix A

Water Quality Results (Gauge, 2016)

Site	Date	Insitu pH	Insitu EC	SWL		TDL	CO_3	HCO_3	SO_4	Cl-	Ca (diss)	Mg (diss)	Na (diss)	K (diss)	Al Total	Sb Total	As Total	Fe Total	Hg Total	NO_3	P react.	C6–C9	C10–C36 (sum)
		pH units	µS/cm	mBGL	mRL	mg/L									µg/L					mg/L		µg/L	
Guidelines (Fitzroy)																							
Zone 34	Shall. 80th	7.1-8.1	*8910*			-	-	878	318	3185	215	389	1500	-	-	-	-	246	-	5.3	-	-	-
	Deep 80th	7.4-8.03	*16000*			-	-	650	398	5905	442	491	2565	-	-	-	-	140	-	14.92	-	-	-
ANZECC stock		6.0-9.0	*5970*			4000			1000		1000				5000	-	500	-	2				
NHMRC D.W.*		6.5-8.5	*895**			600			500	250			180		200	3	10	300	1	11.3			
MB31	02/12/2008			4.82	217.08																		
MB31	29/07/2009			4.68	217.22																		
MB31	26/10/2009	7.44	7330	4.14	217.76	4890	<1	641	1190	1490		195	1260				1						
MB31	14/12/2009	7.65	7640	4.95	216.95	4870	<1	505	1160	1400	140	203	1270	57			<1						
MB31	29/04/2010	7.33	4940	3.52	218.38	2920	<1	649	656	840	81	99	907	39			<1						
MB31	27/07/2010	7.45	4940	3.55	218.35	3120	<1	729	665	932	66	113	1030	37			<1						
MB31	24/01/2011	7.14	3990	2.15	219.75	2560	21	732	478	797	29	72	852	35			1						
MB31	29/04/2011	7.65	4500	4.4	217.5	2740	<1	725	551	723	62	81	806	36			<1						
MB31	25/05/2011	7.65	4500	4.4	217.5	2740	<1	725	551	723	62	81	806	36			<1						
MB31	25/07/2011	8	4388	3.07	218.83	2740	<1	725	551	723	62	81	806	36									
MB31	25/10/2011	8.61	3961	3.07	218.83	2740	38	723	600	723	74	88	838	38			<1						
MB31	21/06/2012	8.13	2521			710	<5	500	32	78	86	77	55	1.4			<1						
MB31	24/07/2012	9.64	5358	2.36	219.54	2900	<5	1000	490	720	68	87	920	53			1			<0.005	3.4	<10	<100
MB31	26/10/2012	9.25	5882	3.1	218.8	2500	45	790	360	550	63	77	780	48			1			<0.005	3.2	<10	<100
MB31	22/01/2013	8.25	7468	3.48	218.42	2900	29	1100	630	930	70	90	870	61			2			<0.005	8.2	<10	<100
MB31	22/04/2013	8.25	6500			3300	120	1200	650	970	79	100	970	82			1			0.088	8.3	<10	430

MB31	25/07/2013	9.28	7477			3300	99	1200	520	860	72	97	970	72						<0.005	11	<10	<100
MB31	22/10/2013																						
MB31	21/01/2014	8.12	7272			3530	136	1180	662	947	92	119	1060	95	80	<1	2	340	<0.1			<20	570
MB31	23/04/2014		7233			3640	131	1410	770	1170	93	107	1030	91	<10	<1	1	60	<0.1			<20	<20
MB31	24/07/2014																						
MB31	10/09/2014	6.794	9210	5.3	216.6	5810	<1	458	1560	2390	273	324	1530	77	<10	<1	<1	11800	<0.1			<20	100
MB31	25/11/2014	6.556	9270	6.29	215.61	6640	<1	515	1480	2430	266	330	1690	73	470	<1	<1	3920	<0.1			<20	<50
MB31	20/01/2015	6.917	9710	5.53	216.37	6920	<1	494	1730	2660	299	344	1720	83	540	<1	<1	4130	<0.1			<20	<50
MB31	24/03/2015	6.874	9470	5.68	216.22	6510	<1	526	1610	2440	266	301	1470	61	210	<5	<5	2840	<0.1			<20	<50
MB31	19/05/2015	7.04	9220	5.73	216.17	6260	<1	524	1880	1970	247	276	1340	57	640	<1	<1	2500	<0.1			<20	<50
MB31	16/06/2015	7.02	9040	8.90	213.00	6420	<1	524	1710	2460	262	267	1340	57	200	<1	<1	2360	<0.1			<20	<50
MB31	25/08/2015	6.89	9270	5.51	216.39	606	<1	471	21	42	87	64	38	1								<20	<50
MB31	02/12/2015	6.96	8060	8.08	213.82	918	<1	596	68	221	108	103	101	1	50	<1	<1	110	<0.1			<20	<50
MB31	14/03/2016	7.14	8180	5.92	215.98	606	<1	471	21	42	87	64	38	1			<1		<0.1			<20	<50
MB31	13/06/2016	6.94	9600	5.17	216.73	9580	<1	98	2300	4070	584	220	2450	19	<10	<1	<1	1490	<0.1			<50	<20
MB31	19/09/2016	7.10	4570	4.83	217.07	6420	<1	524	1710	2460	262	267	1340	57	200	<1	<1	2360	<0.1			<20	<50

Site	Date	Insitu pH	Insitu EC	SWL		TDL	CO_3	HCO_3	SO_4	Cl-	Ca (diss)	Mg (diss)	Na (diss)	K (diss)	Al Total	Sb Total	As Total	Fe Total	Hg Total	NO_3	P react.	C6–C9	C10–C36 (sum)
		pH units	µS/cm	mBGL	mRL	mg/L									µg/L					mg/L		µg/L	
Guidelines (Fitzroy)																							
Zone 34	Shall. 80th	7.1-8.1	*8910*			-	-	878	318	3185	215	389	1500	-	-	-	-	246	-	5.3	-	-	-
	Deep 80th	7.4-8.03	*16000*			-	-	650	398	5905	442	491	2565	-	-	-	-	140	-	14.92	-	-	-
ANZECC stock		6.0-9.0	*5970*			4000			1000		1000				5000	-	500	-	2				
NHMRC D.W.*		6.5-8.5	*895**			600			500	250			180		200	3	10	300	1	11.3			
MB33	25/07/2012	5.63	25620	21.92	172.88	16000	<5	720	2200	7700	300	590	5500	120			<1			<0.005	<0.005	<10	<100
MB33	26/10/2012	6.84	27300	21.97	172.83	17000	<5	760	2200	7300	260	480	4900	120			3			<0.005	<0.005	<10	<100
MB33	22/01/2013	6.63	31480	22	172.8	17000	<5	770	2700	8500	280	530	5100	130			2			<0.005	<0.005	<10	<100
MB33	22/04/2013	6.78	26870	22	172.8	16000	<5	790	2900	9000	290	590	5600	130			1			<0.005	<0.005	<10	550
MB33	24/07/2013	6.95	29440	22.57	172.23	17000	<5	750	1800	6700	280	570	5300	130						0.015	0.071	<10	1080
MB33	21/10/2013	6.54	29440	22.57	172.23	16100	<1	705	2240	7120	285	638	4510	130	<10	<1	2	1480	<0.1			<20	<50
MB33	20/01/2014	6.34	26140	22.45	172.35	16500	<1	580	2420	7020	249	627	4550	145	<10	<1	1	1430	<0.1			<20	<50
MB33	22/04/2014		24950	22.46	172.34	15100	<1	735	2390	7420	301	570	4390	118	<50	<5	<5	1410	<0.1			<20	<20
MB33	29/07/2014					16900	<1	718	2150	7560	240	601	4920	141	2340	6	5	7510	<0.1			<20	1680
MB33	09/09/2014	6.737	24033	22.43	172.37		<1	618	2410	7600	318	618	4470	119	140	<1	3	1310	<0.1			<20	120
MB33	25/11/2014	6.657	24466	22.33	172.47	14900	<1	794	2580	7880	332	599	5230	106	130	<1	3	910	<0.1			<20	130
MB33	20/01/2015	6.838	25400	22.34	172.46	17700	<1	787	2550	8190	345	621	4760	111	250	<1	4	1890	<0.1			<20	<50
MB33	24/03/2015	6.729	24267	22.32	172.48	16800	<1	821	2410	7910	360	563	4930	99	1670	<5	7	5000	<0.1			<20	340

MB33	19/05/2015	6.98	24233	22.34	173.46	16400	<1	801	2920	7580	354	575	4530	90	1700	<1	2	1790	<0.1			<20	<50
MB33	16/06/2015	6.83	24000	22.32	172.48	16800	<1	829	2580	7920	352	525	4330	87	920	<1	2	2790	<0.1			<20	<50
MB33	02/12/2015	6.65	23667	21.34	173.54	18400	<1	32	366	10500	840	216	4790	28	190	2	1	700	<0.1			<50	200
MB33	14/03/2016	7.60	23900	21.26	173.54	15100	<1	735	2390	7420	301	570	4390	118	<50	<5	<5	1410	<0.1			<50	<20
MB33	13/06/2016	7.95	23900	21.28	173.52	3640	131	1410	770	1170	93	107	1030	91	<10	<1	1	60	<0.1			<50	<20
MB33	19/09/2016	7.60	24100	21.07	173.73	16400	<1	801	2920	7580	354	575	4530	90	170	<1	2	1790	<0.1			<20	<50

Site	Date	Insitu pH	Insitu EC	SWL		TDL	CO_3	HCO_3	SO_4	Cl-	Ca (diss)	Mg (diss)	Na (diss)	K (diss)	Al Total	Sb Total	As Total	Fe Total	Hg Total	NO_3	P react.	C6–C9	C10–C36 (sum)
		pH units	µS/cm	mBGL	mRL	mg/L									µg/L					mg/L		µg/L	
Guidelines (Fitzroy)																							
Zone 34	**Shall. 80th**	**7.1-8.1**	***8910***			**-**	**-**	**878**	**318**	**3185**	**215**	**389**	**1500**	**-**	**-**	**-**	**-**	**246**	**-**	**5.3**	**-**	**-**	**-**
	Deep 80th	**7.4-8.03**	***16000***			**-**	**-**	**650**	**398**	**5905**	**442**	**491**	**2565**	**-**	**-**	**-**	**-**	**140**	**-**	**14.92**	**-**	**-**	**-**
ANZECC stock		**6.0-9.0**	***5970***			**4000**			**1000**		**1000**				**5000**	**-**	**500**	**-**	**2**				
NHMRC D.W.*		**6.5-8.5**	***895****			**600**			**500**	**250**			**180**		**200**	**3**	**10**	**300**	**1**	**11.3**			
MB35	26/07/2012	6.01	1125	27.96	156.64	600	<5	510	28	79	48	78	110	1.4			<1			<0.005	0.005	<10	<100
MB35	26/10/2012	7.51	1313	16.37	168.23	720	<5	550	28	75	39	65	100	1.4			3			<0.005	0.02	<10	<100
MB35	22/01/2013	7.0	1501	16.55	168.05	630	<5	550	31	83	42	73	110	1.4			2			<0.005	0.016	<10	<100
MB35	22/04/2013	7.06	1428	17.1	167.5	630	<5	570	35	94	50	81	130	1.9			1			<0.005	0.02	<10	<100
MB35	25/07/2013	7.88	1401	19.98	164.62	690	<5	560	25	70	46	76	110	1.5						0.028	0.028	<10	<100
MB35	21/10/2013	6.49	1450	17.25	167.35	859	22	505	35	101	49	80	115	2	130	<1	1	<50	<0.1			<20	<50
MB35	20/01/2014	6.45	1479	28.89	155.71	672	94	400	35	105	24	82	127	2	<10	<1	1	<50	<0.1			<20	<50
MB35	22/04/2014		1309	17.31	167.29	669	<1	520	35	94	50	81	121	1	<10	<1	1	<50	<0.1			<20	<20
MB35	29/07/2014					731	<1	505	36	100	49	79	116	2	<10	<1	1	<50	<0.1			<20	<50
MB35	10/09/2014	7.0	1829	17.7	166.9	1010	91	595	81	174	57	94	226	3	1400	<1	2	2190	<0.1			<20	<50
MB35	25/11/2014	6.865	1824	18.35	166.25	942	<1	707	78	151	57	94	241	2	310	<1	2	200	<0.1			<20	<50
MB35	20/01/2015	6.974	2047	18.32	166.28	1050	32	701	103	212	60	100	313	3	320	<1	2	250	<0.1			<20	<50
MB35	24/03/2015	6.946	1857	18.15	166.45	1020	<1	734	85	180	61	91	234	2	510	<1	2	250	<0.1			<20	<50
MB35	19/05/2015	7.01	1672	18.27	166.33	907	<1	635	66	141	57	82	164	2	230	<1	2	180	<0.1			<20	<50
MB35	16/06/2015	7.04	1837	18.34	166.26	987	<1	674	93	185	59	83	218	2	380	<1	2	320	<0.1			<20	<50
MB35	26/08/2015	7.11	1367	17.78	166.82	5000	<1	636	439	2160	256	254	1210	6	50	<1	1	300	<0.1	0.03		<20	<50

MB35	02/12/2015	7.76	1397	18.45	166.15	6520	<1	424	429	3620	398	297	1320	6	600	<1	3	2210	<0.1			<20	<50
MB35	14/03/2016	7.80	2050	18.68	165.92	552	<1	423	26	40	80	65	41	<1			1					<20	<50
MB35	13/06/2016	8.26	1330	18.41	166.19	856	<1	563	62	182	91	102	94	1	150	<1	<1	1160	<0.1			<20	<50
MB35	19/09/2016	7.68	1340	17.87	166.73	907	<1	635	66	141	57	82	164	2	230	<1	2	180	<0.1			<20	<50

Site	Date	Insitu pH	Insitu EC	SWL		TDL	CO_3	HCO_3	SO_4	Cl-	Ca (diss)	Mg (diss)	Na (diss)	K (diss)	Al Total	Sb Total	As Total	Fe Total	Hg Total	NO_3	P react.	C6–C9	C10–C36 (sum)
		pH units	µS/cm	mBGL	mRL	mg/L									µg/L					mg/L		µg/L	
Guidelines (Fitzroy)																							
Zone 34	Shall. 80th	7.1-8.1	*8910*			-	-	878	318	3185	215	389	1500	-	-	-	-	246	-	5.3	-	-	-
	Deep 80th	7.4-8.03	*16000*			-	-	650	398	5905	442	491	2565	-	-	-	-	140	-	14.92	-	-	-
ANZECC stock		6.0-9.0	*5970*			4000			1000		1000				5000	-	500	-	2				
NHMRC D.W.*		6.5-8.5	*895**			600			500	250			180		200	3	10	300	1	11.3			
MB36	26/07/2012	5.96	7658	19.58	178.22	4300	<5	660	440	1900	180	230	1100	8.1			2.0			<0.005	<0.005	<10	<100
MB36	26/10/2012	7.33	8143	19.39	178.41	4300	<5	720	400	1800	160	190	970	11			1.0			<0.005	<0.005	<10	<100
MB36	22/01/2013	6.92	9541	19.38	178.42	4700	<5	730	450	2000	180	210	1000	8.9			1.0			<0.005	<0.005	<10	<100
MB36	22/04/2013	7.10	8052	20.00	177.80	4400	<5	770	460	2100	170	230	1200	27			2.0			<0.005	<0.005	46	<100
MB36	25/07/2013	7.65	7479	17.15	180.65	4800	<5	750	340	1600	190	210	1200	9						<0.005	<0.005	<10	460
MB36	22/10/2013	6.83	8710	19.88	177.92	4610	22	565	435	1660	192	223	1040	7	20	<1	1	760	<0.1			<20	<50
MB36	20/01/2014	6.40	7873	27.23	170.57	4650	94	474	440	1640	158	214	1050	7	<10	<1	1	630	<0.1			<20	<50
MB36	22/04/2014		7579	19.64	178.16	4220	<1	665	493	2140	204	234	1140	5	<10	<1	1	630	<0.1			<20	<20
MB36	29/07/2014					4850	<1	646	422	1730	187	235	1110	6	<10	<1	1	600	<0.1			<20	<50
MB36	10/09/2014	6.742	10150	19.44	178.36		91	354	362	3500	312	347	1440	9	310	<1	3	1740	<0.1			<20	<50
MB36	25/11/2014	6.656	10003	19.32	178.48	6140	<1	468	360	3180	303	324	1430	8	880	<1	3	2210	<0.1			<20	<50

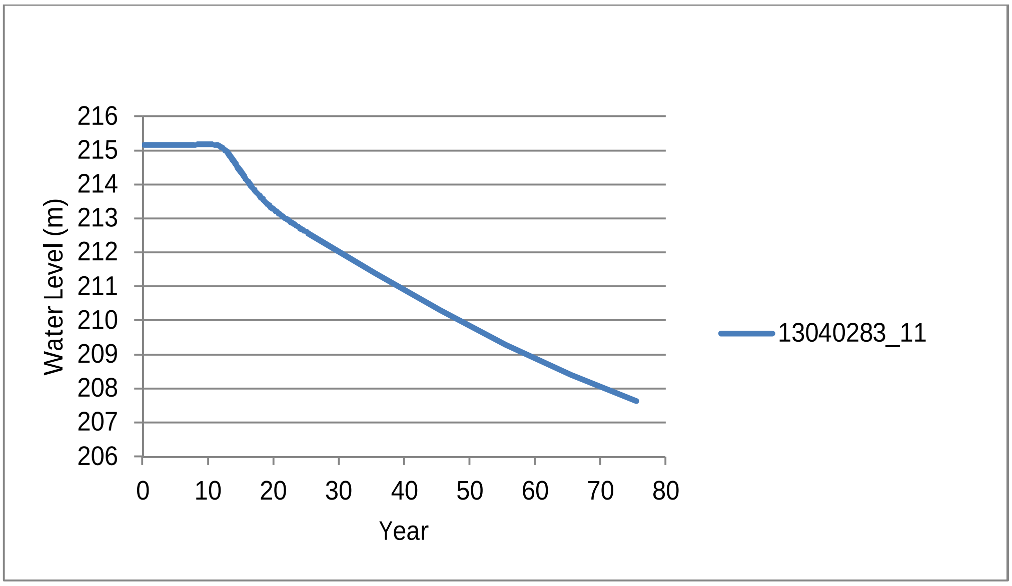
MB36	20/01/2015	6.879	10790	19.25	178.55	6830	32	389	404	3860	344	368	1680	8	480	<1	3	1670	<0.1			<20	60
MB36	24/03/2015	6.807	10517	19.19	178.61	6720	<1	399	369	3720	459	345	1480	6	460	<1	<5	1960	<0.1			<20	380
MB36	19/05/2015	6.84	9953	19.35	178.45	6140	<1	471	512	3200	386	295	1280	6	530	<1	3	1990	<0.1			<20	<50
MB36	16/06/2015	6.85	10327	19.10	178.70	6520	<1	424	429	3620	398	297	1320	6	600	<1	3	2210	<0.1			<20	<50
MB36	26/08/2015	7.59	7743	18.20	178.60	9200	<1	95	2060	3910	490	204	2560	20	200	<1	<1	810	<0.1	<0.01		<20	<50
MB36	02/12/2015	7.37	8677	18.10	178.70	9730	<1	112	2250	4470	540	198	2330	17	250	<1	<1	960	<0.1			<20	<50
MB36	21/04/2016	7.80	8480	17.96	179.84	669	<1	520	35	94	50	81	121	1	<10	<1	1	<50	<0.1			<50	<20
MB36	13/06/2016	7.58	7890	17.95	179.85	6260	<1	524	1880	1970	247	276	1340	57	640	<1	<1	2500	<0.1			<20	<50
MB36	19/09/2016	7.50	7830	17.84	179.96	6140	<1	471	512	3200	386	295	1280	6	530	<1	3	1990	<0.1			<20	<50

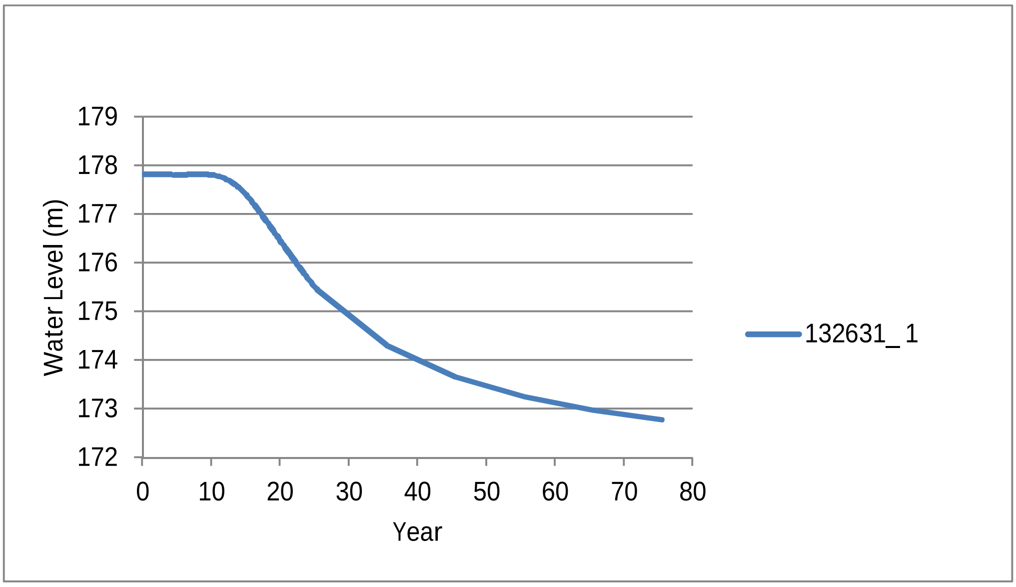
Site	Date	Insitu pH	Insitu EC	SWL		TDL	CO_3	HCO_3	SO_4	Cl-	Ca (diss)	Mg (diss)	Na (diss)	K (diss)	Al Total	Sb Total	As Total	Fe Total	Hg Total	NO_3	P react.	C6–C9	C10–C36 (sum)
		pH units	µS/cm	mBGL	mRL	mg/L									µg/L					mg/L		µg/L	
Guidelines (Fitzroy)																							
Zone 34	Shall. 80th	7.1-8.1	*8910*			-	-	878	318	3185	215	389	1500	-	-	-	-	246	-	5.3	-	-	-
	Deep 80th	7.4-8.03	*16000*			-	-	650	398	5905	442	491	2565	-	-	-	-	140	-	14.92	-	-	-
ANZECC stock		6.0-9.0	*5970*			4000			1000		1000				5000	-	500	-	2				
NHMRC D.W.*		6.5-8.5	*895**			600			500	250			180		200	3	10	300	1	11.3			
MB37	25/07/2012	7.73	15140	12.46	222.34	9300	<5	180	2200	4300	490	190	2700	24			<1			<0.005	<0.005	<10	130
MB37	26/10/2012	8.71	15700	12.20	222.60	9400	<5	280	1800	3500	410	150	2500	22			4.0			0.019	0.092	<10	160
MB37	22/01/2013	7.32	18480	12.34	222.46	5400	<5	150	2100	4200	510	190	2700	25			<1			<0.005	<0.005	<10	<100
MB37	22/04/2013	7.97	15370	13.12	221.68	9500	<5	140	2200	4300	480	200	2800	29			<1			<0.005	<0.005	11	160
MB37	24/07/2013	8.6	15870	13.16	221.64	9600	<5	110	1700	3400	470	200	2700	21						0.009	0.057	<10	<100
MB37	22/10/2013	7.21	17230	13.22	221.58	9650	<1	111	1920	4230	605	243	2670	28	<10	<1	<1	1750	<0.1			<20	<50
MB37	21/01/2014	6.91	15220	27.62	207.18	9030	<1	108	2130	4190	571	226	2550	24	<10	<1	<1	1360	<0.1			<20	<50

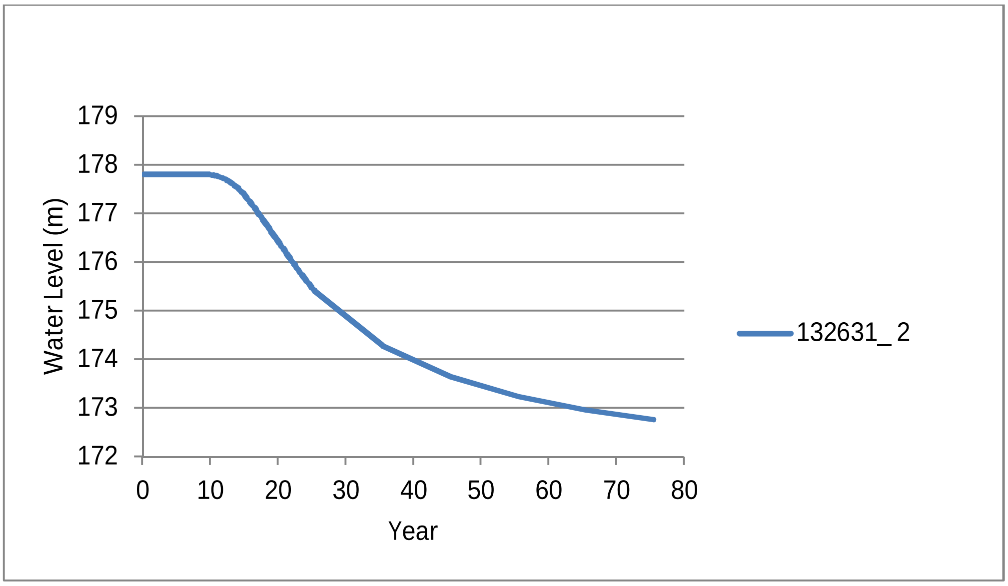
MB37	23/04/2014	7.86	14040	13.52	221.28	9580	<1	98	2300	4070	584	220	2450	19	<10	<1	<1	1490	<0.1			<20	<20
MB37	29/07/2014	7.84	12900			10100	<1	96	1950	4250	520	215	2630	22	640	3	<1	2820	<0.1			<20	1900
MB37	10/09/2014	7.428	14546	13.37	221.43		<1	177	2080	4420	555	239	2610	29	60	<1	<1	1010	<0.1			<20	<50
MB37	25/11/2014	7.294	14230	13.45	221.35	10000	<1	133	1870	4320	545	234	2480	23	130	<1	<1	930	<0.1			<20	<50
MB37	20/01/2015	7.265	14326	13.49	221.31	9950	<1	116	2220	4450	530	230	2720	23	70	<1	1	610	<0.1			<20	<50
MB37	24/03/2015	7.489	14207	13.57	221.23	9290	<1	121	1950	4390	575	216	2480	16	140	<5	<5	1070	<0.1			<20	<50
MB37	19/05/2015	7.42	13903	13.60	221.20	9380	<1	117	2310	4180	526	206	2300	18	80	<1	<1	980	<0.1			<20	<50
MB37	16/06/2015	7.34	13963	13.58	221.22	9730	<1	112	2250	4470	540	198	2330	17	250	<1	<1	960	<0.1			<20	<50
MB37	25/08/2015					606	<1	471	21	42	87	64	38	1			<1					<20	<50
MB37	02/12/2015	7.41	13927	12.72	222.08	6700	<1	508	1510	2300	265	288	1400	58	490	<1	<1	2520	<0.1			<20	<50
MB37	14/04/2016	8.15	13650	12.80	222.00	637	<1	497	24	55	71	78	61	<1			<1					<20	<50
MB37	13/06/2016	8.03	13600	12.80	222.00	1100	<1	661	136	263	119	118	154	1	10	<1	<1	850	<0.1			<20	<50
MB37	19/09/2016	8.06	13686	12.54	222.26	9380	<1	117	2310	4180	526	206	2300	18	80	<1	<1	980	<0.1			<20	<50

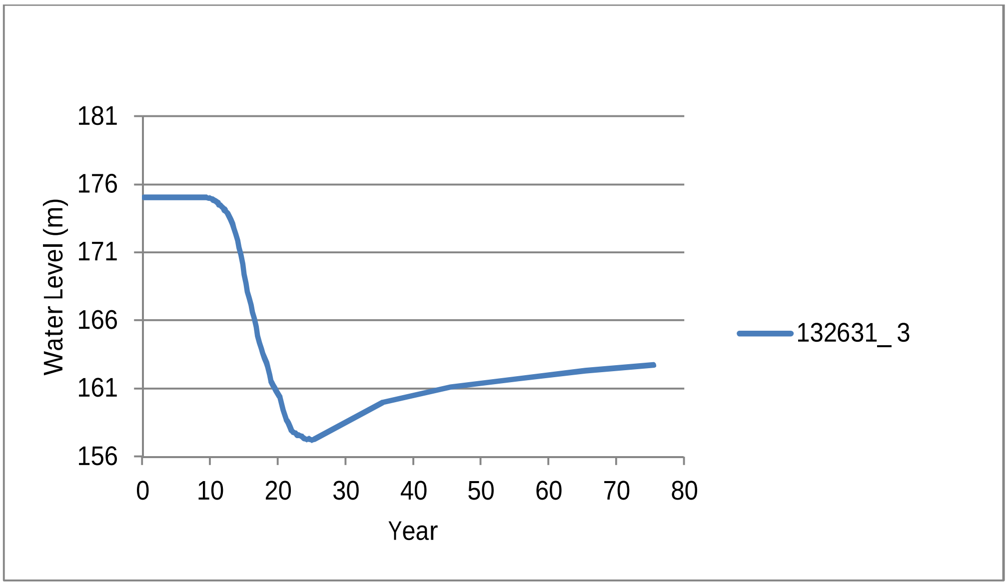
Appendix B

Simulated Water Level Hydrographs

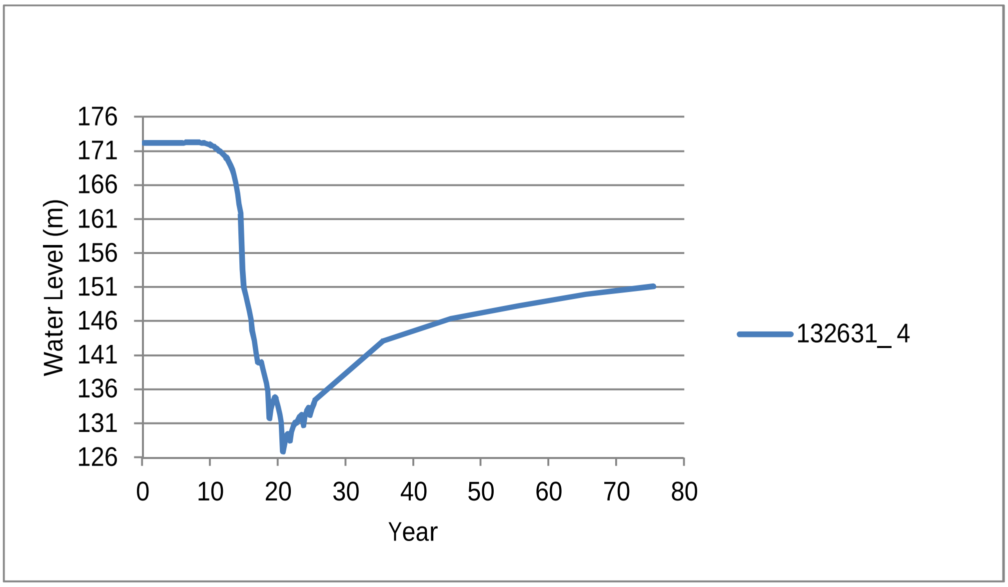

216
215
214
213
212
211
210
209
208
207
206
Water Level (m)
0
10
20
30
40
50
60
70
80
Year
13040283_11


179
178
177
176
175
174
173
172
Water Level (m)
0
10
20
30
40
50
60
70
80
Year
132631_1

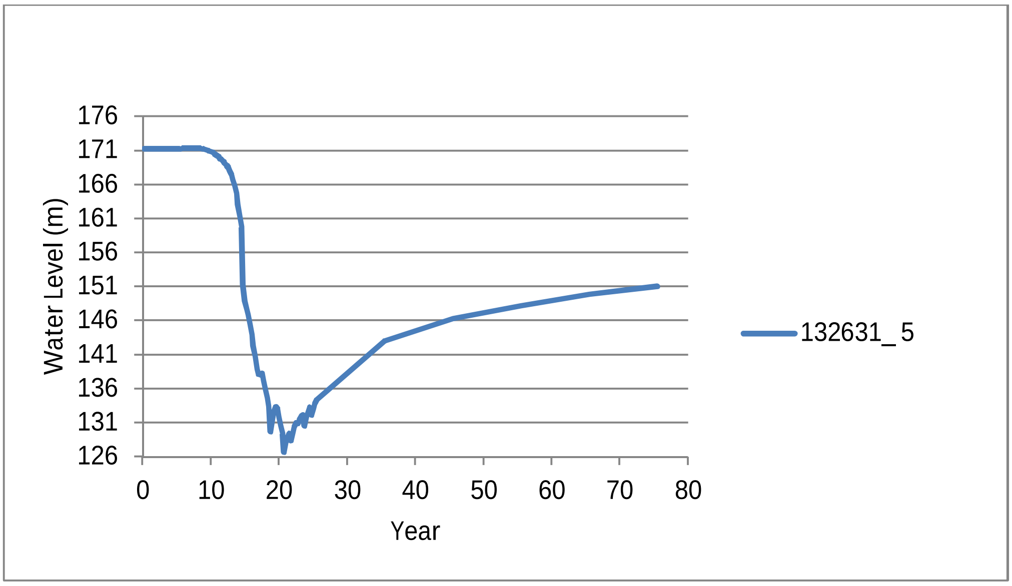

179
178
177
176
175
174
173
172
Water Level (m)
0
10
20
30
40
50
60
70
80
Year
132631_2



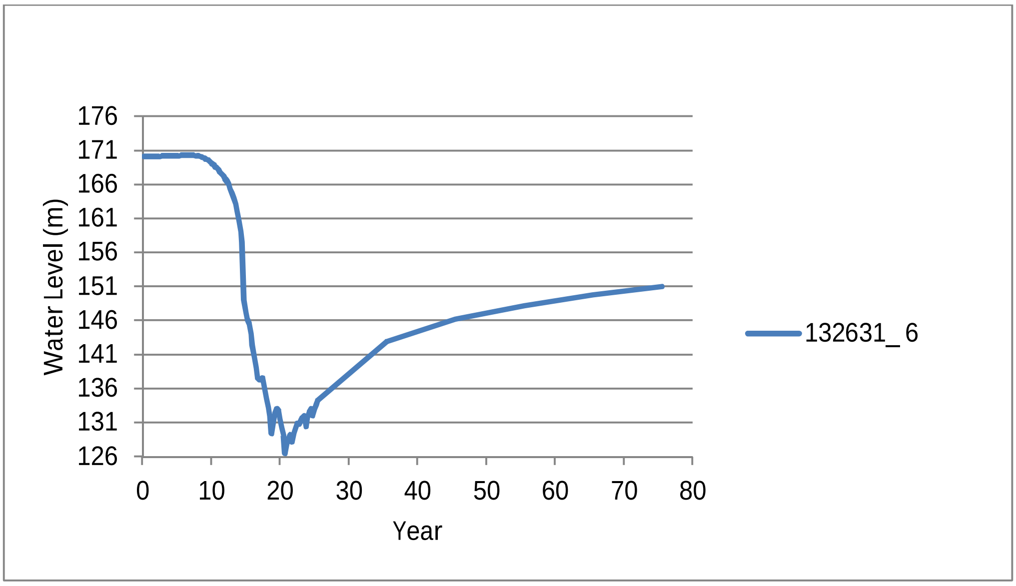
Water Level (m)
181
176
171
166
161
156
0
10
20
30
40
50
60
70
80
Year
132631_ 3



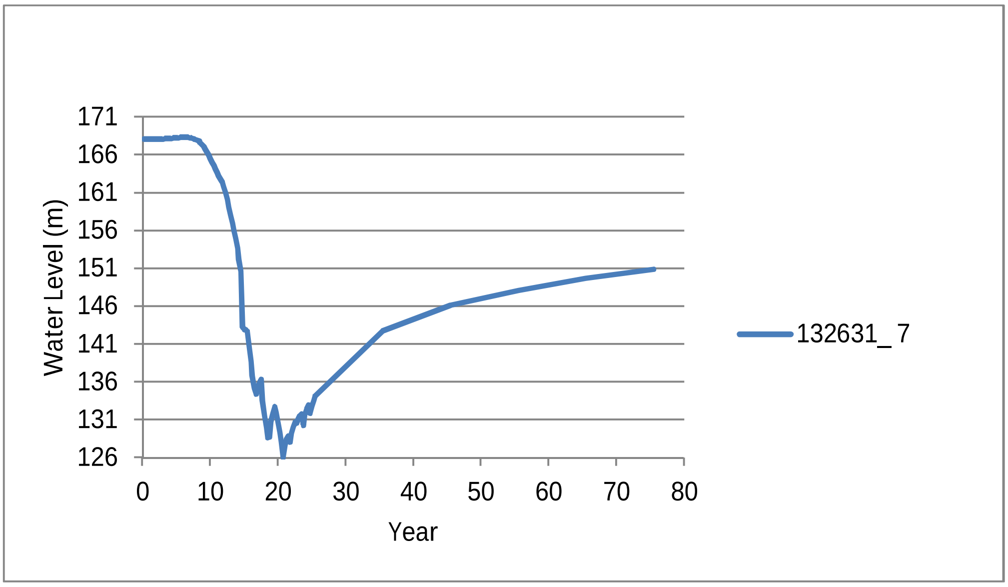
Water Level (m)
176
171
166
161
156
151
146
141
136
131
126
0
10
20
30
40
50
60
70
80
Year
132631_ 4



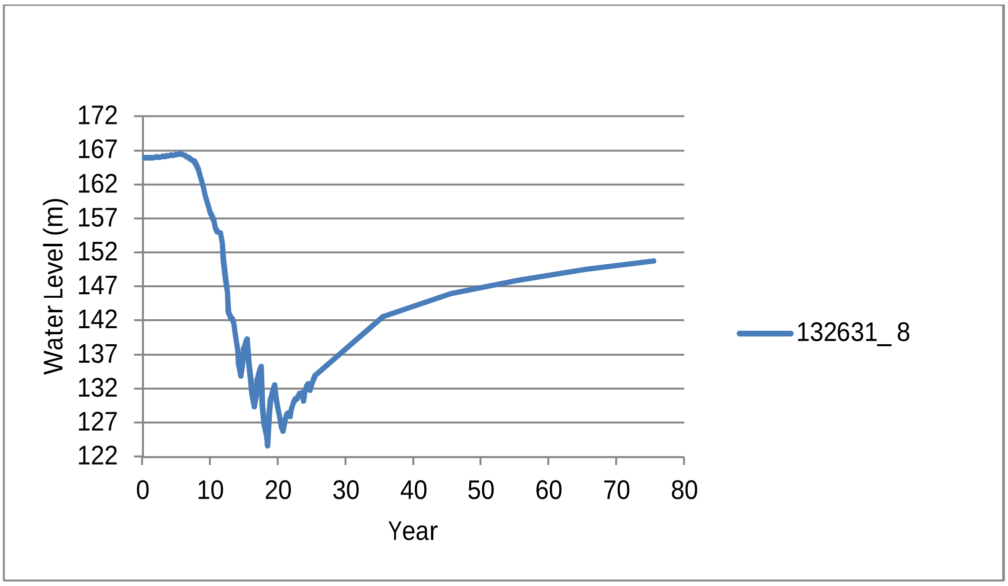
Water Level (m)
176
171
166
161
156
151
146
141
136
131
126
0
10
20
30
40
50
60
70
80
Year
132631_ 5



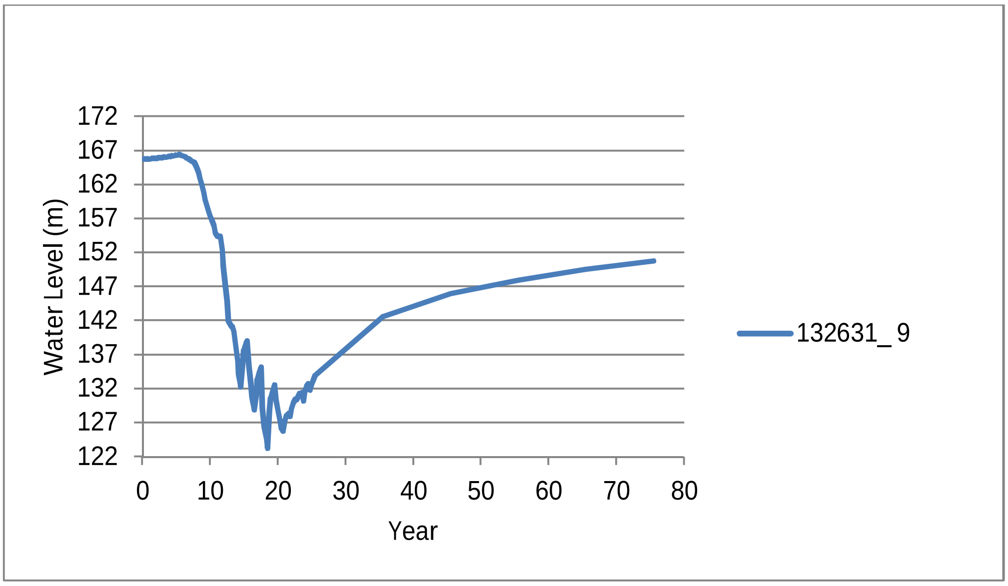
176
171
166
161
156
151
146
141
136
131
126
Water Level (m)
0
10
20
30
40
50
60
70
80
Year
132631_6

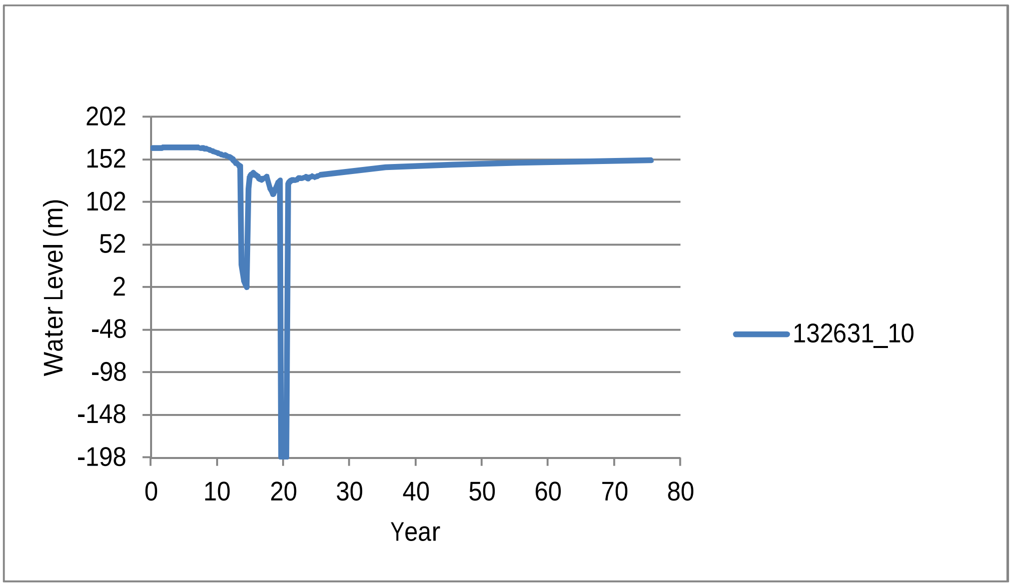


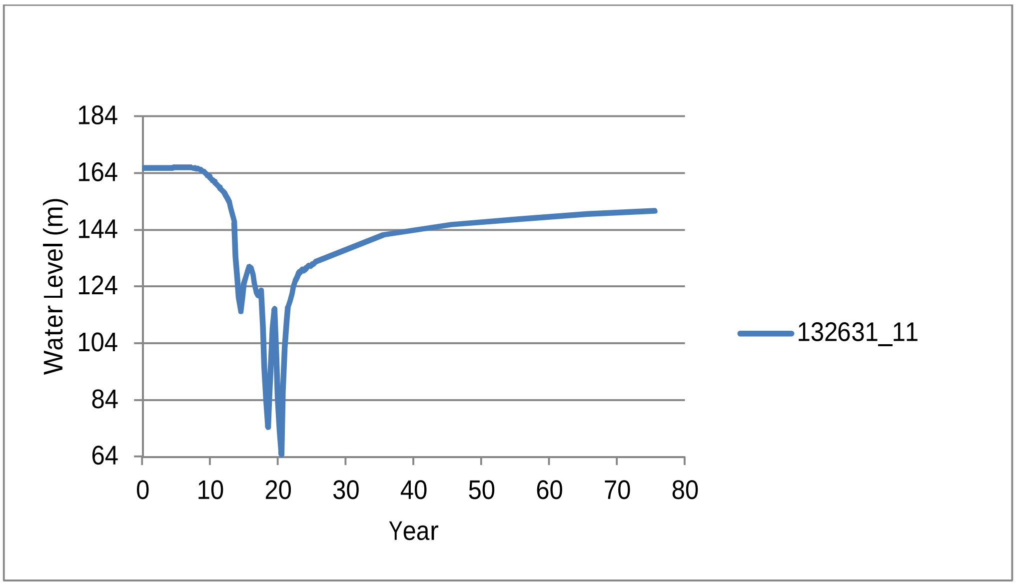
171
166
161
156
151
146
141
136
131
126
Water Level (m)
0
10
20
30
40
50
60
70
80
Year
132631_7

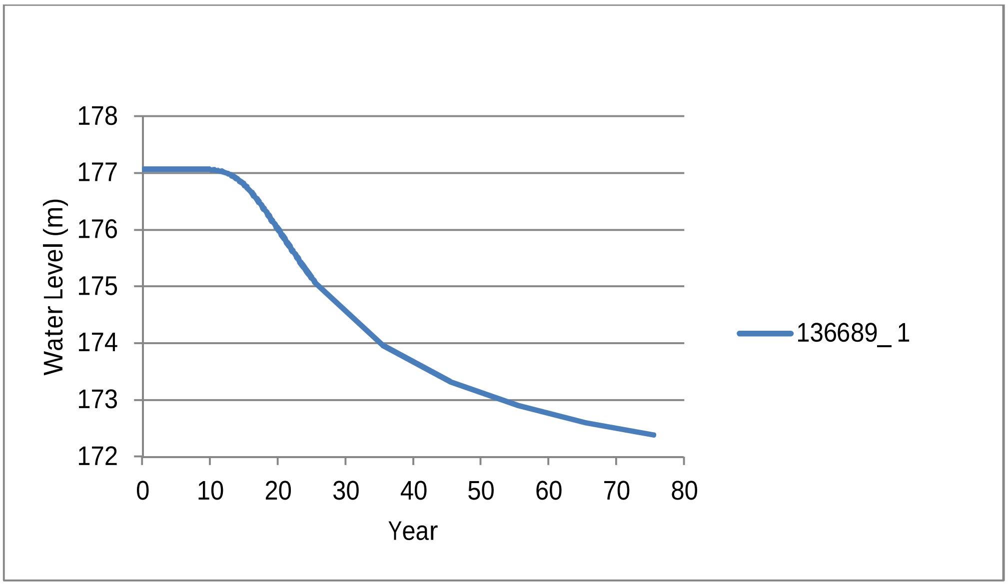


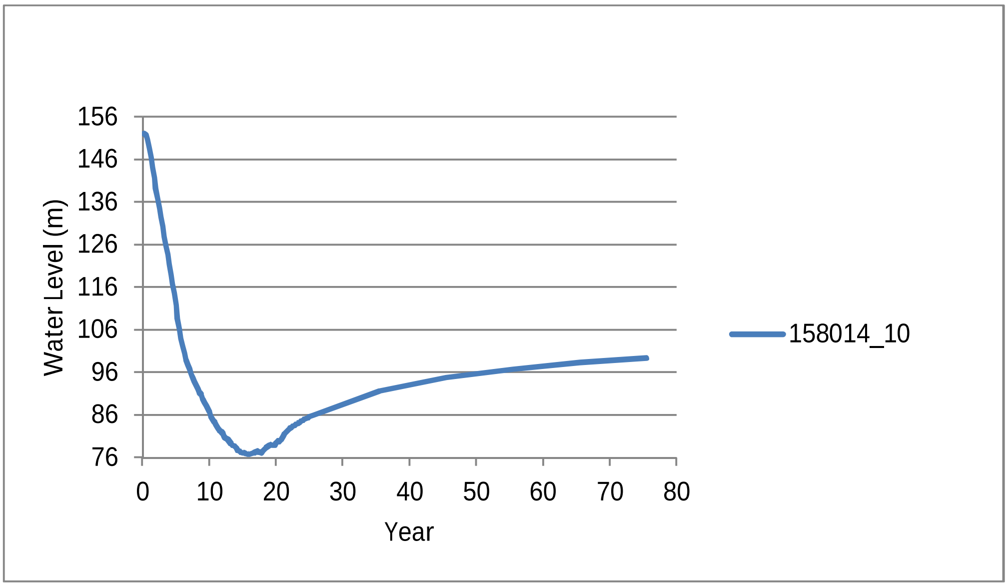
172
167
162
157
152
147
142
137
132
127
122
Water Level (m)
0
10
20
30
40
50
60
70
80
Year
132631_8

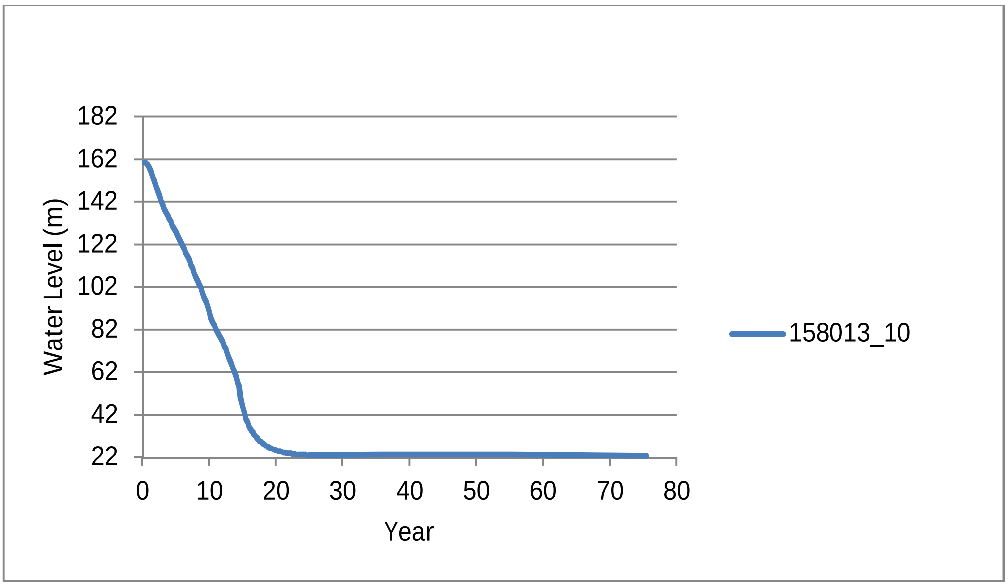

172
167
162
157
152
147
142
137
132
127
122
Water Level (m)
0
10
20
30
40
50
60
70
80
Year
132631_ 9

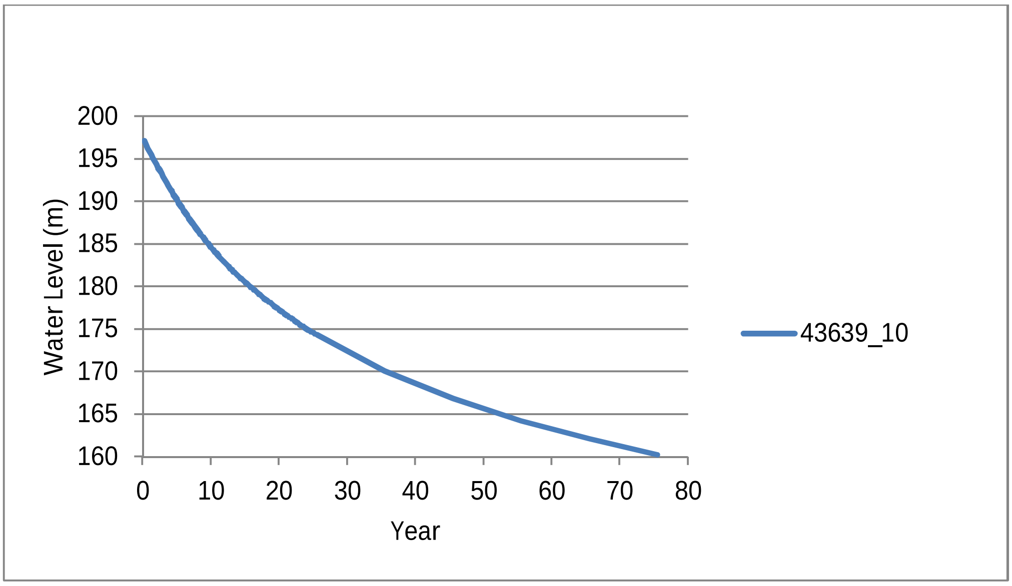

202
152
102
52
2
-48
-98
-148
-198
Water Level (m)
0
10
20
30
40
50
60
70
80
Year
132631_10


184
164
144
124
104
84
64
Water Level (m)
0
10
20
30
40
50
60
70
80
Year
132631_11

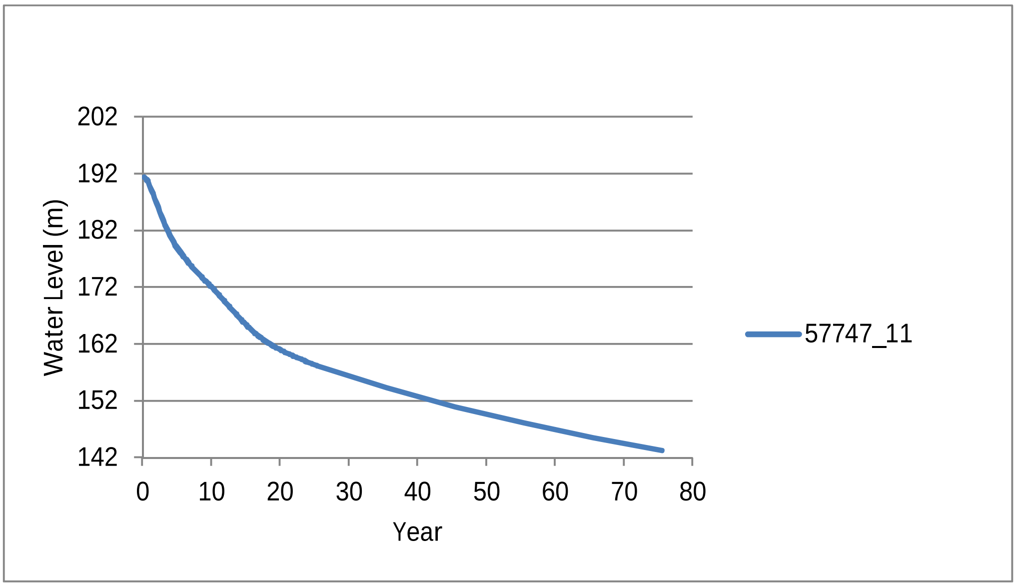

178
177
176
175
174
173
172
0 10 20 30 40 50 60 70 80
Water Level (m)
Year
136689_1


156
146
136
126
116
106
96
86
76
0 10 20 30 40 50 60 70 80
Water Level (m)
Year
158014_10

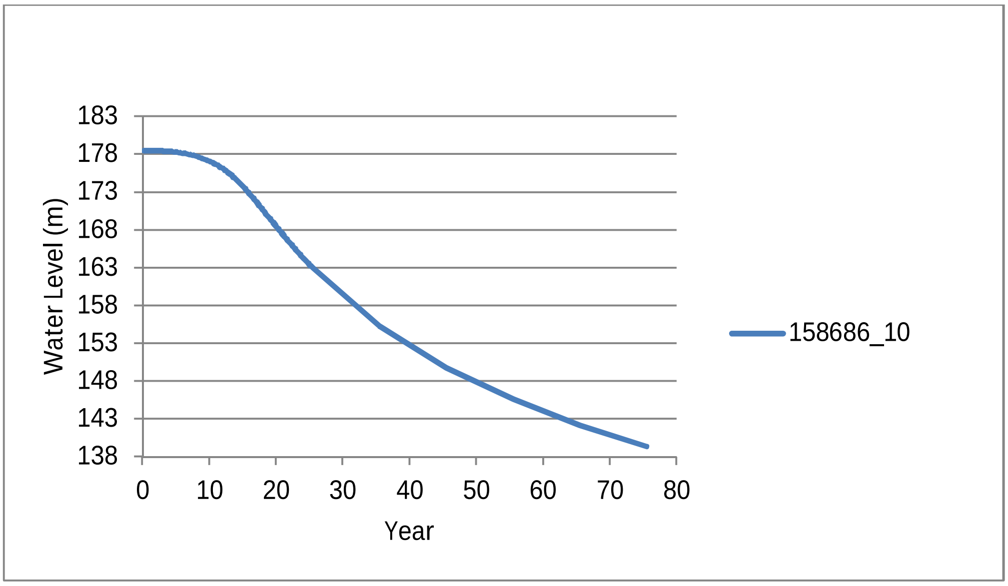

182
162
142
122
102
82
62
42
22
0 10 20 30 40 50 60 70 80
Water Level (m)
Year
158013_10



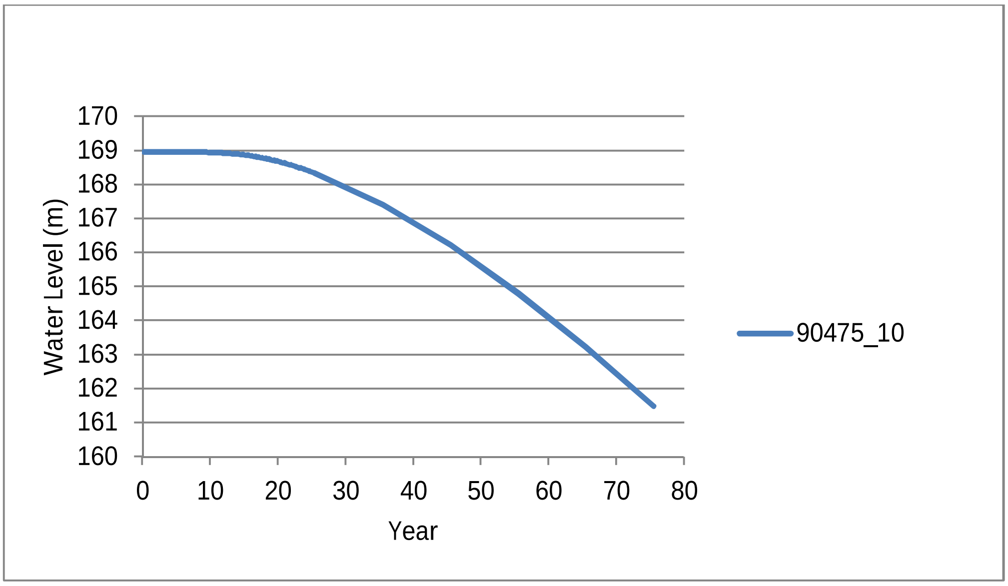
Water Level (m)
200
195
190
185
180
175
170
165
160
0 10 20 30 40 50 60 70 80
Year
43639_10



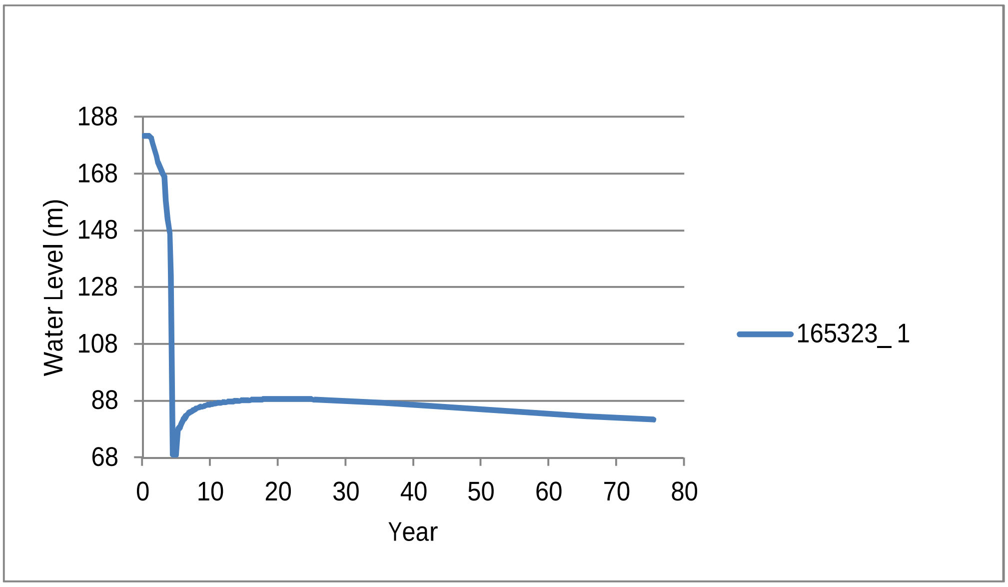
Water Level (m)
202
192
182
172
162
152
142
0 10 20 30 40 50 60 70 80
Year
57747_11



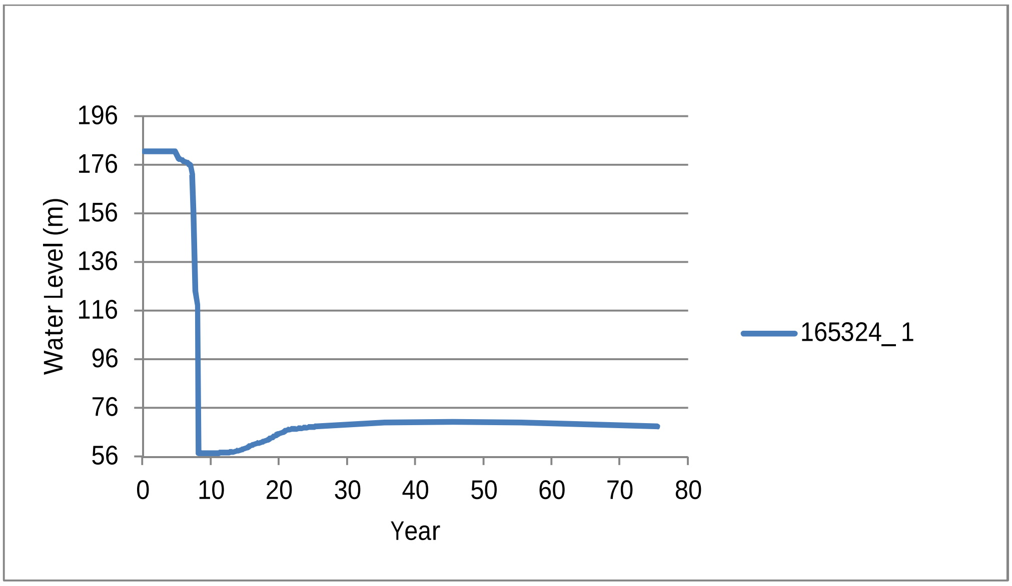
Water Level (m)
183
178
173
168
163
158
153
148
143
138
0 10 20 30 40 50 60 70 80
Year
158686_10



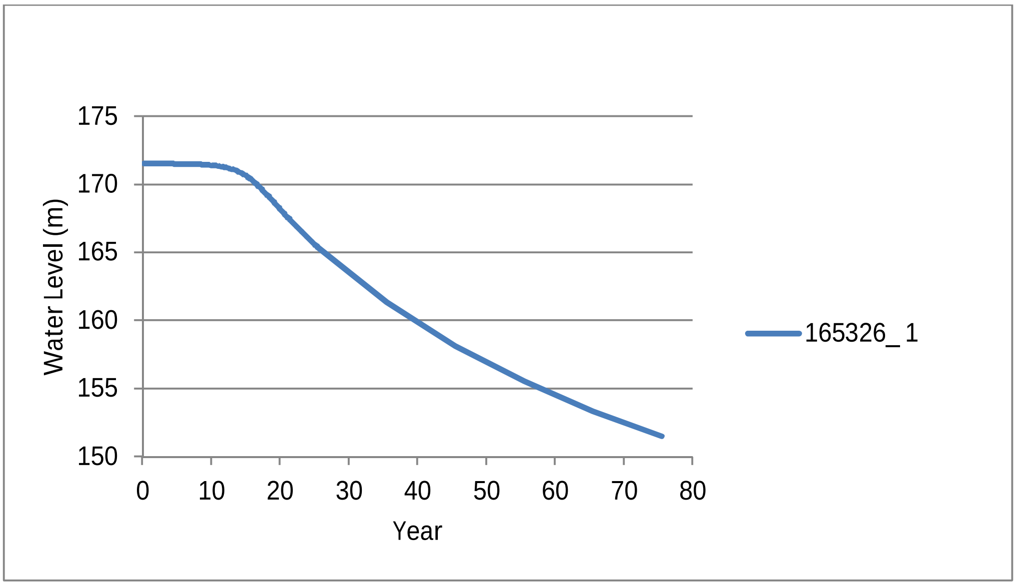
Water Level (m)
170
169
168
167
166
165
164
163
162
161
160
0
10
20
30
40
50
60
70
80
Year
90475_10



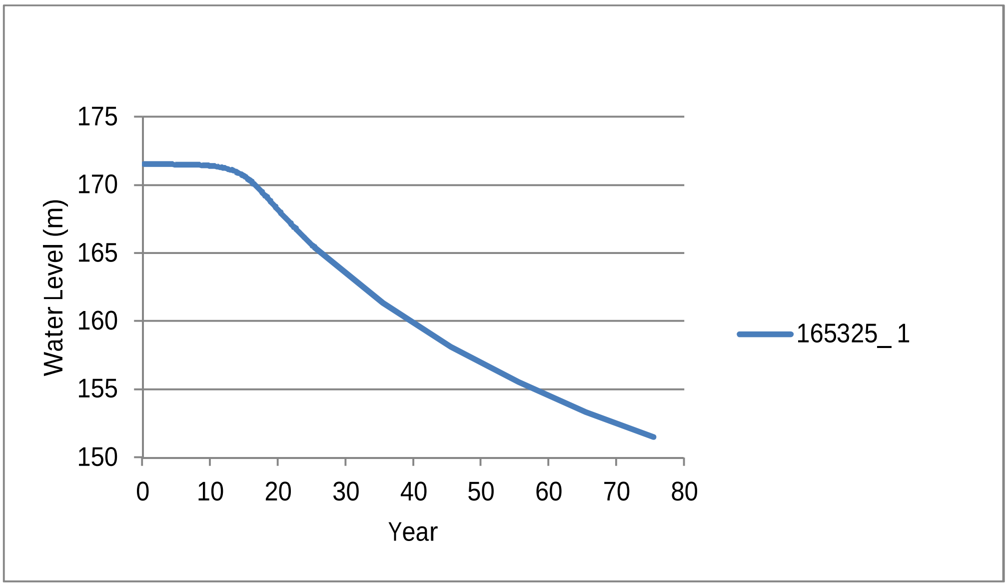
Water Level (m)
188
168
148
128
108
88
68
0
10
20
30
40
50
60
70
80
Year
165323_1



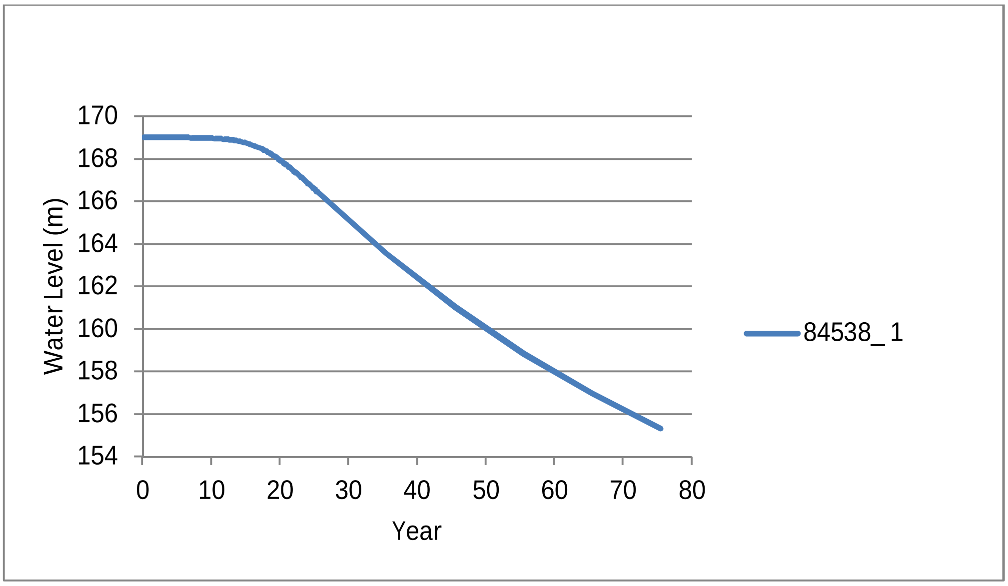
Water Level (m)
196
176
156
136
116
96
76
56
0
10
20
30
40
50
60
70
80
Year
165324_1



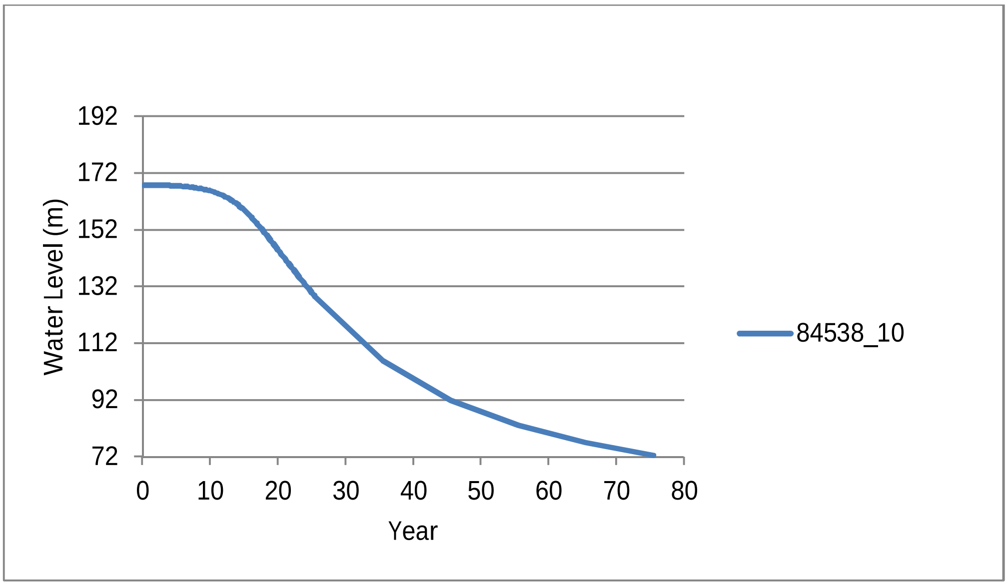
Water Level (m)
175
170
165
160
155
150
0
10
20
30
40
50
60
70
80
Year
165326_1



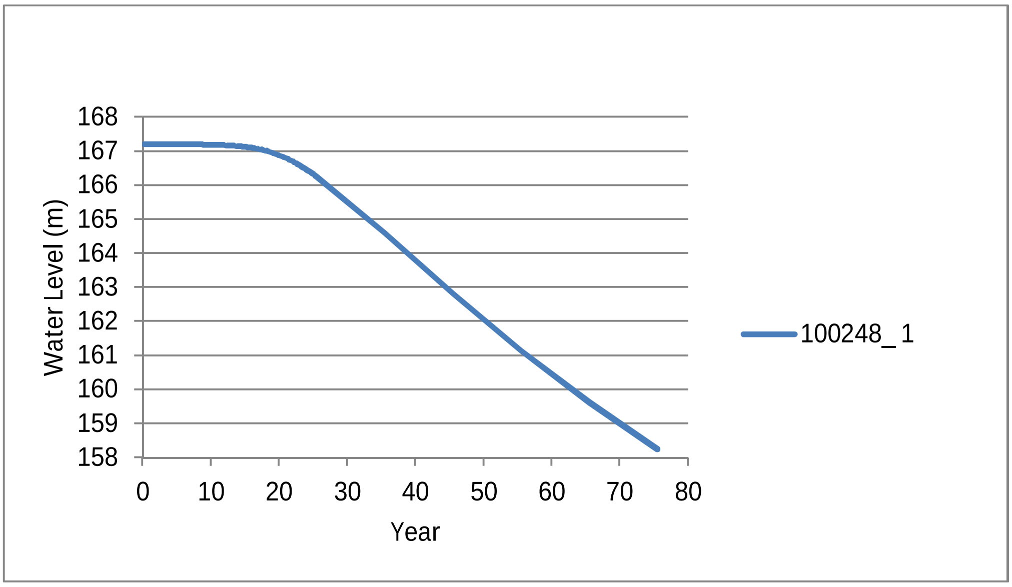
Water Level (m)
175
170
165
160
155
150
0
10
20
30
40
50
60
70
80
Year
165325_1



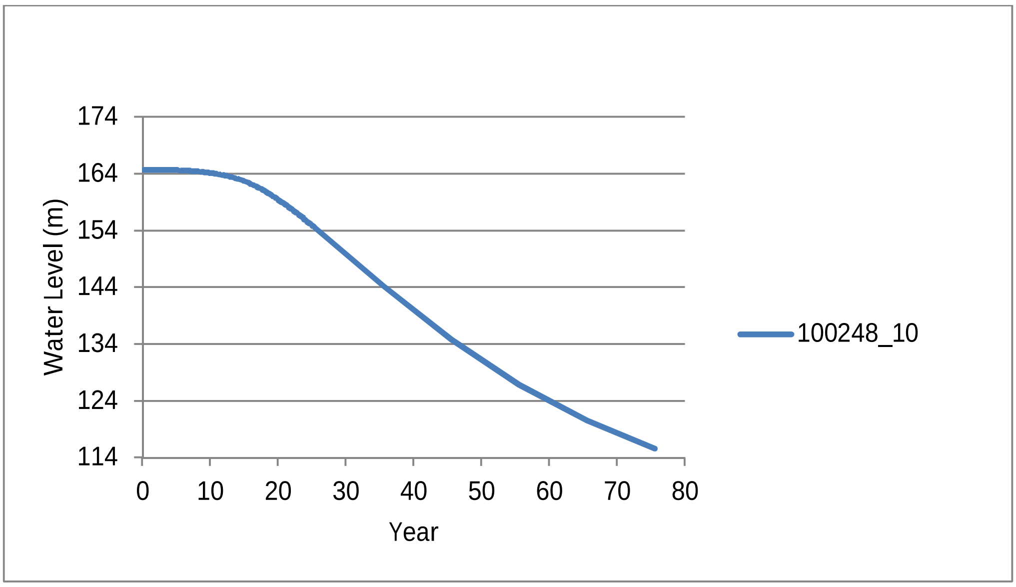
Water Level (m)
170
168
166
164
162
160
158
156
154
0
10
20
30
40
50
60
70
80
Year
84538_1



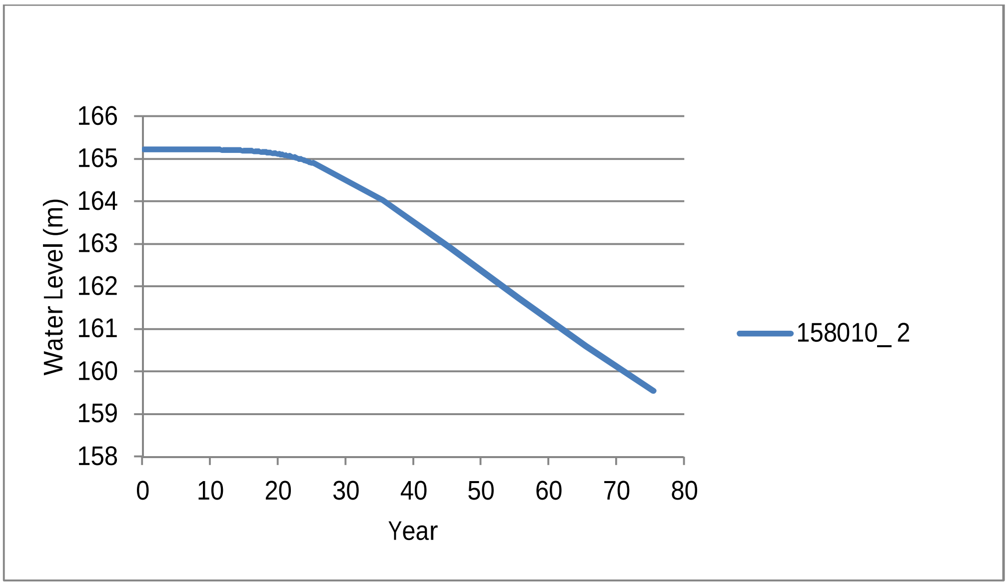
Water Level (m)
192
172
152
132
112
92
72
0
10
20
30
40
50
60
70
80
Year
84538_10

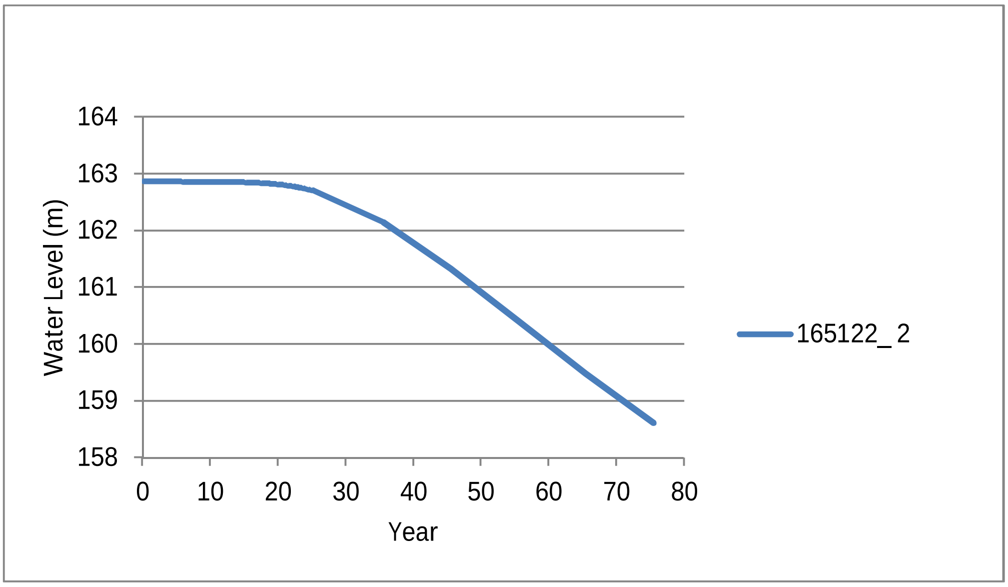


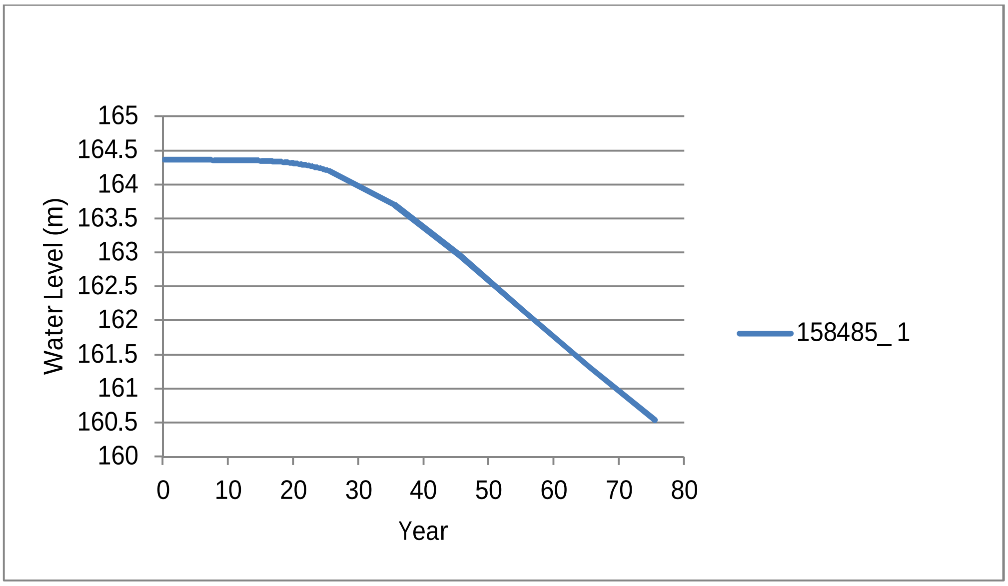
Water Level (m)
168
167
166
165
164
163
162
161
160
159
158
0
10
20
30
40
50
60
70
80
Year
100248_1

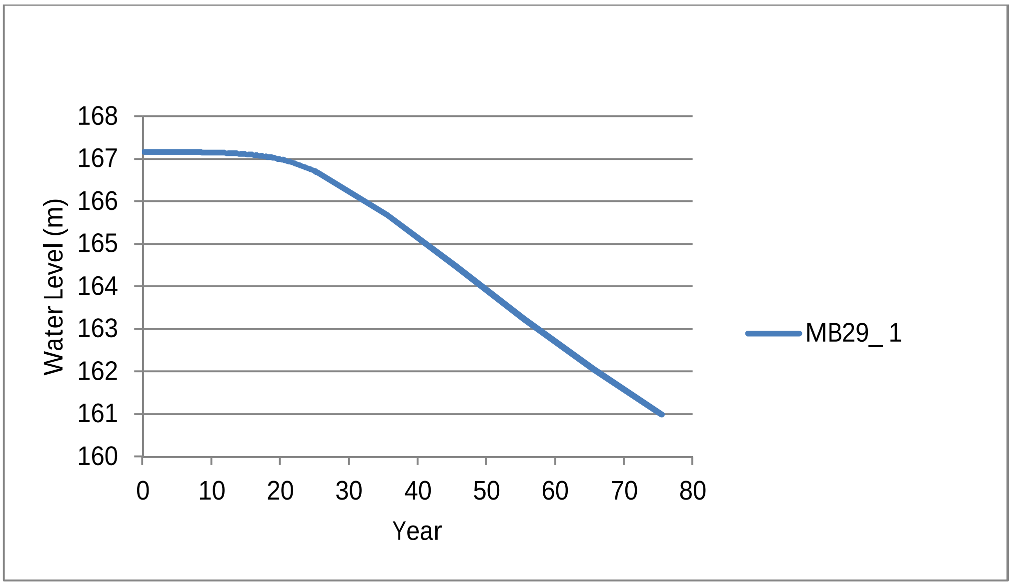


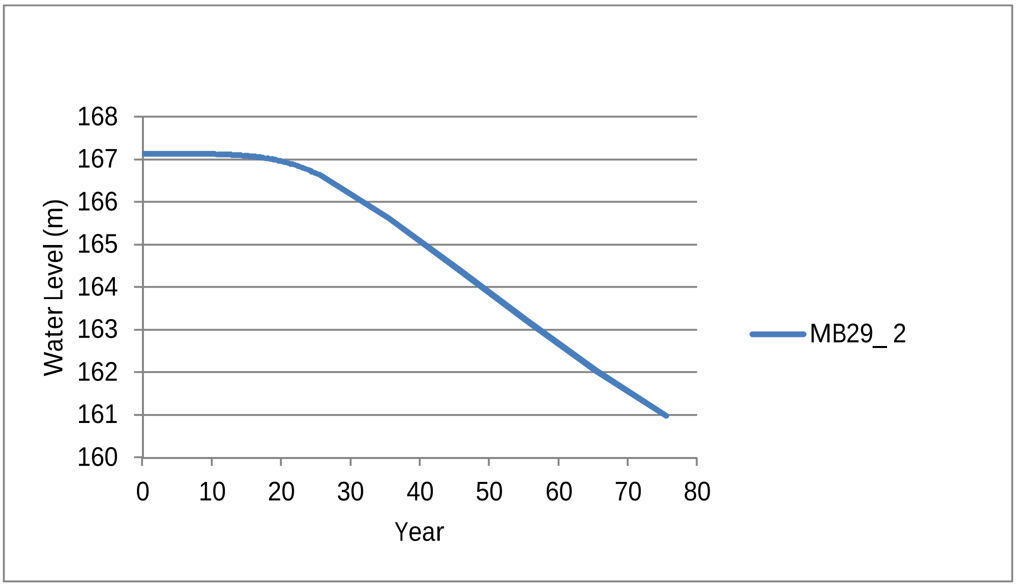
Water Level (m)
174
164
154
144
134
124
114
0
10
20
30
40
50
60
70
80
Year
100248_10

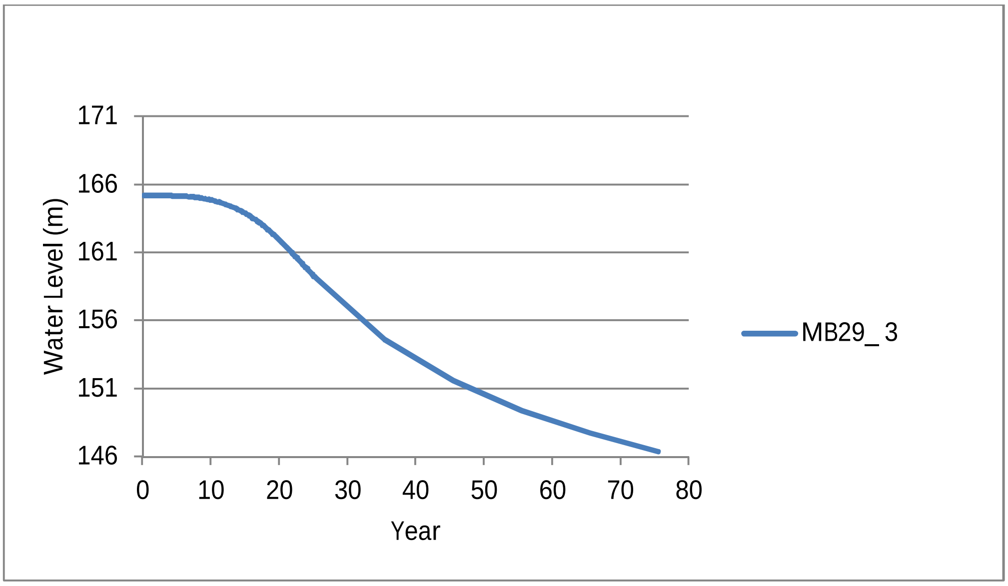

166
165
164
163
162
161
160
159
158
0
10
20
30
40
50
60
70
80
Year
Water Level (m)
158010_2

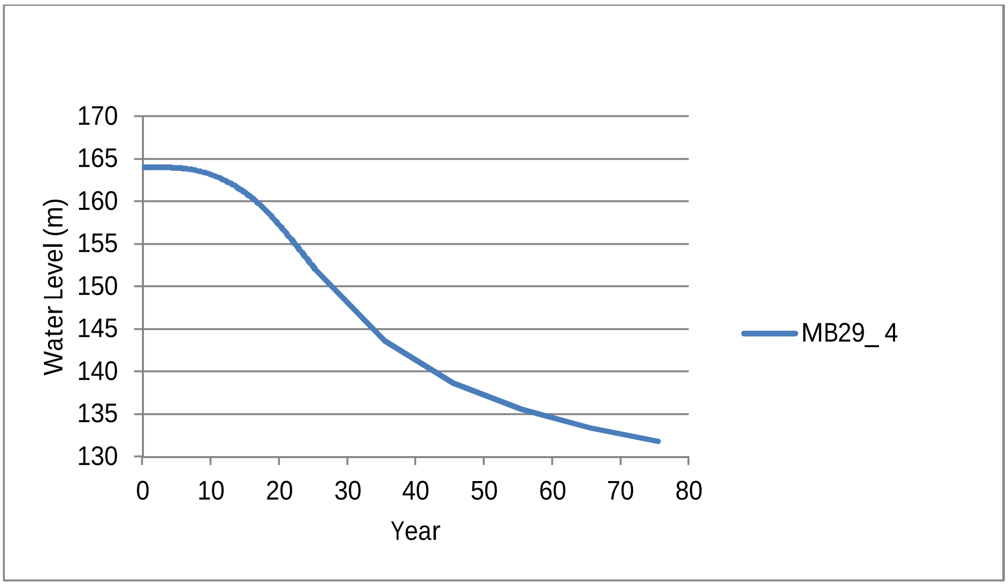

164
163
162
161
160
159
158
0
10
20
30
40
50
60
70
80
Year
Water Level (m)
165122_2


165
164.5
164
163.5
163
162.5
162
161.5
161
160.5
160
0
10
20
30
40
50
60
70
80
Year
Water Level (m)
158485_1

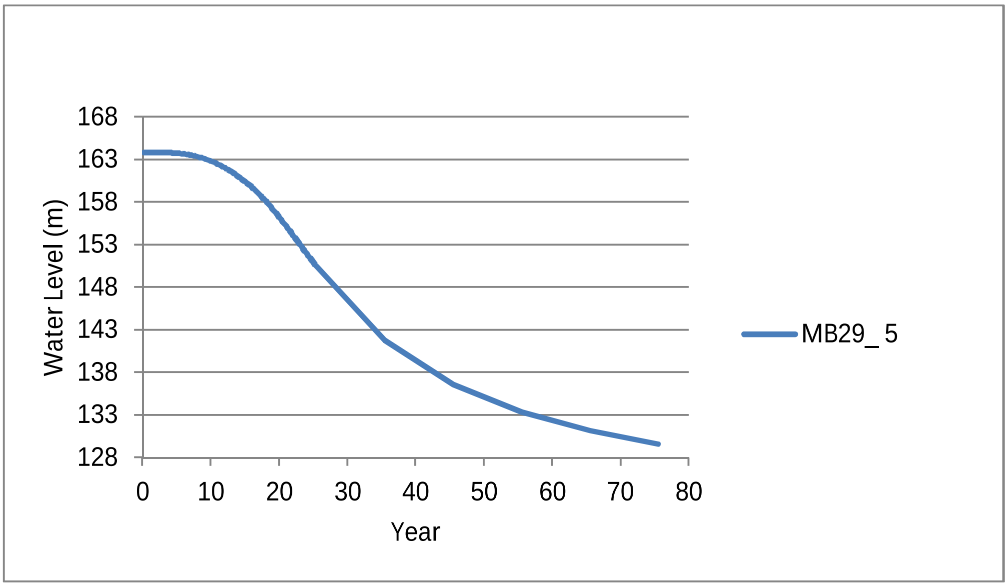

Water Level (m)
168
167
166
165
164
163
162
161
160
0
10
20
30
40
50
60
70
80
Year
MB29_ 1


Water Level (m)
168
167
166
165
164
163
162
161
160
0
10
20
30
40
50
60
70
80
Year
MB29_ 2

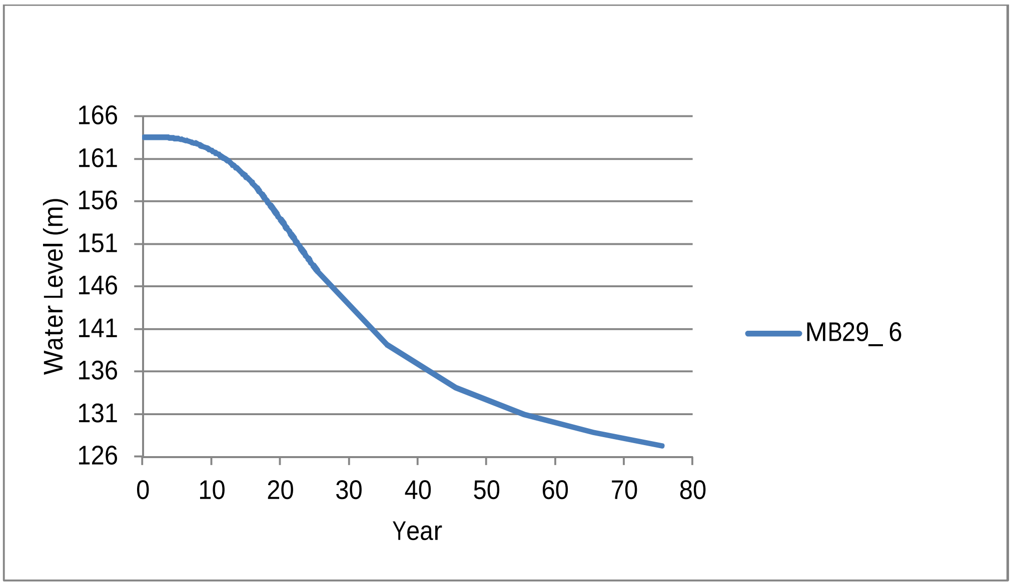

Water Level (m)
171
166
161
156
151
146
0
10
20
30
40
50
60
70
80
Year
MB29_ 3



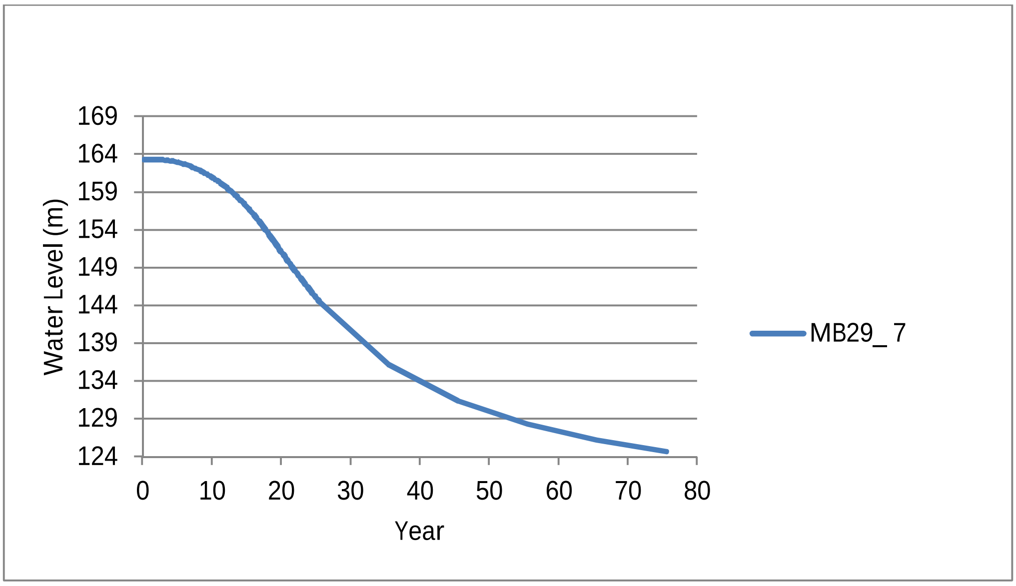
170
165
160
155
150
145
140
135
130
Water Level (m)
0
10
20
30
40
50
60
70
80
Year
MB29_ 4

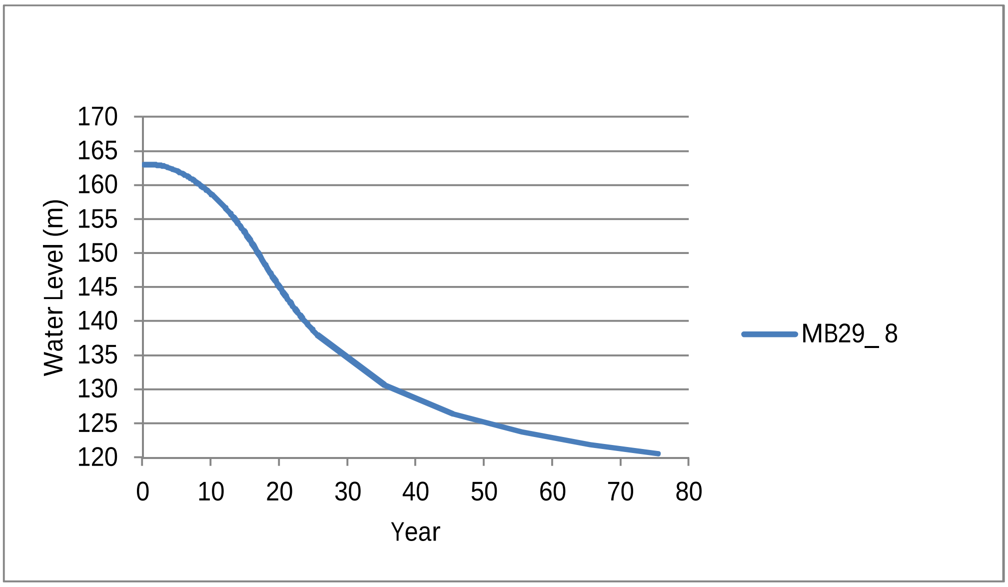


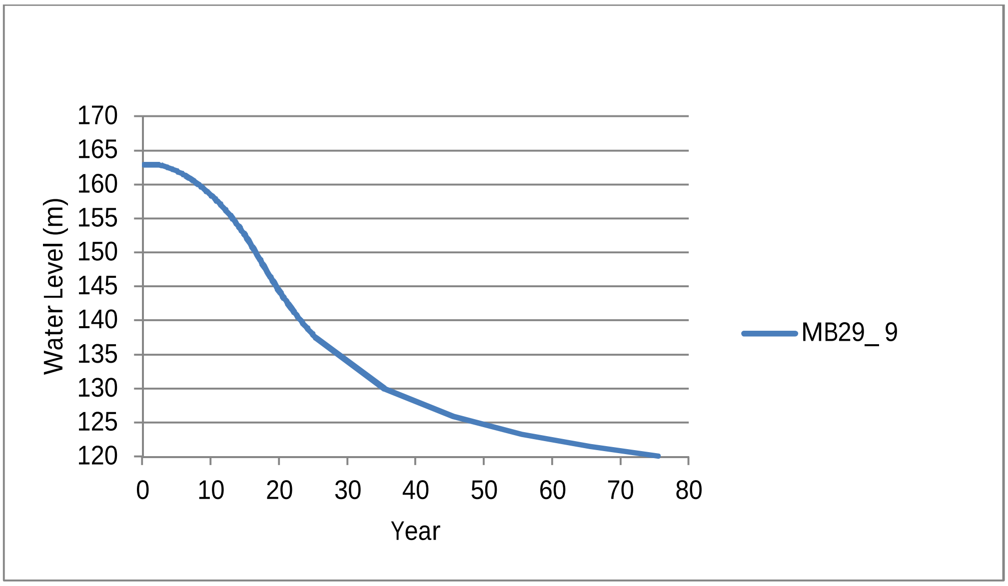
168
163
158
153
148
143
138
133
128
Water Level (m)
0
10
20
30
40
50
60
70
80
Year
MB29_ 5

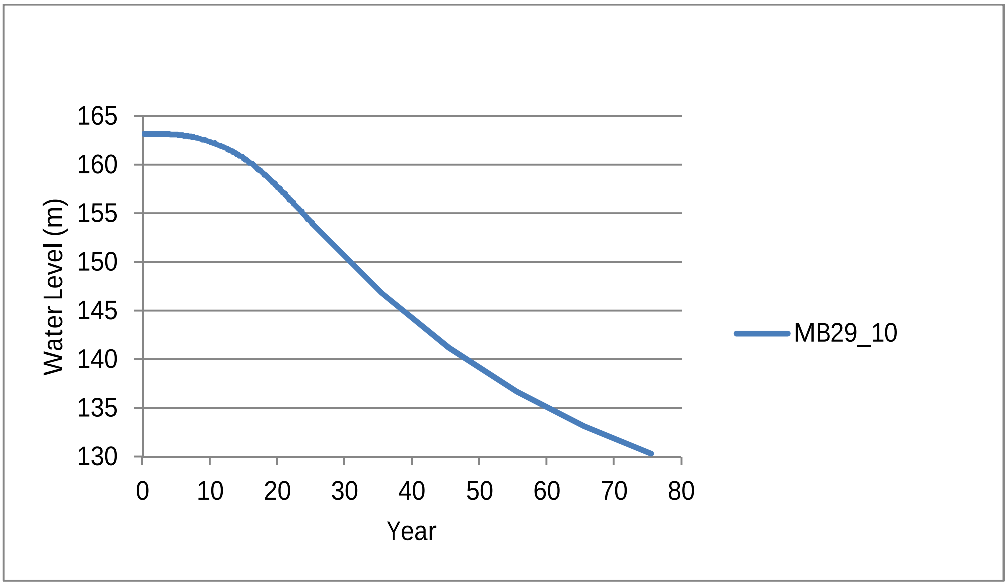


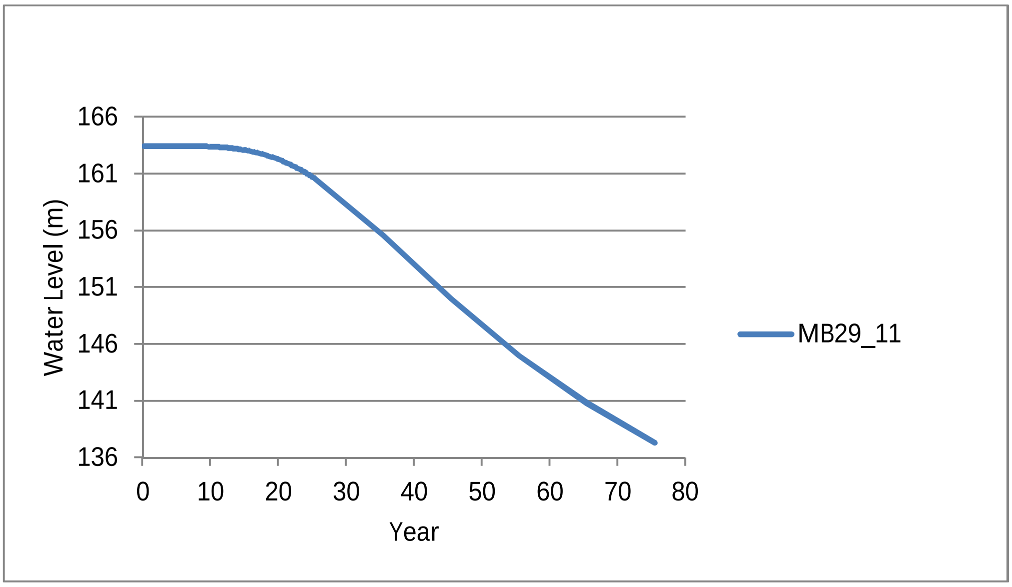
166
161
156
151
146
141
136
131
126
Water Level (m)
0
10
20
30
40
50
60
70
80
Year
MB29_ 6

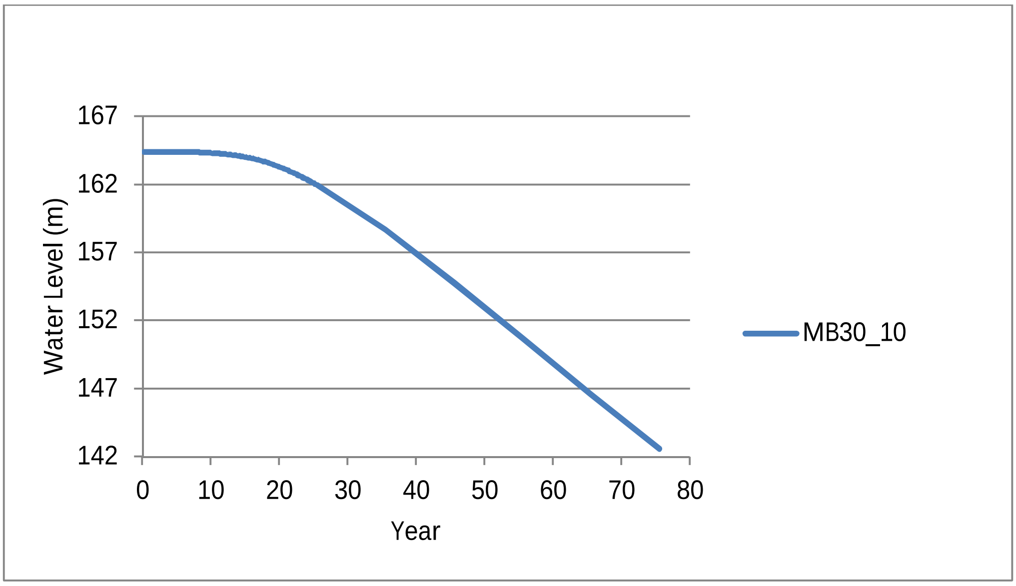

169
164
159
154
149
144
139
134
129
124
Water Level (m)
0
10
20
30
40
50
60
70
80
Year
MB29_ 7

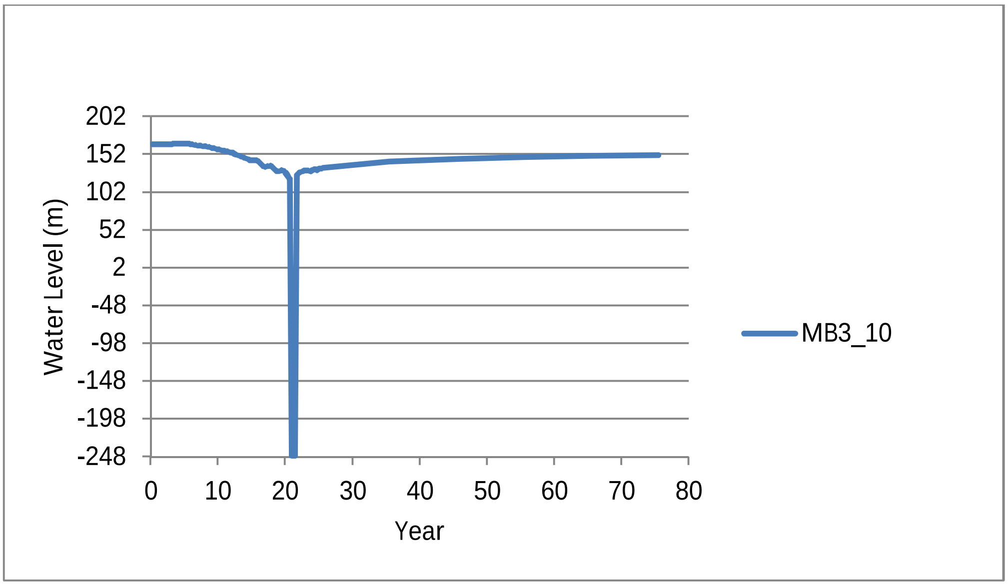

170
165
160
155
150
145
140
135
130
125
120
Water Level (m)
0
10
20
30
40
50
60
70
80
Year
MB29_ 8


170
165
160
155
150
145
140
135
130
125
120
Water Level (m)
0
10
20
30
40
50
60
70
80
Year
MB29_ 9

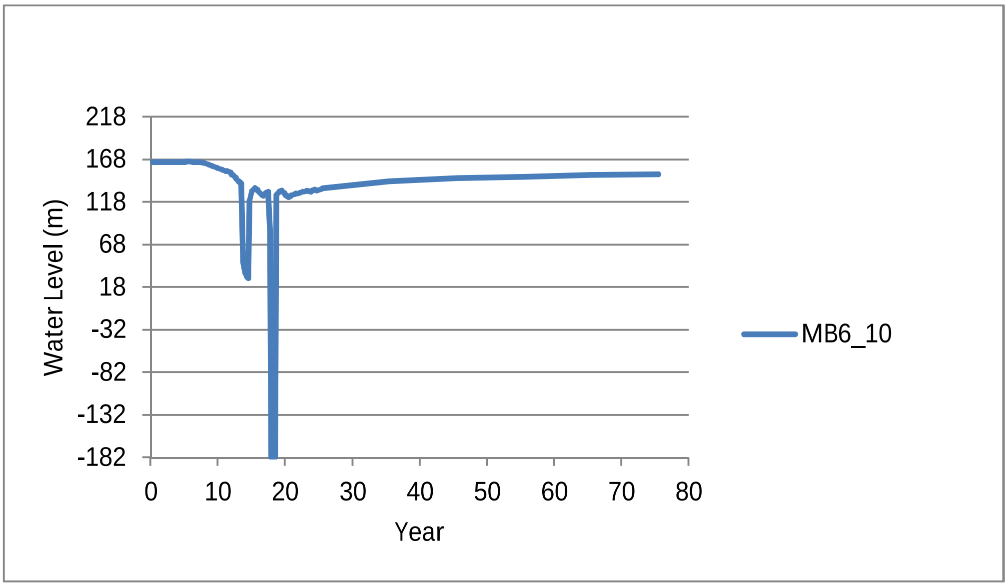

165
160
155
150
145
140
135
130
Water Level (m)
0
10
20
30
40
50
60
70
80
Year
MB29_10


166
161
156
151
146
141
136
Water Level (m)
0
10
20
30
40
50
60
70
80
Year
MB29_11

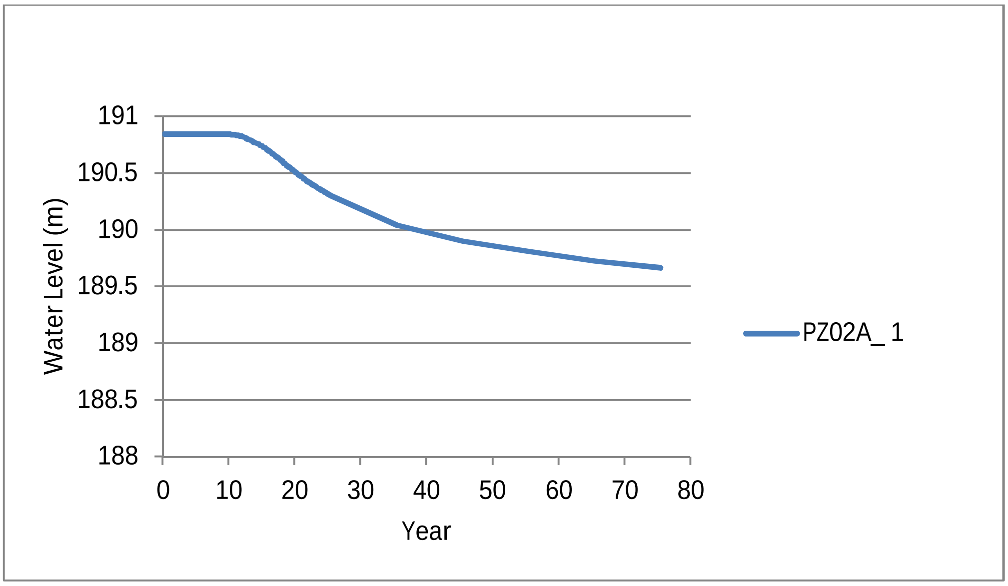

167
162
157
152
147
142
Water Level (m)
0
10
20
30
40
50
60
70
80
Year
MB30_10



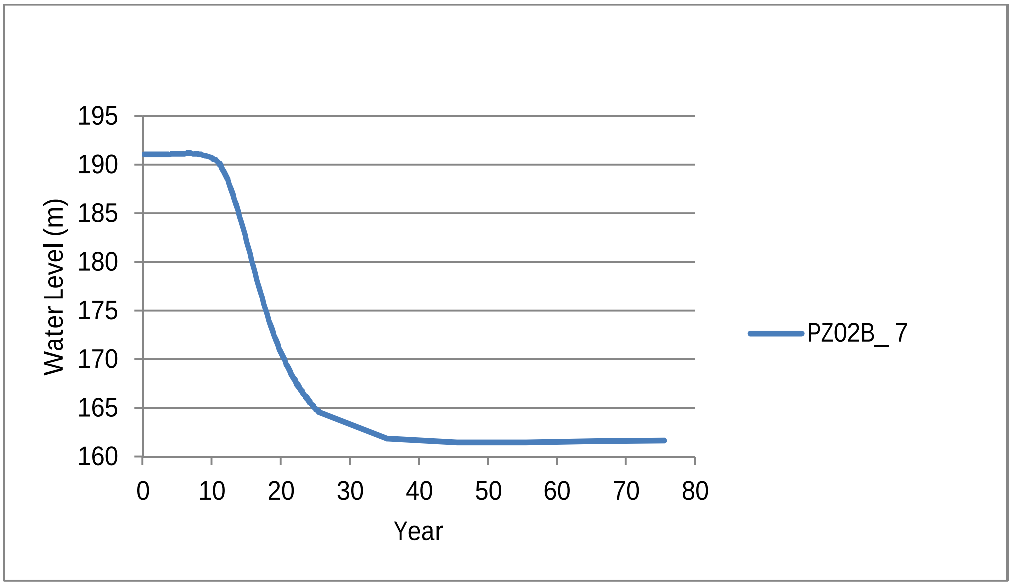
202
152
102
52
2
-48
-98
-148
-198
-248
Water Level (m)
0
10
20
30
40
50
60
70
80
Year
MB3_10

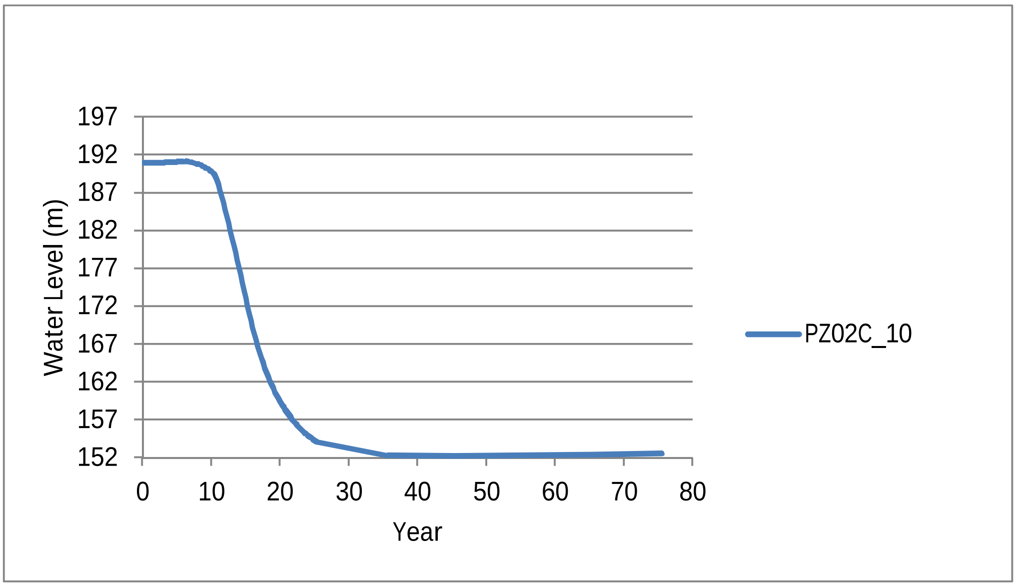


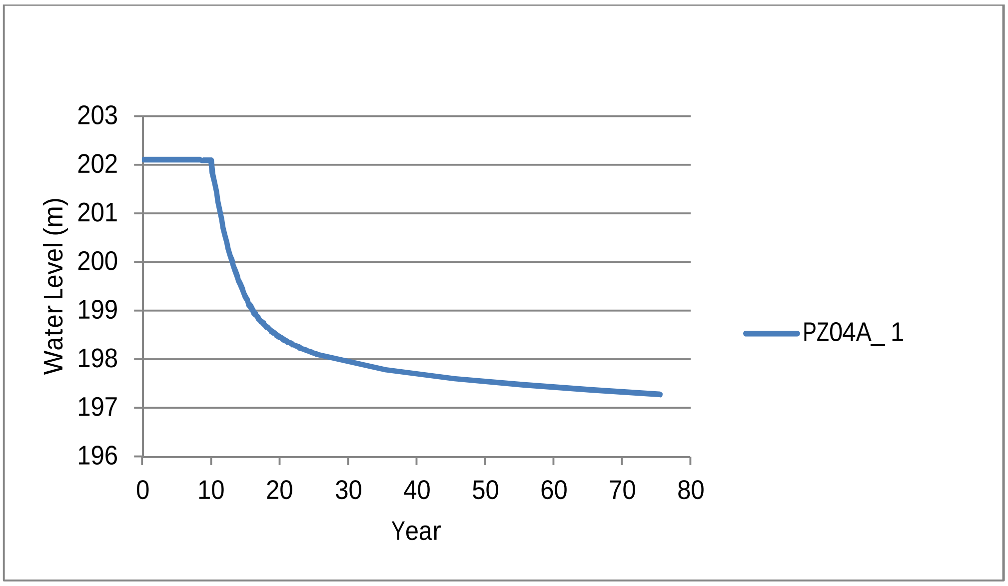
218
168
118
68
18
-32
-82
-132
-182
Water Level (m)
0
10
20
30
40
50
60
70
80
Year
MB6_10

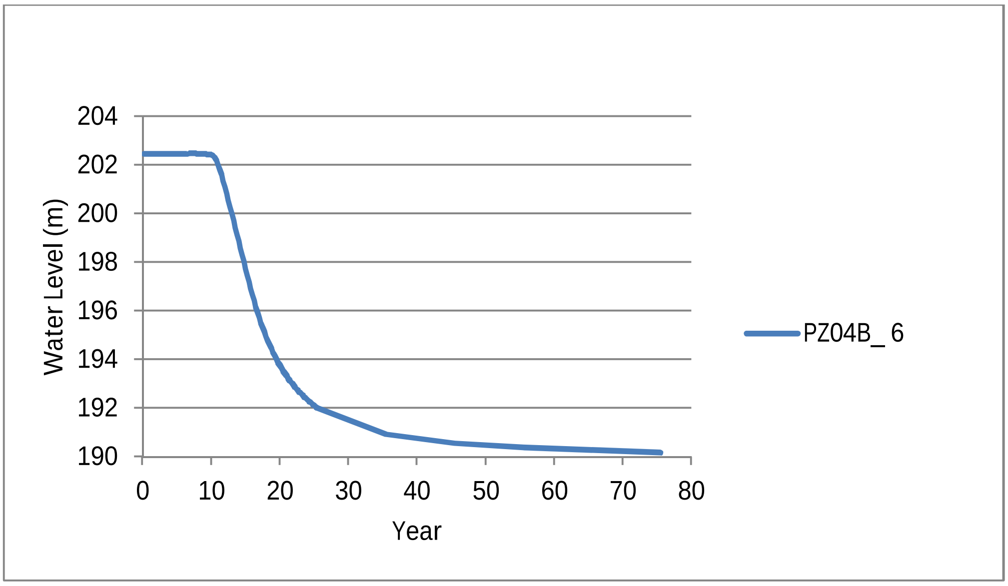


191
190.5
190
189.5
189
188.5
188
Water Level (m)
0
10
20
30
40
50
60
70
80
Year
PZ02A_ 1

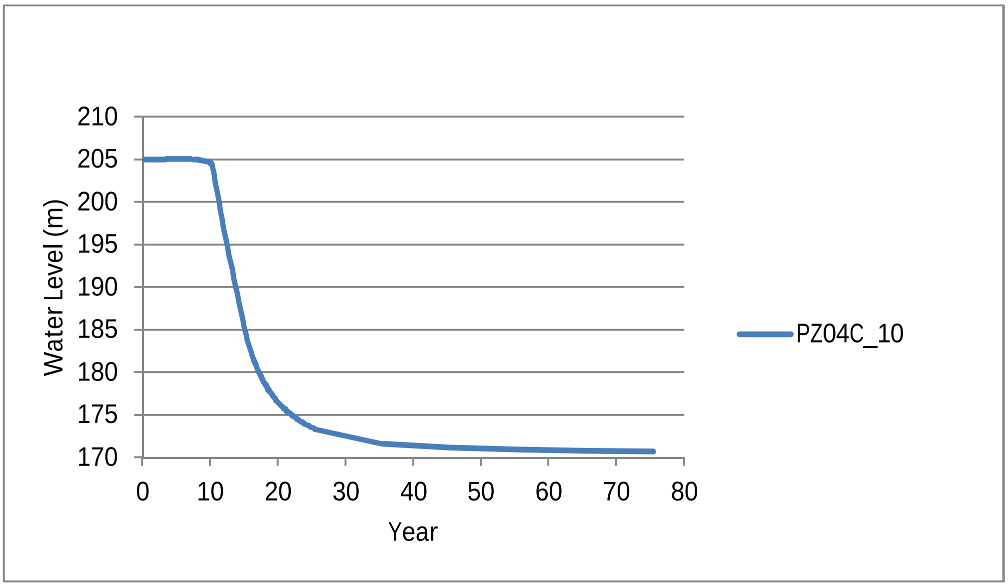

Water Level (m)
195
190
185
180
175
170
165
160
0
10
20
30
40
50
60
70
80
Year
PZ02B_ 7


Water Level (m)
197
192
187
182
177
172
167
162
157
152
0
10
20
30
40
50
60
70
80
Year
PZ02C_10

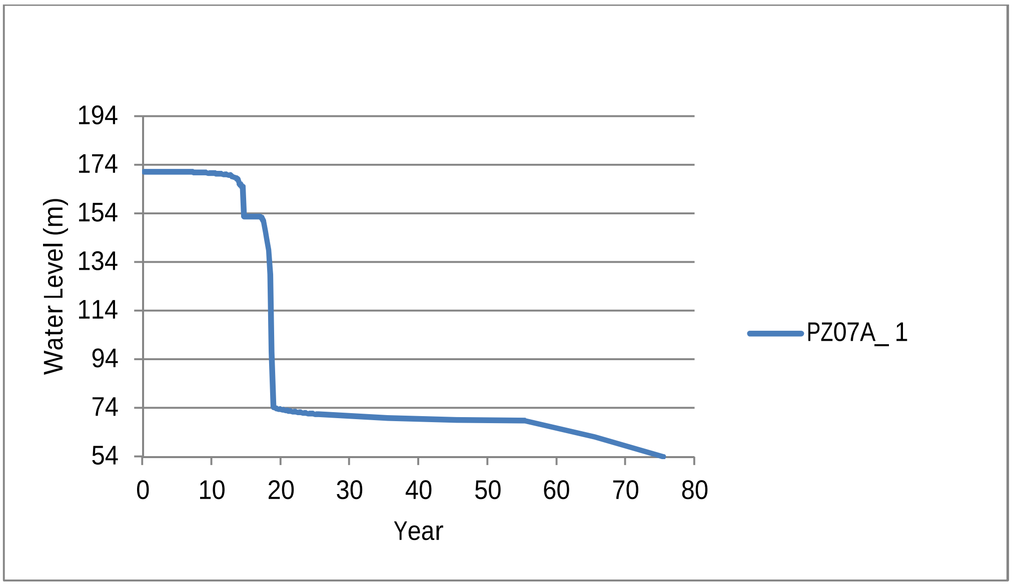

Water Level (m)
203
202
201
200
199
198
197
196
0
10
20
30
40
50
60
70
80
Year
PZ04A_ 1



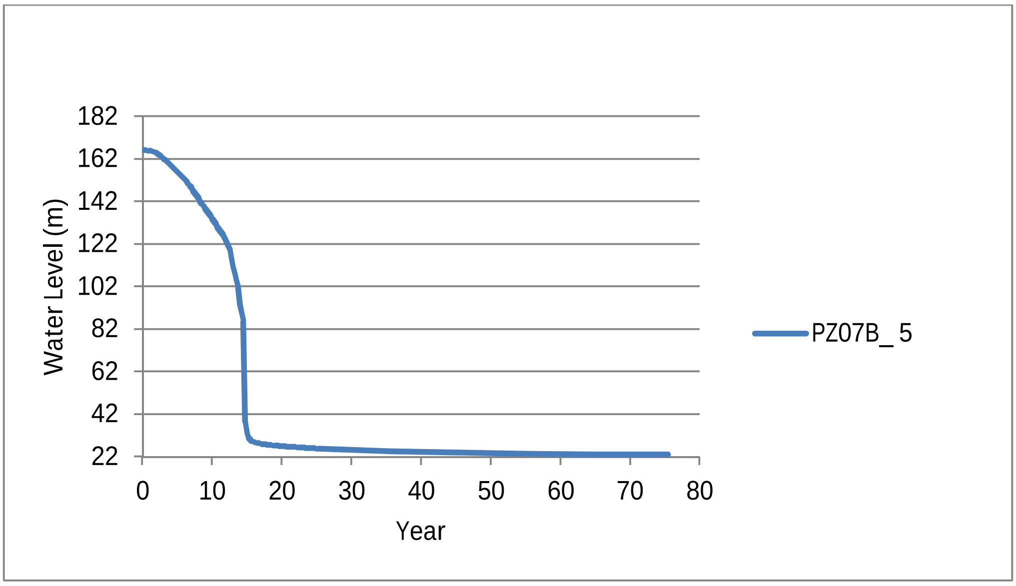
Water Level (m)
204
202
200
198
196
194
192
190
0
10
20
30
40
50
60
70
80
Year
PZ04B_ 6

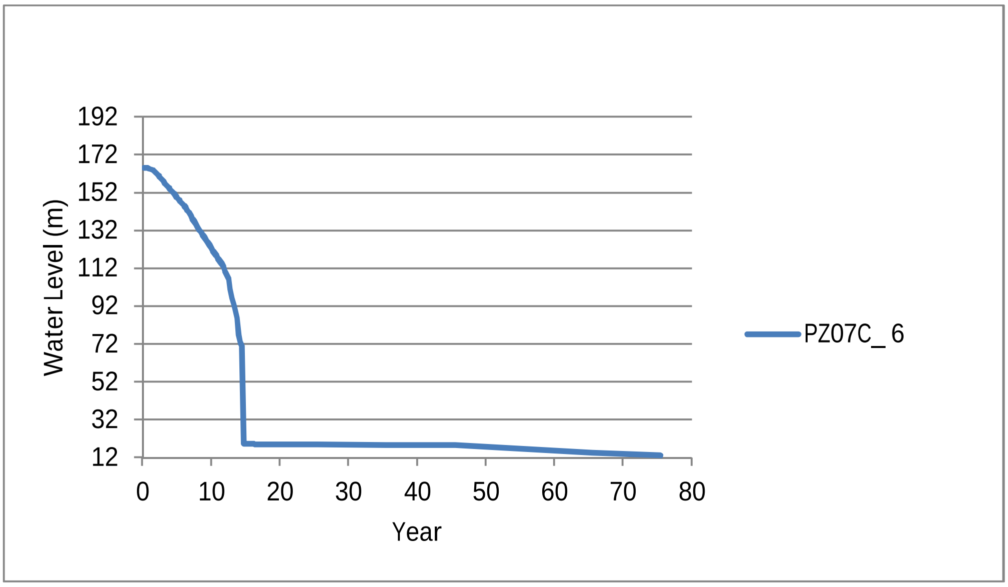


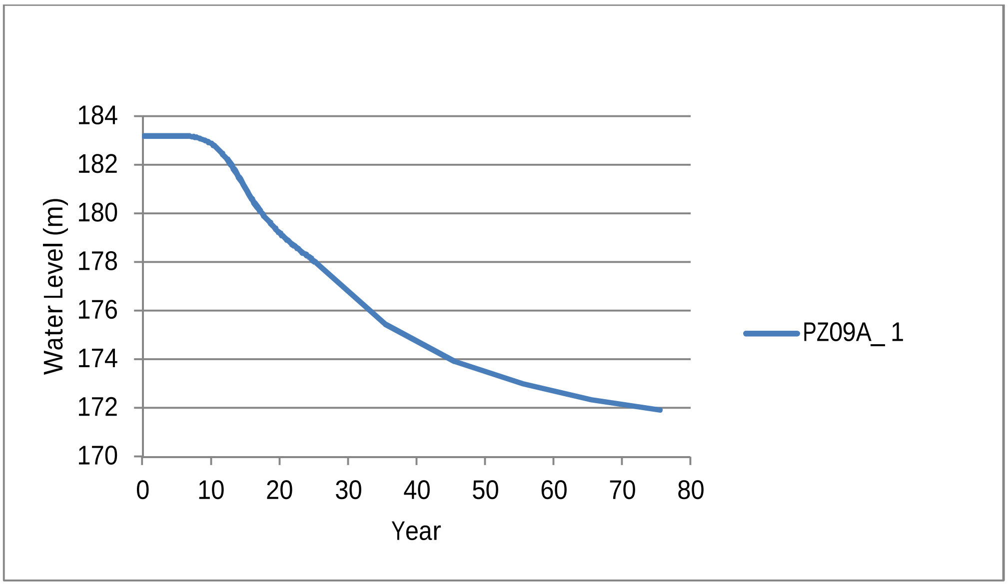
Water Level (m)
210
205
200
195
190
185
180
175
170
0
10
20
30
40
50
60
70
80
Year
PZ04C_10

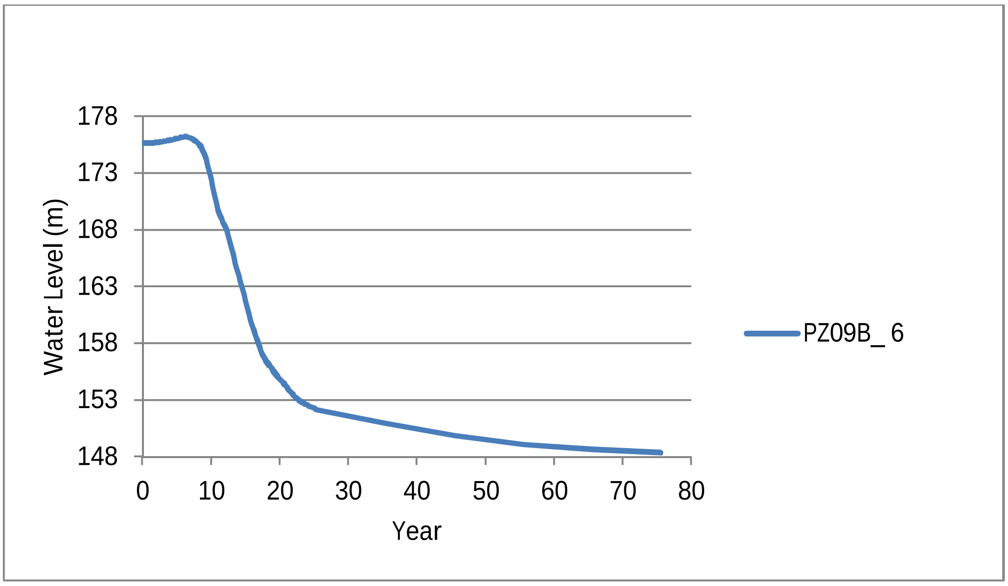


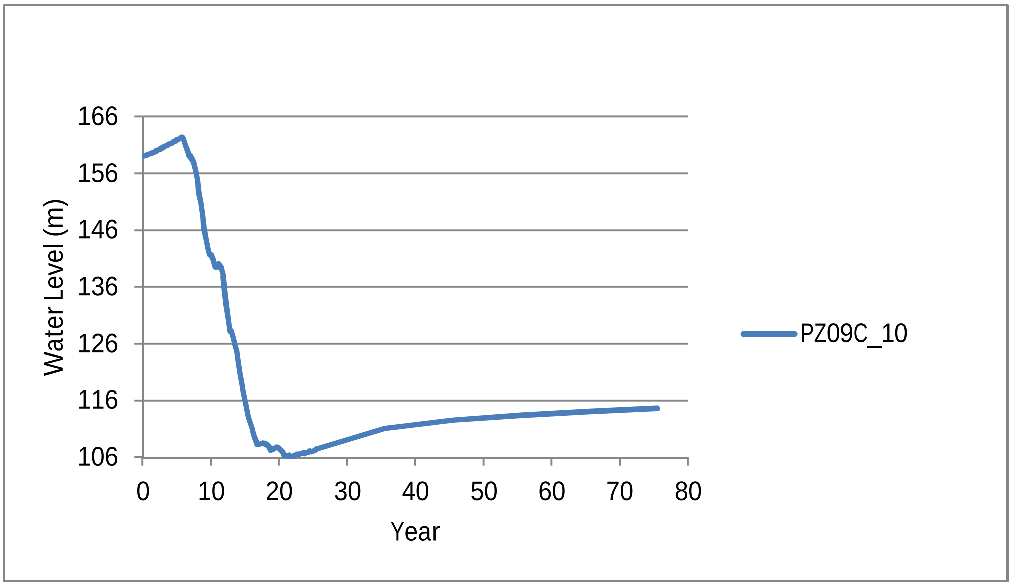
Water Level (m)
194
174
154
134
114
94
74
54
0
10
20
30
40
50
60
70
80
Year
PZ07A_ 1

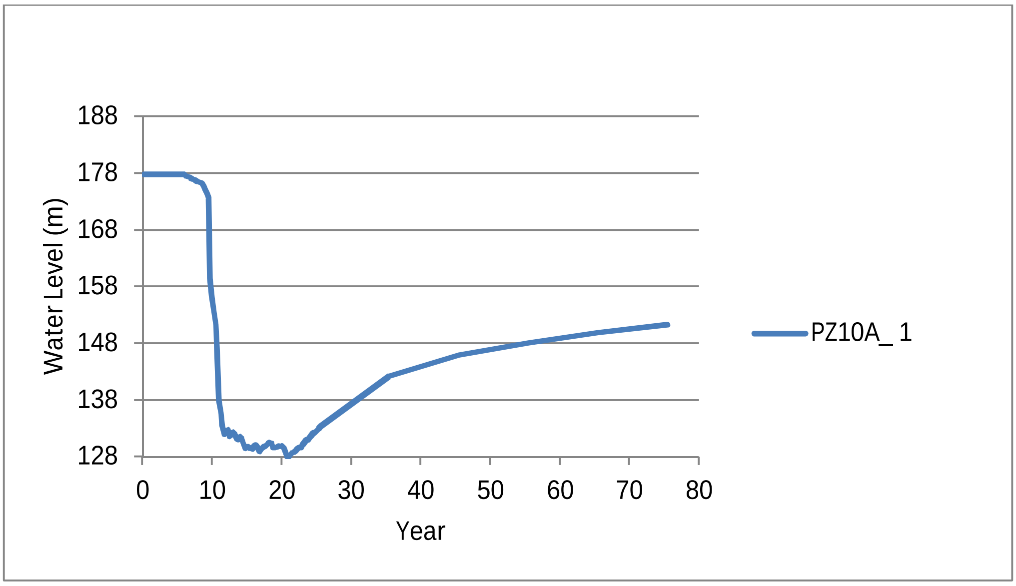

182
162
142
122
102
82
62
42
22
Water Level (m)
0 10 20 30 40 50 60 70 80
Year
PZ07B_ 5

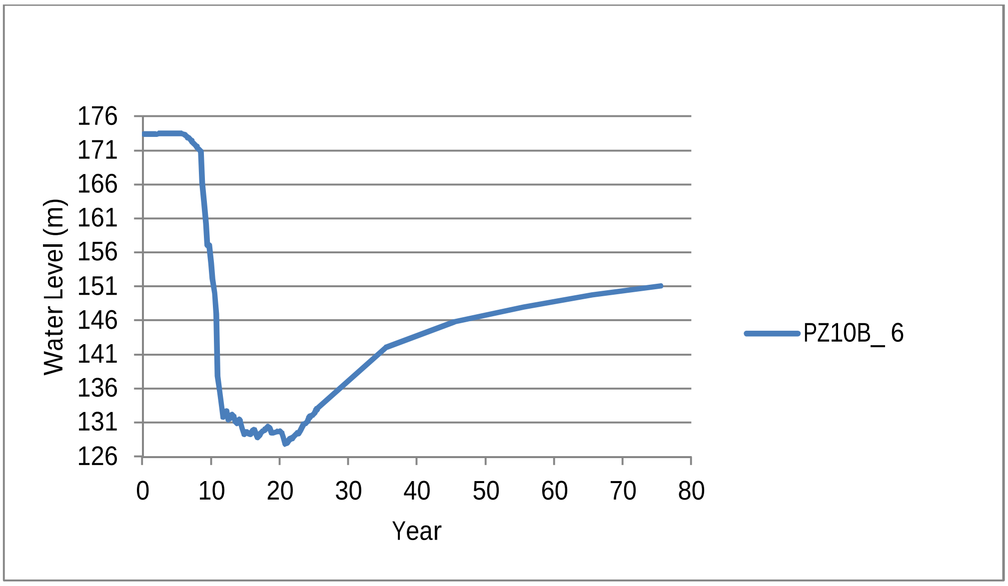

192
172
152
132
112
92
72
52
32
12
Water Level (m)
0 10 20 30 40 50 60 70 80
Year
PZ07C_ 6

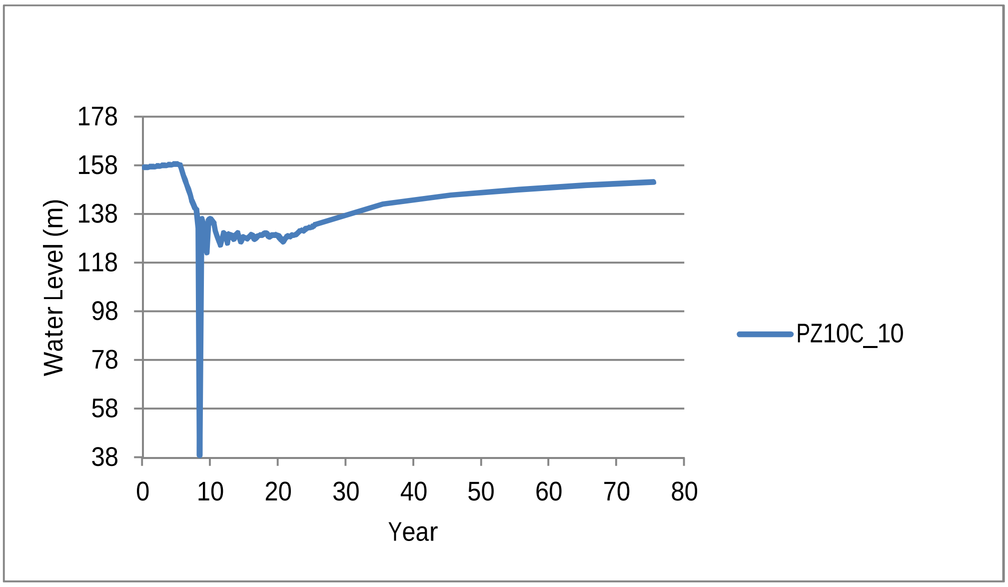

184
182
180
178
176
174
172
170
Water Level (m)
0 10 20 30 40 50 60 70 80
Year
PZ09A_ 1

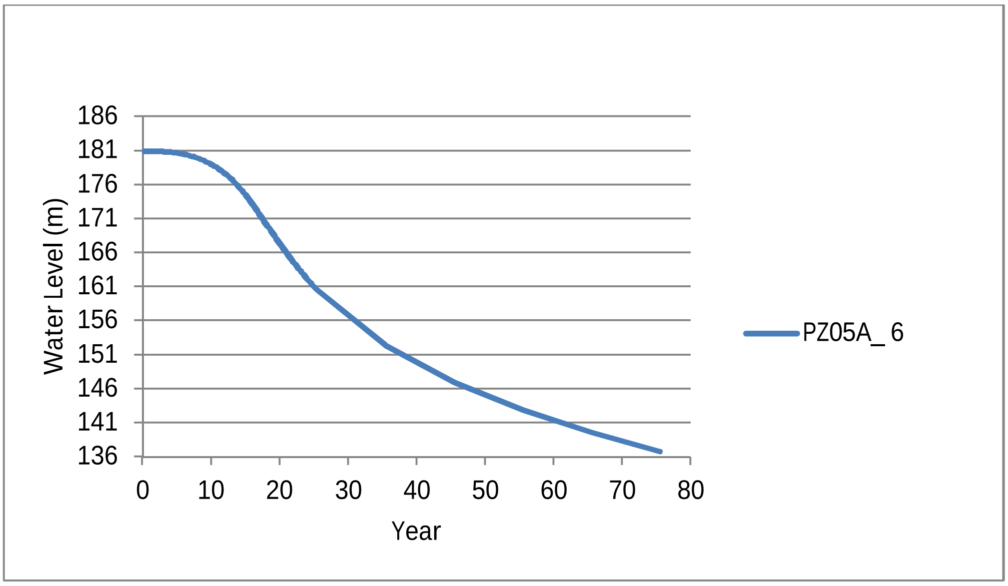

178
173
168
163
158
153
148
Water Level (m)
0
10
20
30
40
50
60
70
80
Year
PZ09B_ 6

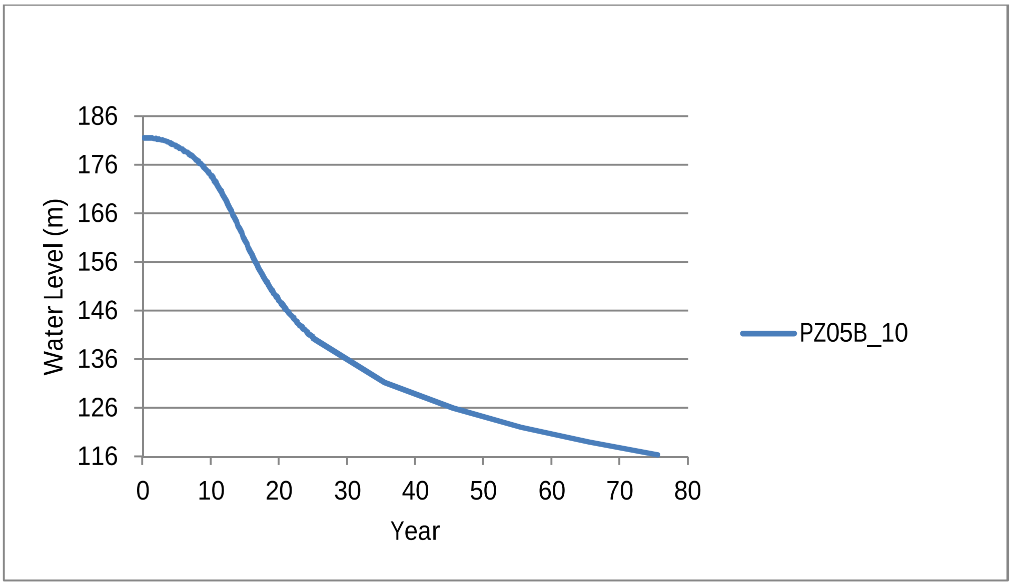

166
156
146
136
126
116
106
Water Level (m)
0
10
20
30
40
50
60
70
80
Year
PZ09C_10


188
178
168
158
148
138
128
Water Level (m)
0
10
20
30
40
50
60
70
80
Year
PZ10A_ 1

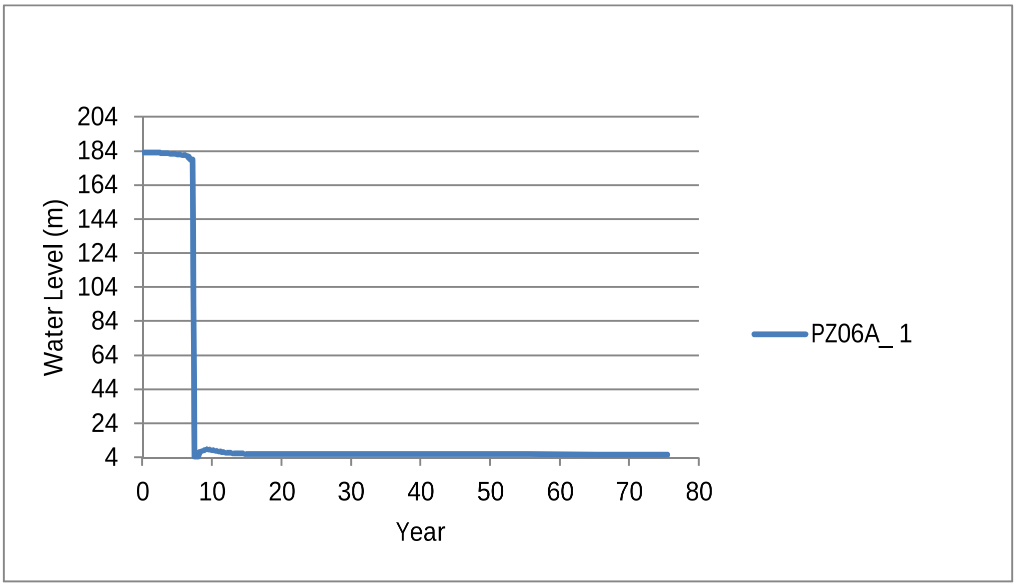

Water Level (m)
176
171
166
161
156
151
146
141
136
131
126
0
10
20
30
40
50
60
70
80
Year
PZ10B_ 6


Water Level (m)
178
158
138
118
98
78
58
38
0
10
20
30
40
50
60
70
80
Year
PZ10C_10

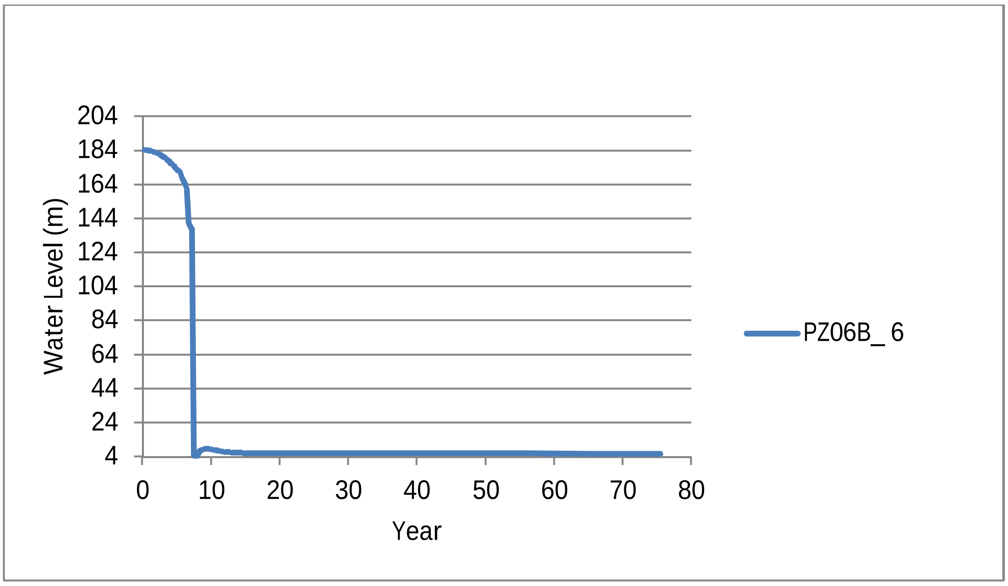

Water Level (m)
186
181
176
171
166
161
156
151
146
141
136
0
10
20
30
40
50
60
70
80
Year
PZ05A_ 6



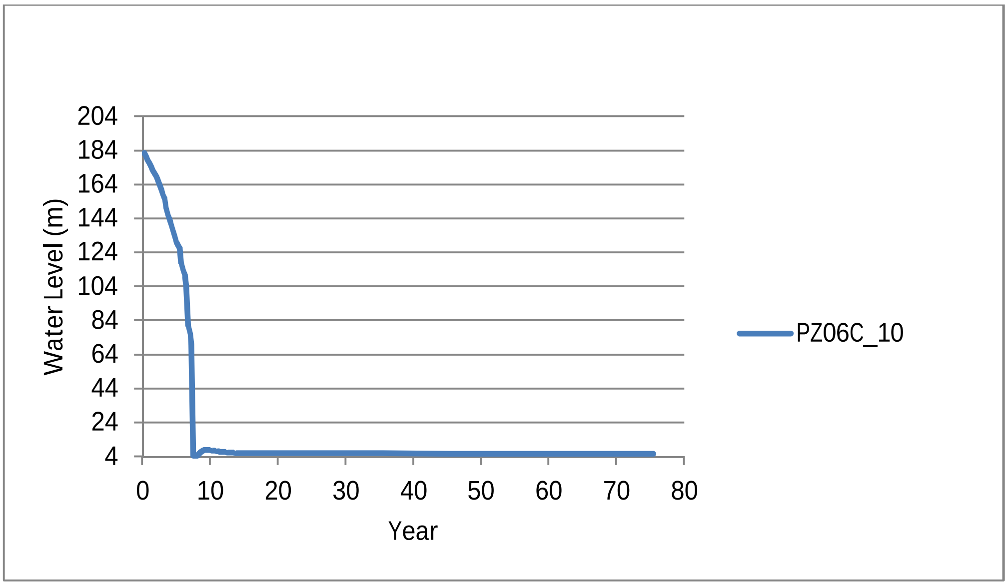
Water Level (m)
186
176
166
156
146
136
126
116
0
10
20
30
40
50
60
70
80
Year
PZ05B_10



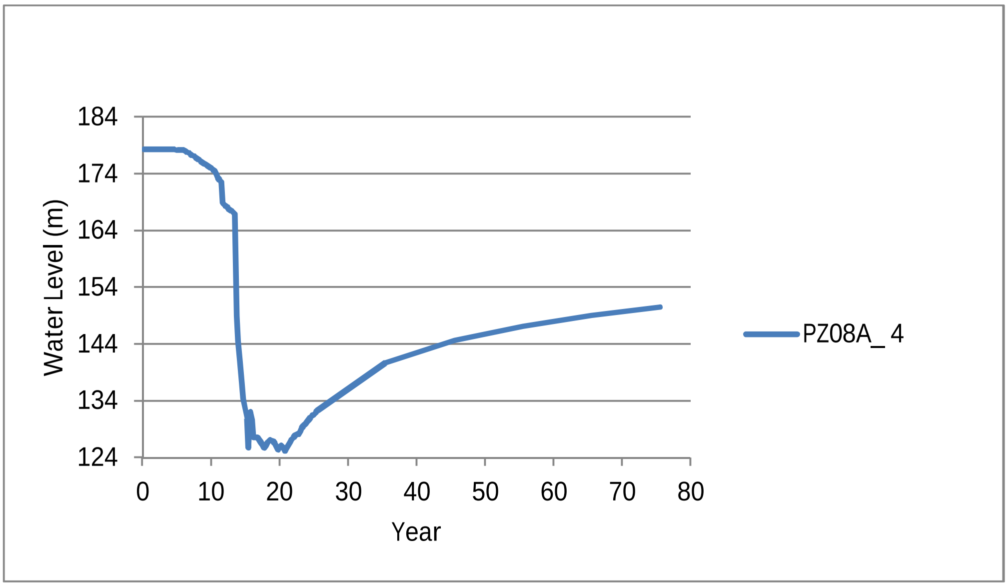
Water Level (m)
204
184
164
144
124
104
84
64
44
24
4
0
10
20
30
40
50
60
70
80
Year
PZ06A_ 1



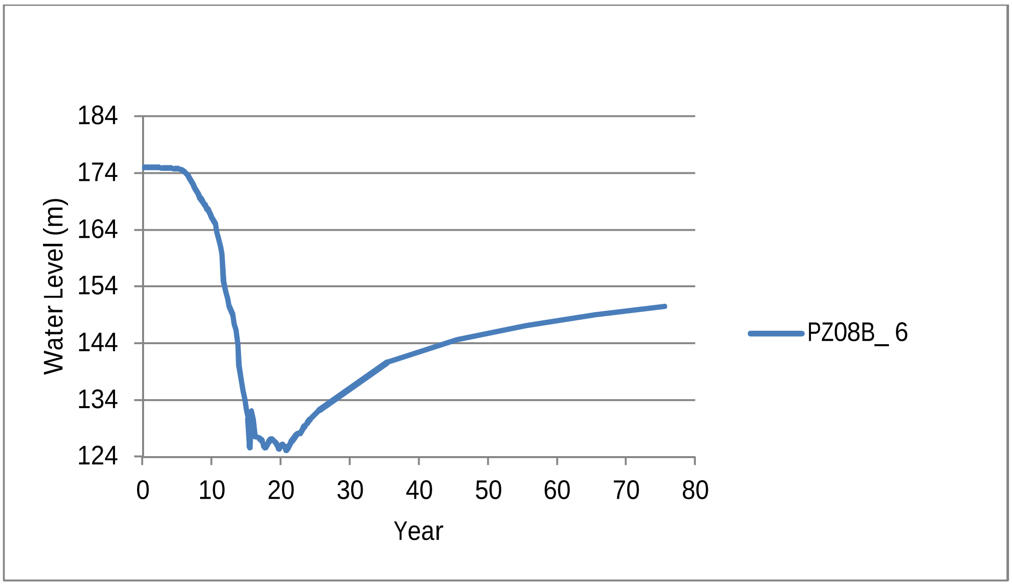
Water Level (m)
204
184
164
144
124
104
84
64
44
24
4
0
10
20
30
40
50
60
70
80
Year
PZ06B_ 6



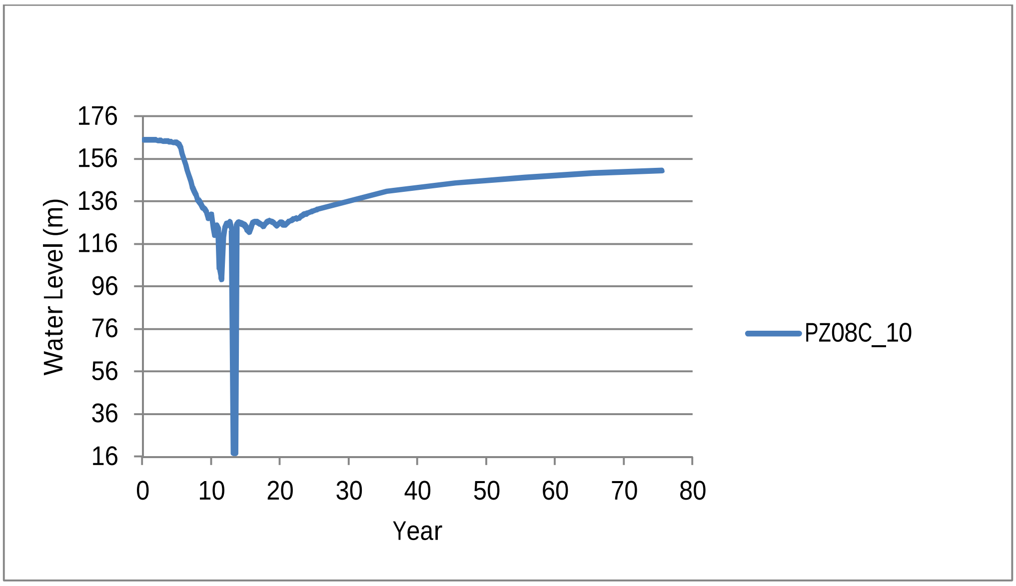
Water Level (m)
204
184
164
144
124
104
84
64
44
24
4
0
10
20
30
40
50
60
70
80
Year
PZ06C_10



Water Level (m)
184
174
164
154
144
134
124
0
10
20
30
40
50
60
70
80
Year
PZ08A_ 4



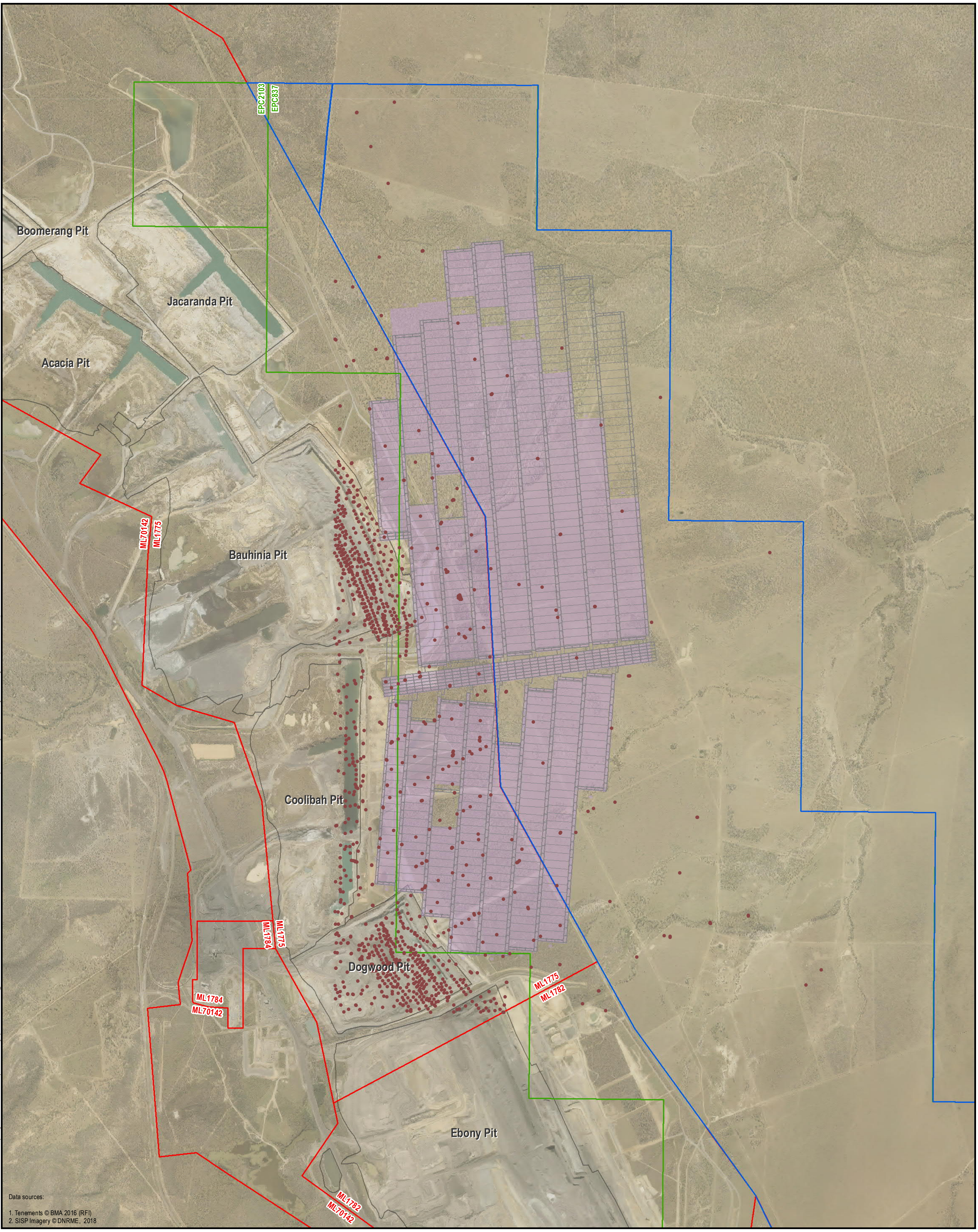
Water Level (m)
184
174
164
154
144
134
124
0
10
20
30
40
50
60
70
80
Year
PZ08B_ 6



Water Level (m)
176
156
136
116
96
76
56
36
16
0
10
20
30
40
50
60
70
80
Year
PZ08C_10

Appendix C

Exploration Holes



LEGEND

- Exploration Holes
- Underground layout (optimised)
- Underground layout (maximised)
- Existing Open-Cut Extent

Mining Tenement

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

N

Appendix C
Exploration Holes

Groundwater Technical Report
Saraji East Mining Lease Project

0 0.375 0.75 1.5
Kilometres

Scale: 1:63,360 (when printed at A4)

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

BHP

DATE: 21/02/2019 VERSION: 0

Appendix D

Mine Ingress Sensitivity

Model Year	Modified OC and UG (m^3/year)	Modified OC and UG +10% Recharge (m^3/year)	Modified OC and UG - 10% Recharge (m^3/year)
1	3.17E+06	3.17E+06	3.17E+06
2	2.03E+06	2.03E+06	2.03E+06
3	8.67E+05	8.66E+05	8.64E+05
4	9.36E+05	9.36E+05	9.33E+05
5	7.75E+05	7.75E+05	7.71E+05
6	2.55E+06	2.55E+06	2.54E+06
7	1.29E+06	1.29E+06	1.28E+06
8	1.23E+06	1.23E+06	1.22E+06
9	1.32E+06	1.32E+06	1.32E+06
10	1.61E+06	1.61E+06	1.61E+06
11	1.99E+06	1.99E+06	1.98E+06
12	1.53E+06	1.53E+06	1.52E+06
13	1.48E+06	1.49E+06	1.48E+06
14	1.54E+06	1.54E+06	1.53E+06
15	1.45E+06	1.45E+06	1.44E+06
16	1.28E+06	1.29E+06	1.28E+06
17	1.19E+06	1.20E+06	1.19E+06
18	1.17E+06	1.17E+06	1.16E+06
19	1.18E+06	1.18E+06	1.17E+06
20	1.25E+06	1.25E+06	1.24E+06
21	1.29E+06	1.30E+06	1.29E+06
22	1.14E+06	1.15E+06	1.13E+06
23	1.16E+06	1.16E+06	1.15E+06
24	1.15E+06	1.16E+06	1.14E+06
25	1.14E+06	1.15E+06	1.13E+06
TOTALS	**2.38E+07**	**2.38E+07**	**2.37E+07**

Note: OC = Open-Cut, UG = Underground