SARAJI EAST MINING LEASE PROJECT

Environmental Impact Statement

Chapter 9
Groundwater

Contents

Saraji East Mining Lease Project

9 Groundwater

9.1 Introduction

This chapter provides an assessment of the Project's likely impacts on groundwater resources. It includes an overview of the surrounding area's hydrogeological regimes, potential impacts of the Project and where necessary, actions to avoid minimise or mitigate these impacts. A detailed assessment is provided in **Appendix F-1 Groundwater Technical Report**.

For purposes of this chapter the Groundwater Assessment Area is defined as the groundwater model domain area, which extends approximately 15 kilometres (km) around the Project Site. This is illustrated in Figure 9-1.

LEGEND

- ● Locality
- Drainage
- Project Site
- 15km Buffer
- Highway
- Major Road

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Figure 9-1
Groundwater Assessment Area

Environmental Impact Statement
Saraji East Mining Lease Project

0 4.25 8.5 17
Kilometres

Scale: 1:962,924 (when printed at A4)

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

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9.2 Legislation and policy

9.2.1 Commonwealth Legislation

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 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 Environmental Impact Statement (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). Table 9.1 addresses the specific groundwater requirements of IESC (2015) within this chapter.

Table 9.1 IESC requirements

IESC Specific information needs – groundwater	Chapter Section
Description of the proposal	
A regional overview of the proposed Groundwater Assessment 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 9.4
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 9.2
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.	Section 9.1 and 9.5
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 9.2
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 9.4.1
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 9.4
Description of the likely recharge, discharge and flow pathways for all hydrogeological units likely to be impacted by the proposed development.	Section 9.4
Values for hydraulic parameters (e.g. vertical and horizontal hydraulic conductivity and storage characteristics) for each hydrogeological unit.	Section 9.4
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 9.4
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.	Section 9.3

IESC Specific information needs – groundwater	Chapter Section
Undertaken in accordance with the Australian Groundwater Modelling Guidelines, 2009), including peer review.	Section 9.3
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 9.3
Representations of each hydrogeological unit, the thickness, storage and hydraulic characteristics of each unit, and linkages between units, if any.	Section 9.3
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 9.3
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 9.5
Identification of the volumes of water predicted to be taken annually with an indication of the proportion supplied from each hydrogeological unit.	Section 9.5
An explanation of the model conceptualisation of the hydrogeological system or systems, including key assumptions and model limitations, with any consequences described.	Section 9.3
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 9.3
Sensitivity analysis of boundary conditions and hydraulic and storage parameters, and justification for the conditions applied in the final groundwater model.	Section 9.5 Appendix F-1
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.	Appendix F-1
A program for review and update of the models as more data and information become available, including reporting requirements.	Appendix F-1
Information on the time for maximum drawdown and post-development drawdown equilibrium to be reached.	Section 9.5.2
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 9.5

IESC Specific information needs – groundwater	Chapter Section
• 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 9.3
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 9.3
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.	Appendix F-1
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 9.5 and 9.7
Proposed mitigation and management actions for each significant impact identified, including any proposed mitigation or offset measures for long-term impacts post mining.	Section 9.6
Description and assessment of the adequacy of proposed measures to prevent/minimise impacts on water resources and water-dependent assets.	Section 9.6
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 9.4
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 9.6
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 9.6
Water quality monitoring complying with relevant National Water Quality Management Strategy (NWQMS) guidelines and relevant legislated state protocols.	Sections 9.6
Cumulative Impacts – context and conceptualisation	
Cumulative impact analysis with sufficient geographic and time boundaries to include all potentially significant water-related impacts.	Section 9.5
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 9.5

<table>
<tr><th>IESC Specific information needs – groundwater</th><th>Chapter Section</th></tr>
<tr><td colspan="2">Cumulative Impacts – impacts</td></tr>
<tr><td>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).</td><td>Section 9.5 and 9.7</td></tr>
<tr><td>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.</td><td>Section 9.5 and 9.7</td></tr>
<tr><td colspan="2">Cumulative Impacts – mitigation, monitoring and management</td></tr>
<tr><td>Identification of modifications or alternatives to avoid, minimise or mitigate potential cumulative impacts</td><td>Section 9.6</td></tr>
<tr><td>Identification of measures to detect and monitor cumulative impacts, pre and post development, and assess the success of mitigation strategies</td><td>Section 9.6</td></tr>
<tr><td>Identification of cumulative impact environmental objectives.</td><td>Section 9.6</td></tr>
<tr><td>Appropriate reporting mechanisms.</td><td>Section 9.6</td></tr>
<tr><td>Proposed adaptive management measures and management responses.</td><td>Section 9.6</td></tr>
</table>

9.2.2 State legislation

Water Act 2000

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 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.

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
- 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 an Underground Water Impact Report (UWIR) and associated consultation.

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.

BMA is applying for a new site-specific Environmental Authority (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.

9.2.3 Policies, plans and guidelines

Environmental Protection (Water and Wetland Biodiversity) Policy 2019

Under the EP Act, the Environmental Protection (Water and Wetland Biodiversity) Policy 2019 *(*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
- monitoring and reporting on the condition of Queensland waters
- provides monitoring and reporting guidelines for the condition of waters.

Groundwater environmental values relevant to the Project are presented in detail in Section 9.4 of this chapter.

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.

9.3 Methodology

Impacts to groundwater were assessed by means of a predictive groundwater model which was developed based on a conceptualisation of the existing geology and groundwater resources.

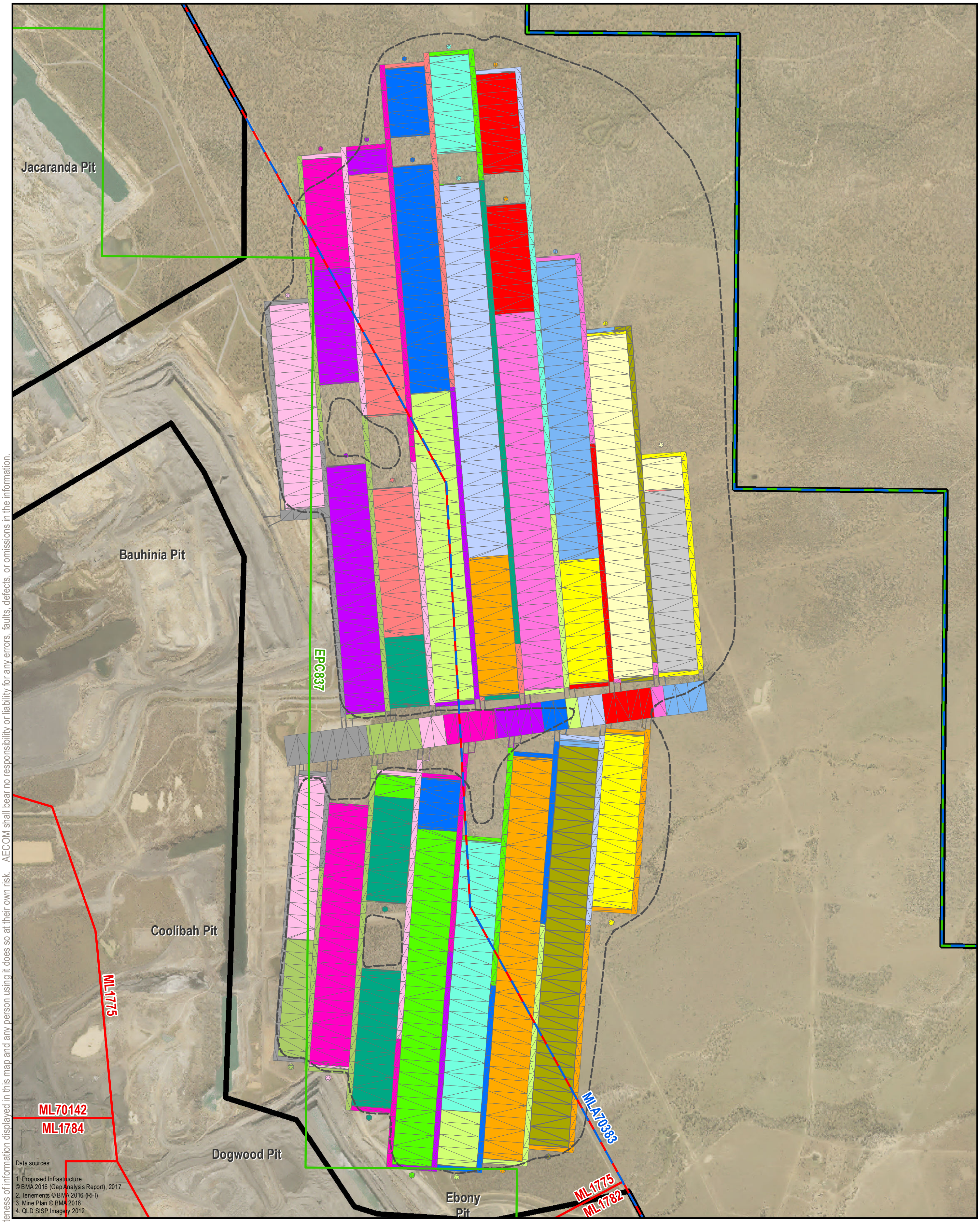
9.3.1 Mine plan assessment

This chapter assesses the potential environmental impacts to groundwater associated with the optimised underground layout. The optimised mine plan for the Project is shown in Figure 9-2. The assessment is informed by groundwater modelling undertaken based on a maximised underground layout which relates to the maximum limit of predicted subsidence (shown in Figure 9-2). It is considered that this approach provides a conservative assessment of the largest potential impacts of mining on 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 9-3), 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. In areas where there are both open-cut mining and underground mining proposed, the sections of open-cut have been removed and replaced by underground mining only.



LEGEND

- Project Site
- Exploration Permit Coal (EPC)
- Mining Lease (ML)
- Mining Lease Application (MLA)
- Limit Of Subsidence

Optimised Mine Plan

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

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Figure 9-2
Mine Plan

Environmental Impact Statement
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)

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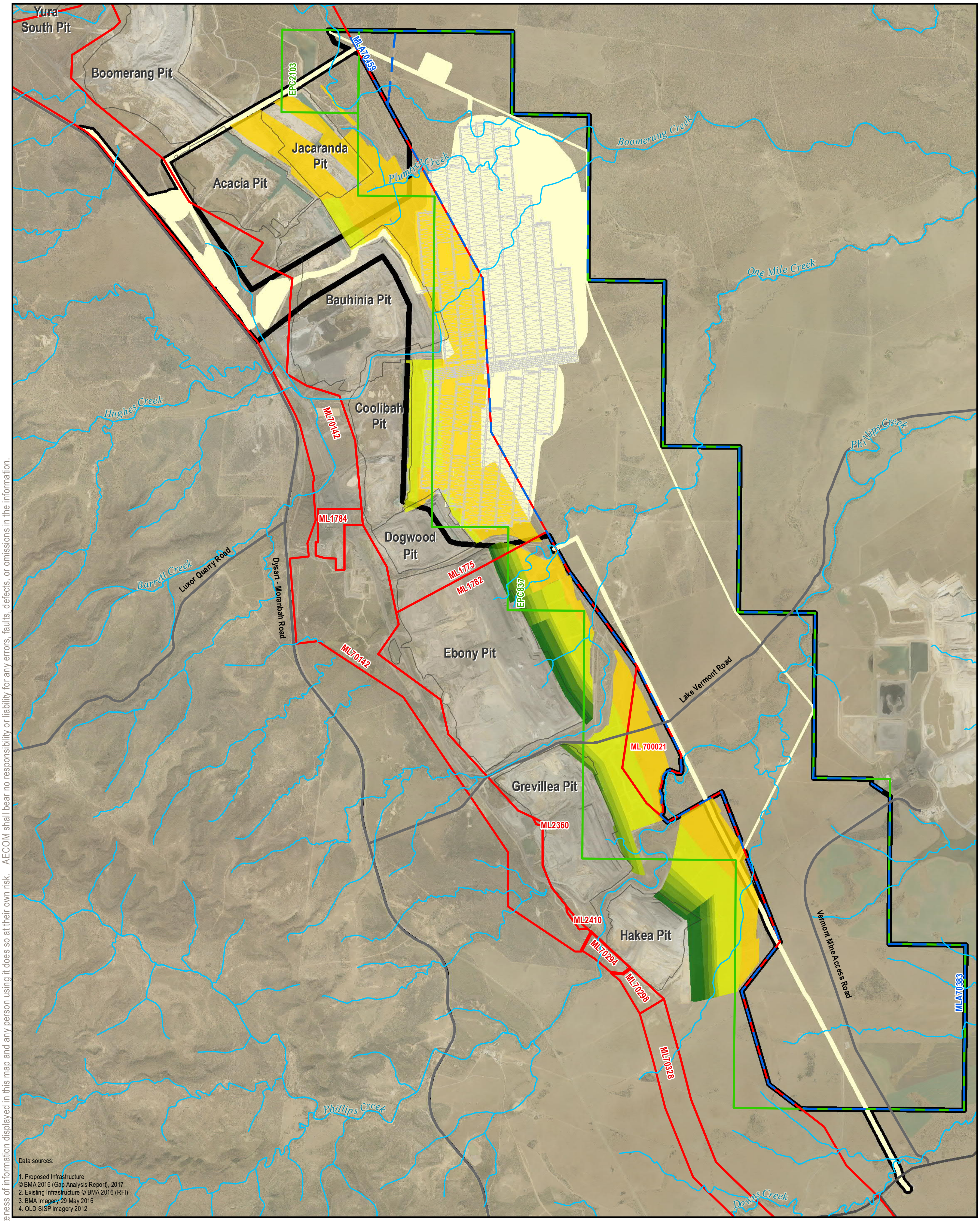

LEGEND

- Project Site
- Project Footprint
- Exploration Permit Coal (EPC)
- Mining Lease (ML)
- Mining Lease Application (MLA)
- Underground layout (optimised)
- Existing Open-Cut Extent
- Public Road

Conceptual Mine Plan

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

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Figure 9-3
Approved Saraji Open-cut Mine Plan

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Saraji East Mining Lease Project

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Kilometres

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

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

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9.3.2 Hydrogeological understanding

The hydrogeological understanding of the Groundwater Assessment Area was determined from a combination of previous groundwater investigations, data from the existing monitoring network, exploration drilling and information held by the Department of Natural Resources, Mines and Energy (DNRME).

Three aquifers are present within the Groundwater Assessment Area. These aquifers are associated with the following geological strata:

- quaternary alluvium
- Tertiary Sediments
- coal seams contained with the Permian Coal Measures.

Overburden and interburden material within the Permian Coal Measures are considered to act as aquitards.

9.3.3 Hydrogeological conceptualisation

The conceptualisation indicated that there are two separate groundwater systems within the Groundwater Assessment Area; these aquifer systems are associated with the following geological units:

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

Key understandings from the hydrogeological conceptualisation included the following:

- there are differences in groundwater levels measured in the Tertiary and deeper permian aquifers which indicates that there is limited hydraulic connection between these groundwater systems.
- recharge occurs from infiltration from rainfall and creek flows 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 steeper gradients around the pits.

9.3.4 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 (model Layer 10), Harrow Creek coal seam (model Layer 6) and overlying Tertiary and Quaternary sediment (model Layer 1) was undertaken.

All model predictions of underground mining impacts also included simulation of the approved Saraji Mine open-cut operations (including the Grevillea Pit extension on ML 70021).

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 (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 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 the existing Saraji Mine
- the prediction of groundwater ingress into the existing 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.

Groundwater level drawdown

Initial (2016) groundwater levels were established throughout the model domain from the model calibration (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 model, backfilling of the open-cut pits was simulated to occur after one year, allowing for the change in model layer parameters.

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.

Bore trigger thresholds

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

9.3.5 Model boundaries

The eastern model boundary is roughly coincident with the Isaac River alignment. 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 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 were selected sufficiently far from the approved and planned underground and open-cut mining areas so as not to markedly influence model predictions.

9.4 Description of environmental values

9.4.1 Geology

The description of the existing geology with particular relevance to groundwater is summarised below.

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 stratigraphic sequence in the Groundwater Assessment Area comprises the following:

- middle permian back creek group (basement)
- late permian blackwater group Sediments (and coal measures)
- Tertiary Sediments
- unconsolidated Quaternary alluvium Sediments.

Table 9.2 summarises the stratigraphy of the Project Site and surrounds.

The surface geology for the Groundwater Assessment Area is shown in Figure 9-4 and the basement geology in Figure 9-5.

The location of mapped faults and structures within and surrounding the Project Site are shown in Figure 9-5.

Figure 9-5 shows that faults in the Groundwater Assessment 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.

Figure 9-4
Surface Geology
(1:100,000)

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Environmental Assessment Report

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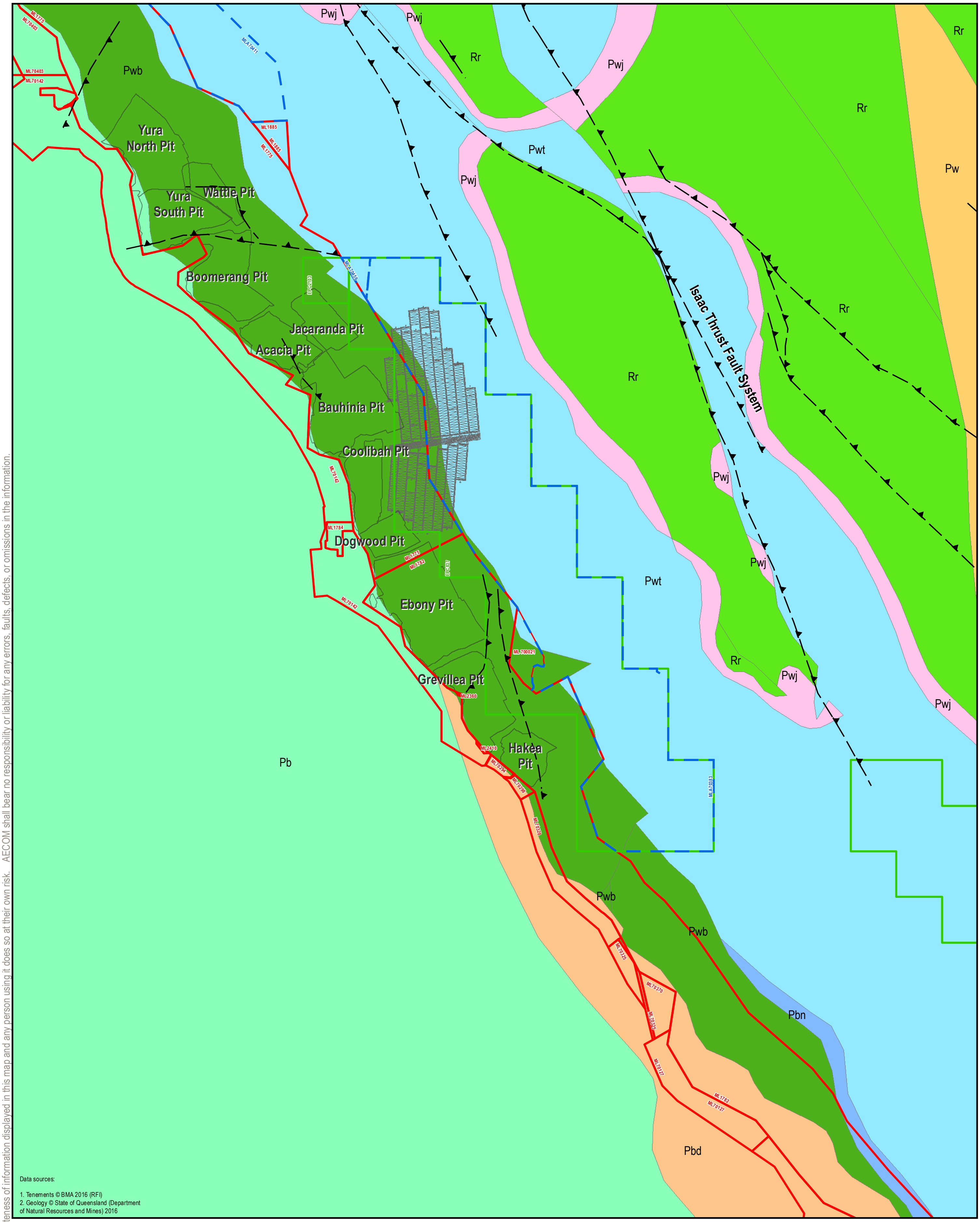

LEGEND

Fault
Underground layout (optimised)
Existing Open-Cut Extent

Mining Tenement
- Exploration Permit Coal (EPC)
- 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

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Figure 9-5
Basement Geology
(1:500,000)

Environmental Impact Statement
Environmental Assessment Report

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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Table 9.2 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 Groundwater Assessment 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 Groundwater Assessment Area. Outcrops west of Saraji Mine and extends under mined areas to the east

9.4.2 Groundwater resources

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 Groundwater Assessment Area. These aquifers and aquitards are likely to be in hydraulic connection to the Project and are therefore sensitive to the Project's groundwater-affecting activities. The aquitards are 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.

Groundwater supply is not considered to be a major water source in the Groundwater Assessment Area. Based on a review of available data, the beneficial use of groundwater in the Groundwater Assessment Area is considered to be low due to low sustainable yields and poor groundwater quality.

Figure 9-6 provides an illustration of the bores within the Groundwater Assessment Area.

These following sections detail the physical and chemical characteristics of these aquifers within the context of the prevailing regional hydrogeological regime.

Quaternary alluvium

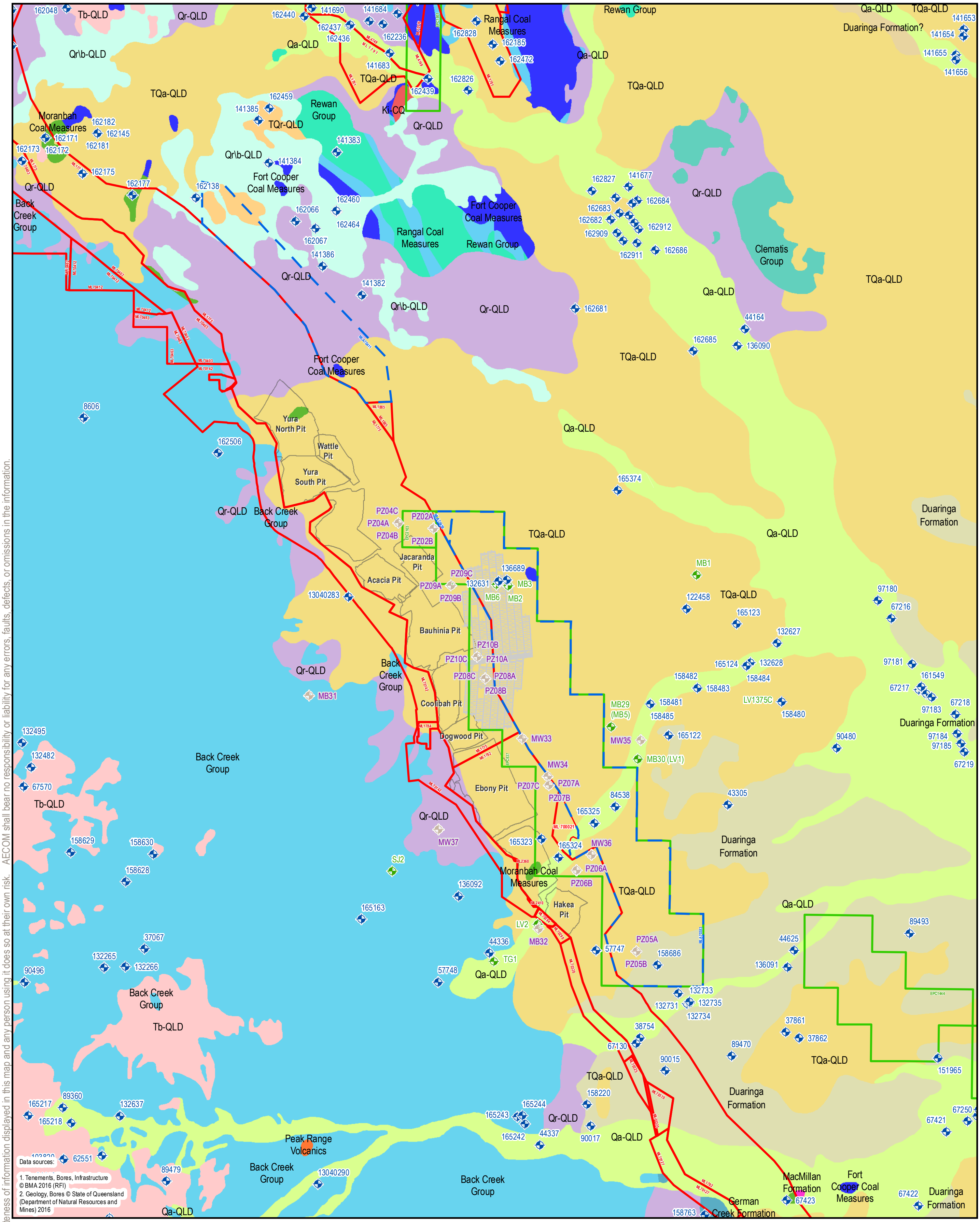
Occurrence

Quaternary alluvium is not mapped within the footprint of the proposed underground mine (Figure 9-4). 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 in close proximity to 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 9-6), has been reported to contain water during groundwater monitoring events.



LEGEND

- Saraji Monitoring Bores
- Registered Bore
- Census Bore
- Underground layout (optimised)
- Existing Open-Cut Extent
- Exploration Permit Coal (EPC)
- 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)
- Tb-QLD (Tb)

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Figure 9-6
Groundwater Bores

Environmental Impact Statement
Saraji East Mining Lease Project

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Kilometres

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

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

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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.

Hydraulic parameters

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

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

No site-specific aquifer data was obtained during previous groundwater investigations for the existing 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).

Tertiary Sediments

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 the existing 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 Groundwater Assessment Area between 13 m and 35 m (Australasian Groundwater and Environmental Consultants (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 Groundwater Assessment 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.

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.

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).

Permian Sediments

Occurrence

Permian Sediments in the Groundwater Assessment Area include the Fort Cooper Coal Measures (FCCM) and Moranbah Coal Measure (MCM). While the Permian Sediments do not outcrop in the underground mining footprint, they subcrop under the Tertiary Sediments. Figure 9-5 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).

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 vibrating wire piezometers (VWPs) constructed in the FCCM (JBT, 2014) that the interburden units which over- and under-lie the coal seams act as effective aquitards. These aquitards have very low vertical hydraulic conductivity resulting in marked differences in piezometeric pressures between the different coal seams and interburden (i.e. a 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.

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 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).

Hydraulic parameters

Rising head permeability tests were undertaken by AGE (2011) at groundwater monitoring bores PZ02B&C, PZ04B&C, PZ07B, PZ09B, and PZ10B&C.

The coal seam aquifers within the Groundwater Assessment 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.

Packer tests performed across Permian interburden indicated that they 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).

9.4.3 Groundwater levels and flows

Quaternary groundwater levels

Ten bores were reported to intersect Quaternary alluvium. Groundwater level data was limited due to the seasonal nature of the alluvium. For this unit, available data included:

- 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 identified during a bore census. This bore is located upstream of the Saraji Mine on Phillips Creek (Figure 9-6). The available groundwater level data for MB32 shows fluctuations over an approximately 7 m range. Groundwater levels within MB32 do not correlate with the cumulative rainfall deviation 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.

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 Groundwater Assessment Area. 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 (mbGL).

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

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 metres Australian Height Datum (mAHD) in the north-west to around 170 mAHD in the south-east across the Groundwater Assessment Area. This is similar to the regional groundwater contours generated for the Permian coal seams across the entire Bowen Basin.

The regional groundwater flow pattern across the Groundwater Assessment 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.

Permian groundwater levels indicate no marked seasonal fluctuation (response to dry and wet seasons) and no influence of mining (even though the mining at the existing Saraji Mine has been operating since 1974).

Dewatering from existing mining

Those monitoring bores which contain several years of monitoring data (MB31 to MB37) do not indicate any decline or downward trend in groundwater levels despite some bores being located within close vicinity (and down dip) to existing open-cut pits, (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.

9.4.4 Groundwater quality

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 Groundwater Assessment Area. Groundwater associated with the alluvium is generally brackish and bicarbonate dominant.

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

Tertiary Sediments

The Tertiary groundwater ranges from slightly acidic to slightly alkaline and is dominated by sodium and chloride with TDS in excess of 6,000 milligrams per litre (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 the available Tertiary monitoring bores contain insufficient groundwater to collect additional samples.

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.

The analyses indicated that the Permian coal seam groundwater range 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.

Seven monitoring bores (MB31 to MB37) form part of the existing Saraji Mine 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).

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

- bores mb33 and mb34 had the highest salinities, with electrical conductivity (ec) of 23,000 microsiemens per centimetre (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 occurred 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 had tds concentrations greater than 500 mg/l which exceeds the drinking water guideline
- sulphate concentrations in mb31, mb33, and mb37 were greater than the cattle stock watering guideline (1,000 mg/l)
- total metals in groundwater samples were less than the australia and new zealand environment and conservation council (anzecc) stock water guidelines
- concentrations of nitrate were all below guideline values
- orthophosphate (reactive phosphate) concentrations were highest in mb31, a bore located within farming land up gradient of saraji mine
- low levels of hydrocarbons were 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.

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 cattle, this TDS limit is in 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.

9.4.5 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.

The National Atlas of GDE (GDE Atlas) was consulted to identify whether GDEs have been mapped within the area. 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). 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.

The assessment concluded that there is a low potential for aquatic, terrestrial and subterranean GDEs within or in the vicinity of the Project Site.

9.4.6 Groundwater environmental values

The EPP (Water) identifies environmental values of groundwater to be protected or enhanced in Queensland. The existing groundwater environment has been assessed against these environmental values in Table 9.3.

Table 9.3 Environmental values for groundwater

Environmental value	Relevance to the Project Site
Aquatic ecosystems	There is no known aquatic, terrestrial or subterranean GDEs that have been identified within the Groundwater Assessment 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.
Irrigation	Section 4.2.4 of the ANZEEC 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 Groundwater Assessment Area also suggests that groundwater is not useable as a source of irrigation water.
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.
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 ANZEEC 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 the variable salinity levels for groundwater hosted in the Tertiary and Permian aquifers are within this range and there are some cases greater than 10,000 mg/L, the regional groundwater would generally not be considered suitable for livestock.
Primary recreation	This category of environmental value is considered not applicable to groundwater in-situ. There are also no registered groundwater springs in the Groundwater Assessment 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 Groundwater Assessment Area.
Drinking water supply	The suitability of water for human consumption is defined in the Australian Drinking Water Guidelines (NHMRC and NRMMC, 2011). The groundwater quality data indicates that groundwater is unsuitable for human consumption before treatment due to elevated levels of salinity. Groundwater resources within the Groundwater Assessment 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.
Cultural and spiritual values	There are no registered groundwater springs or seeps that supply surface water bodies in the Groundwater Assessment Area.

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 is sporadic and seasonal and is not considered to provide sufficient (sustainable supply) in the Groundwater Assessment Area to allow for evaluation.

The only recognised groundwater environmental value to be enhanced or protected within the Groundwater Assessment Area is stock watering.

9.5 Potential impacts

9.5.1 Overview

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, therefore no additional groundwater impacts are envisaged during construction.

Operational phase

The principal activities during the operational phase of the Project which may impact groundwater resources would occur during extraction of the optimised underground mine layout and include:

- dewatering of workings
- alteration of geology, and associated aquifer hydraulic properties, due to goaf formation
- the cumulative drawdown of open-cut mining along strike, with the extended down-dip underground mining (portal construction and 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 9-11), have been considered.

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, the Project has the potential to increase the frequency or length of no flow periods within the creek during operation.

Post closure

It is considered that on completion of the proposed underground workings, the existing 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.

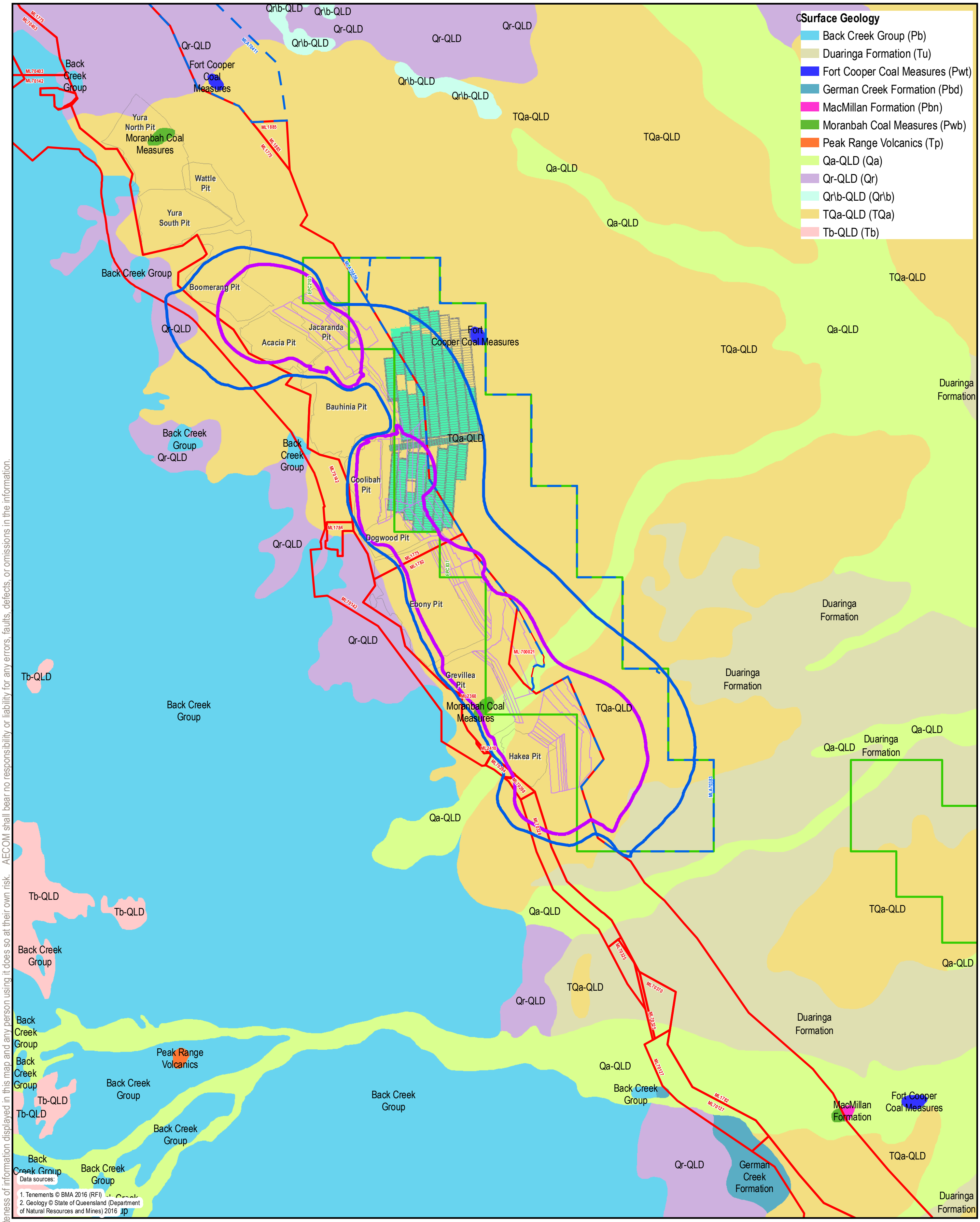
Final voids can gradually fill with water once dewatering operations have ceased. Potential evaporation losses from the voids are considered to exceed predicted groundwater inflow and hence the voids are expected to remain mainly dry, except following prolonged heavy rainfall events. In this case, ongoing 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 Groundwater Assessment Area but not to pre-mining levels across the Groundwater Assessment Area due to final voids.

9.5.2 End of mining drawdown

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 9-7
- Layer 6 - Harrow Creek (H16) seam, which is shown in Figure 9-8
- Layer 10 - Dysart Lower (D14, D24) coal seam, which is shown in Figure 9-9.



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

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Figure 9-7
End of Mining Drawdown Contours - Quaternary/ Tertiary (Layer1)

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Kilometres

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

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

BHP

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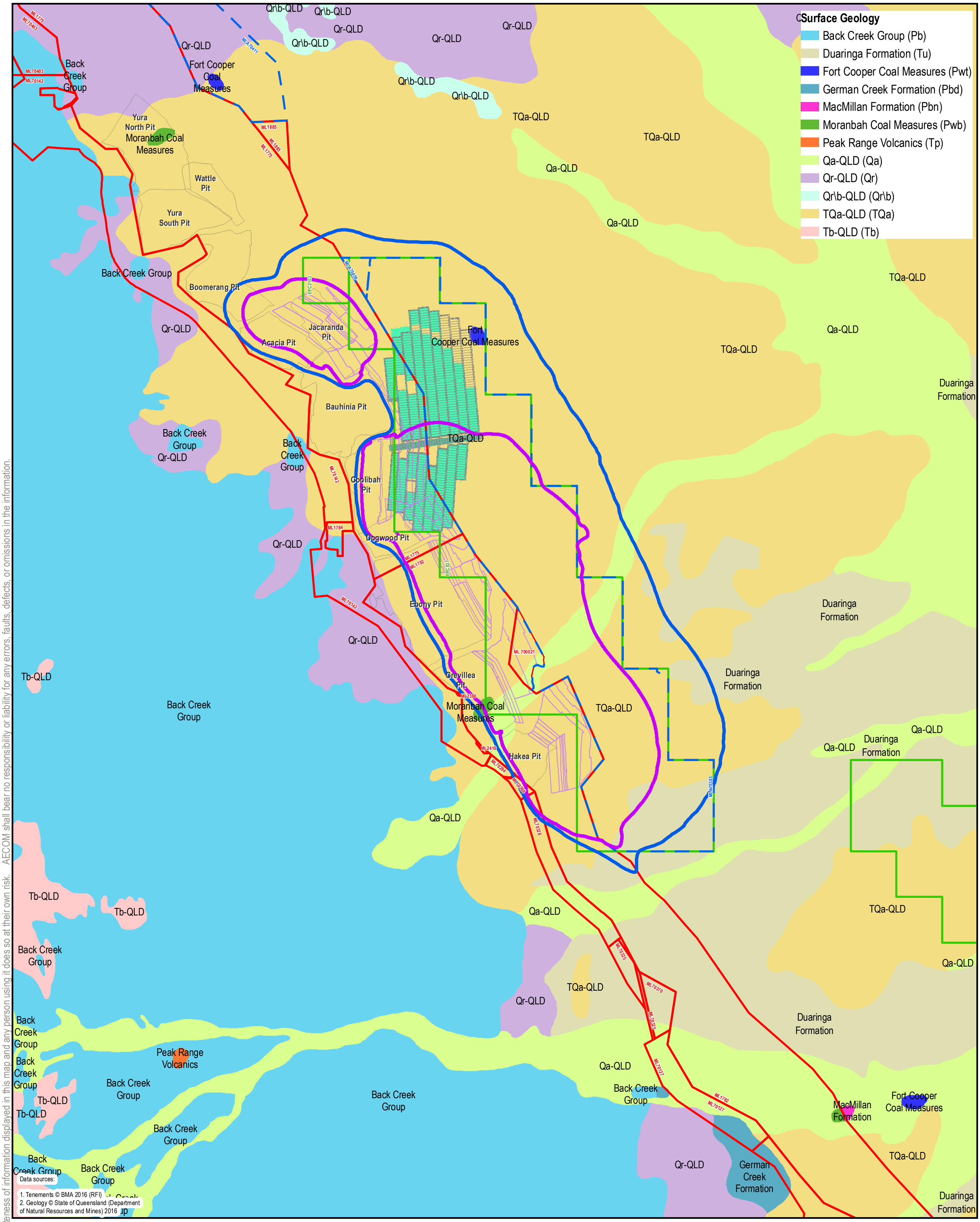

LEGEND

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

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Figure 9-8
End of Mining Drawdown Contours Harrow Creek (H16) Seam (Layer6)

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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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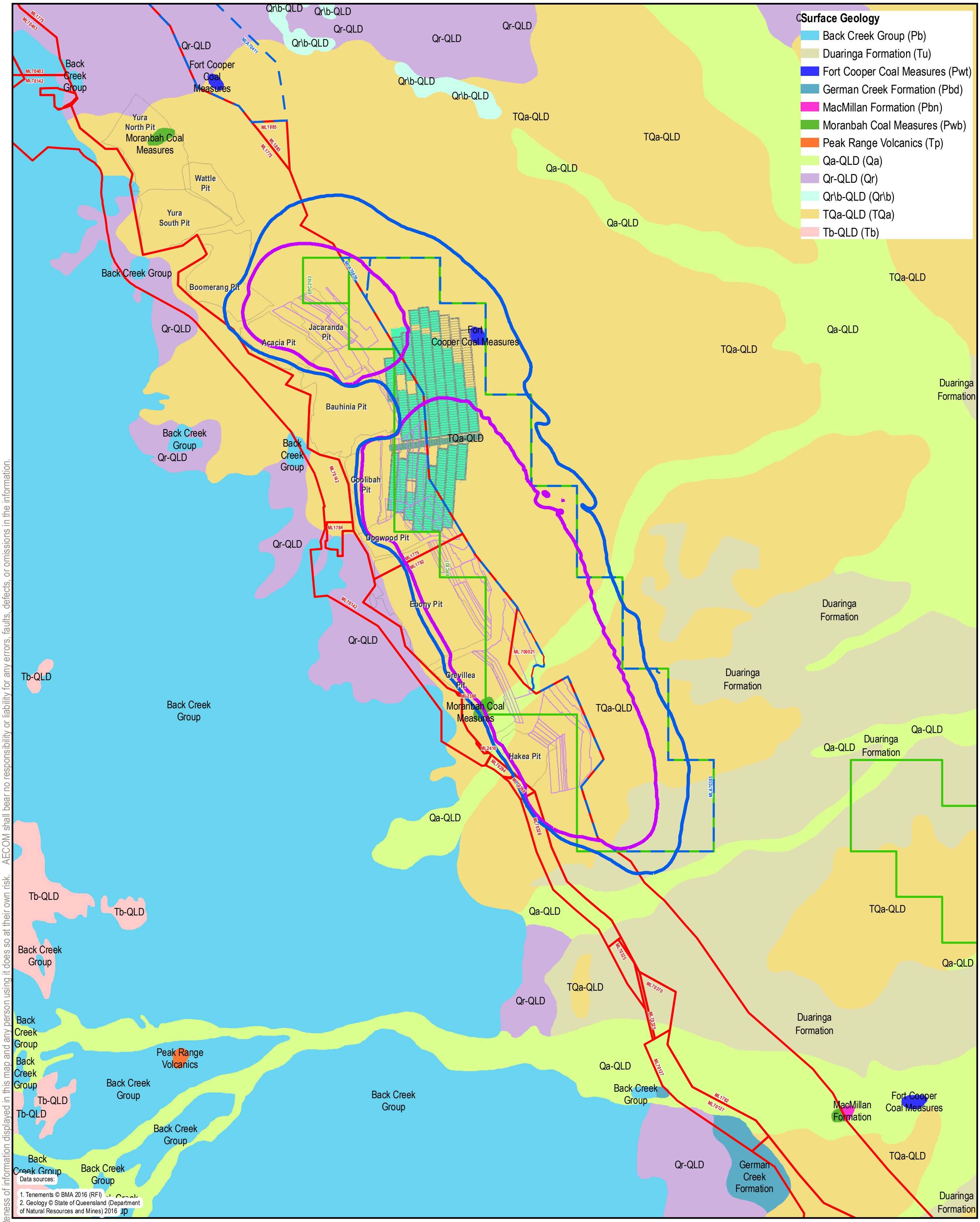

LEGEND

- 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 (optimised)
- Underground layout (maximised)
- Existing Open-Cut Extent
- Exploration Permit Coal (EPC)
- Mining Lease (ML)
- Mining Lease Application (MLA)

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Figure 9-9
End of Mining Drawdown Contours Dysart Lower (D14, D24) seam (Layer10)

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

Drawdown contours for end of approved open-cut mining, including the Grevillea Pit extension and excluding underground mining impacts, are also shown in Figure 9-7, Figure 9-8 and Figure 9-9 to allow for comparison of drawdown predictions in the absence of 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 as identified in Section 9.3.1. 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).

A summary of the predicted end of underground mining drawdown contours, for each of the three modelled layers, is summarised in Table 9.4.

Table 9.4 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 9-7)	• two metre drawdown contours not predicted to extend any further than five kilometres from mining operations to the east • 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 9-8)	• 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 9-9)	• 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.

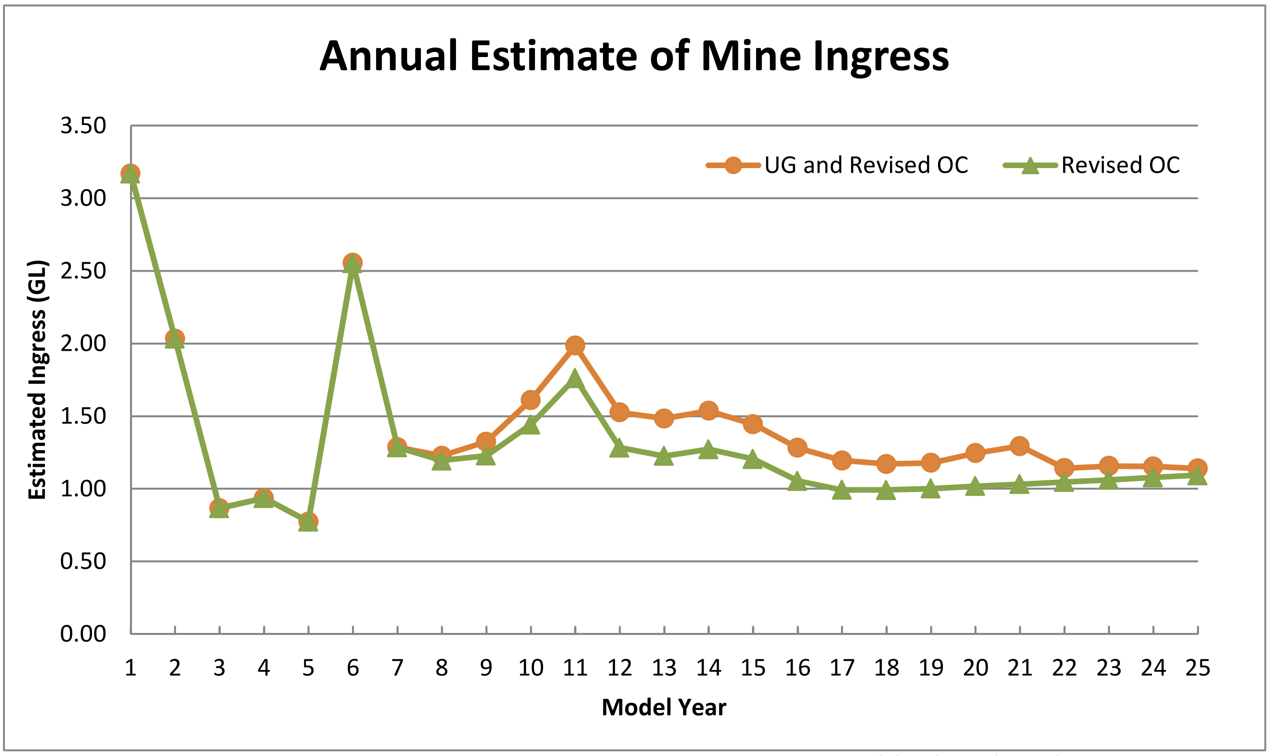
Groundwater ingress estimates

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 9.5 presents the estimates of groundwater ingress.

Table 9.5 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**	

The estimate of groundwater ingress, as included in Table 9.5, is presented in Figure 9-10.



Note: OC = Open-Cut, UG = Underground

Figure 9-10 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 9.5 shows that the total amount of ingress as a result of underground mining is predicted to be 1,527,725 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 plus/minus ten per cent. The sensitivity results 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 Gigalitre (GL), which equates to approximately 45 Litres per second (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 one to two per cent 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).

9.5.3 Impacts on groundwater levels and existing groundwater users

Figure 9-11 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 Financial Year (FY) 2042.

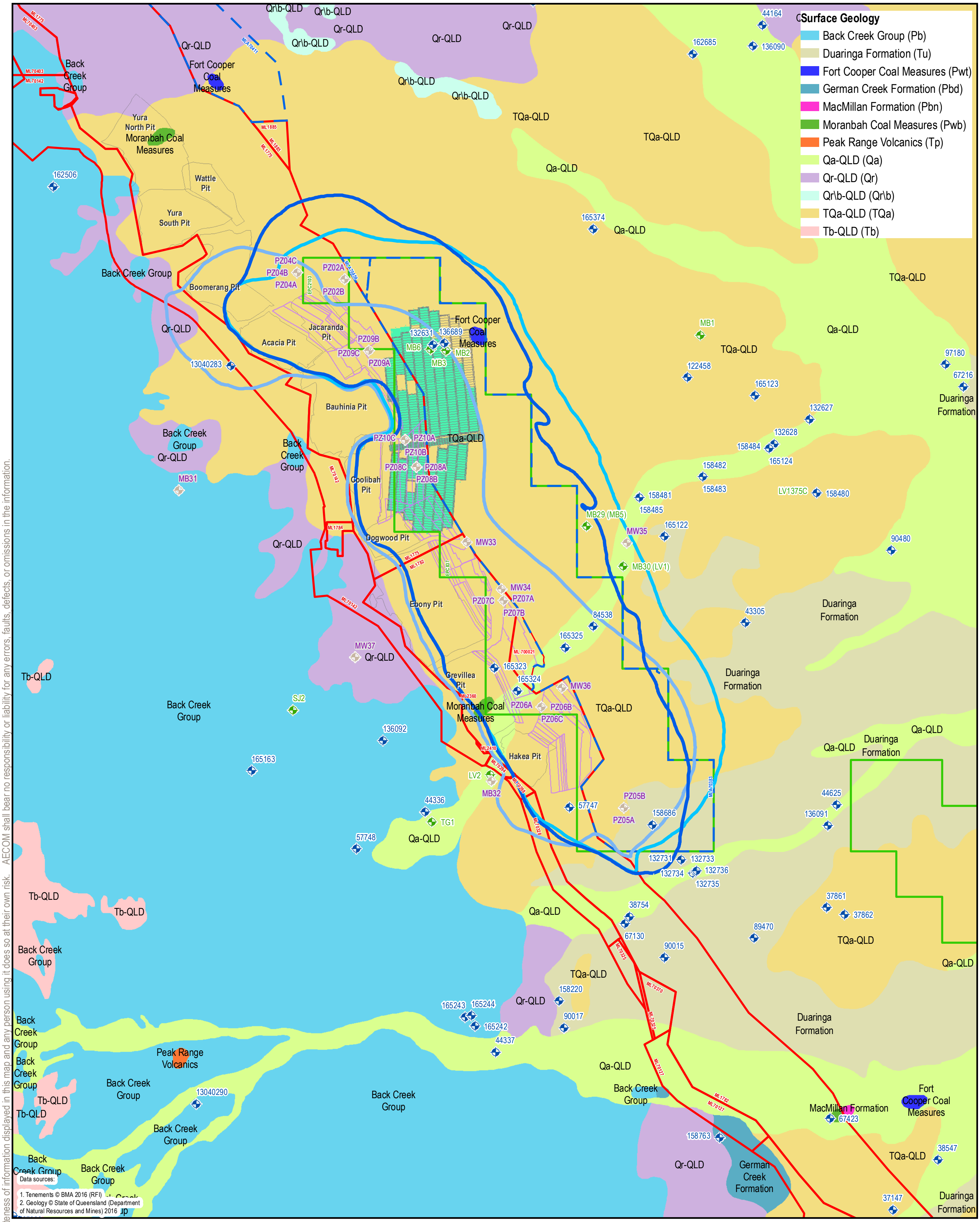
The drawdown contours, associated with the existing Saraji Mine open-cut mining and the proposed underground mining, results in drawdown of groundwater levels in several bores in a number of hydrostratigraphic units. The bore thresholds as defined in the Water Act were considered when assessing potential impacts on neighbouring groundwater bores.

Figure 9-11 shows that there are 18 groundwater bores within the end of underground mining drawdown thresholds comprising 17 registered bores and one unregistered bore.

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.



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

Figure 9-11
Bores Located within End of Underground Mining (FY42) Predicted Groundwater Drawdown Contours

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Kilometres

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9.5.4 Groundwater quality

During mining, a cone of depression is likely to 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 Groundwater Assessment Area, there is unlikely to be a significant impact upon any existing values.

9.5.5 Environmental impacts

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

- the surface water system in the Groundwater Assessment Area is generally 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.

9.6 Monitoring program

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.

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 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.

While a separate monitoring program will be developed, a number of existing monitoring bores will be utilised. The monitoring program will ensure the following:

- the determination of groundwater level responses to mine activities within the groundwater assessment 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 proposed groundwater monitoring program is to be modified in response to mine activities change (i.e. operations or closure).

If groundwater levels decline in excess of the levels defined through predictive modelling is identified, an investigation will commence 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 complete an investigation into the potential for environmental harm and notify the administering authority within 28 days.

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 9-6), additional monitoring bores are recommended prior to the Project mining activities, These are detailed in Table 9.6 and in Figure 9-12.

Table 9.6 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

All monitoring bores will 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.

Field monitoring equipment, such as electrical conductivity and pH meters will be calibrated. QA/QC laboratory samples will be collected. All external laboratories will be NATA accredited for the analytical procedures they are performing.

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

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.

LEGEND

- Existing Bores
- Proposed Bore
- Underground layout (optimised)
- Existing Open-Cut Extent
- Exploration Permit Coal (EPC)
- 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)
- Tb-QLD (Tb)

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Figure 9-12
Existing and Proposed Monitoring Bores

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9.7 Residual impacts

Potential impacts to groundwater because of the Project were 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.

9.8 Summary and conclusions

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.

The potential environmental impacts of the Project are considered low as:

- the surface water system in the Groundwater Assessment 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.

The assessment is supported by a conservative groundwater modelling approach with actual impacts expected to be equal to or lower than predictions.