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Report on

2025 Bowen UWIR MGP

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Executive Summary

This Underground Water Impact Report (UWIR) provides information on the potential decline in water levels in aquifers present within the Moranbah Gas Project (MGP) Area as a result of the taking of water during production of coal seam gas (CSG) and production testing. The MGP comprises Petroleum Leases (PLs) 191, 196, 223 and 224.

A conceptual hydrogeological model was developed as part of the UWIR and this report also includes predictions of potential depressurisation impacts on groundwater resources as a result of CSG production. These predictions were made by updating an existing groundwater model that was used for previous MGP UWIR iterations. The updated groundwater model was recalibrated using additional monitoring data for the MGP and the neighbouring Bowen Gas Project (BGP). Updated historic CSG water extraction records for both projects were also used along with updated future field development plans, which in the case of the MGP have not changed relative to the previous UWIR.

This 2025 MGP UWIR includes:

- the quantity of water taken because of the exercise of any previous relevant underground water rights;
- the quantity of water estimated to be taken because of the exercise of any relevant underground water rights over the next three years;
- an updated description of aquifers potentially affected (informed by information collected since the publication of the previous UWIR) including how the aquifer interacts with other aquifers;
- the predicted water level decline as a result of the taking of water and a description of the methods and techniques used to make the prediction;
- information on water bores that may be impacted by a water level decline in excess of relevant bore trigger thresholds; and
- a program for conducting an annual review of the impact predictions.

Historical water production from the MGP was 6,114 ML up to the end of August 2024. In the next three years a further 318 ML is expected to be extracted from the MGP.

The validity of the existing conceptual hydrogeological model was reviewed, and it was concluded that:

- data obtained to date is in support of the existing conceptual hydrogeological model, and hence; and
- that the same groundwater flow model used for previous iterations can be updated and re-used for predicting groundwater impacts as a result of CSG operations for the MGP as part of this UWIR.

The updated 2025 groundwater model developed as part of this UWIR simulates historical and forecast production as well as historical production testing. The model has been utilised to predict water level decline in aquifers due to the taking of water during production of CSG and production testing. This includes identification of Immediately Affected Areas (IAAs; where the predicted drawdown within the next three years exceeds the relevant bore trigger threshold) and the Long-term Affected Areas (LAAs; where the predicted drawdown exceeds the relevant bore trigger threshold at any time).

Key findings are:

- IAA and LAA areas (i.e. areas where more than 5 m of drawdown is predicted) associated with the MGP are predicted for the Moranbah Coal Measures (MCM).
- No areas are predicted to experience more than 5 m of drawdown in any other aquifers (including Alluvial and Tertiary aquifers), in either the short or long term.
- Whilst nine useable landholder bores are understood to be located within the predicted IAA of the MCM:
 - only one of these bores (AEN1182) appears to be deep enough that it could tap into the MCM and therefore actually experience drawdown in excess of 5 m;
 - no depth or screening information is available for four bores (AEN1300, AEN1010, AEN2112 and AEN2135) and hence these bores could be affected if they are deep enough to reach the top of the MCM, which varies between 91 and 273 metres below ground level at these locations;

- baseline assessment results for three bores (AEN1012, AEN2138, AEN2139) suggest that these bores are not deep enough to tap into the MCM and hence are not predicted to experience drawdown of more than 5 m; and
- no baseline assessment is undertaken for the remaining one bore (RN162554), but Queensland Globe data suggest this bore is not deep enough to intersect the MCM.
- In addition to the IAA landholder bores mentioned above a further six abandoned but still useable landholder bores are located within the MCM LAA.
 - Five of these bores (AEN1068, AEN1069, AEN1070, AEN1071 and AEN1072) are understood to be converted gas wells and hence are deep enough that these could experience a drawdown greater than the bore trigger threshold at some point in the future, if they actually tap into the MCM.
 - The remaining bore (RN162809) is located in an area where the MCM is estimated to be relatively shallow at 50 m below ground level, and hence this bore could also be deep enough that it could tap into the MCM. However, the bore depth is currently unknown since a baseline assessment has not been completed for this bore and no bore construction details are available via the Queensland Globe.
- No areas are predicted to experience a water table drawdown of more than 0.2 m and as such no terrestrial, lacustrine and aquatic GDEs which rely on shallow groundwater systems are predicted to be impacted by the MGP.
- No springs sourced by deep groundwater units are located within 200 km of the MGP and hence predictions do not show any drawdown at these locations.

A water monitoring strategy has been prepared. The strategy includes the installation and monitoring of a total of 16 groundwater monitoring bores, located within the MGP area, all which have been completed. Other than ongoing monitoring at these locations no additional monitoring points are proposed at this time.

As the new tenure holder for the MGP, QPME has also now prepared a revised Baseline Assessment Plan (BAP) for the MGP which was approved separately by DETSI on 3 March 2026. The BAP commits QPME to complete a baseline assessment for three bores (AEN1300, RN162554 and RN162809). Baseline assessments have already been completed at all other potentially affected landholder bores by the previous tenure holder (Arrow Energy).

This UWIR report will be reviewed annually. The review will consider:

- new hydrogeological data that significantly alters the conceptual model;
- whether new production testing or production has been undertaken or is planned; and
- whether the predictions made have materially changed.

1 Introduction

1.1 Preamble

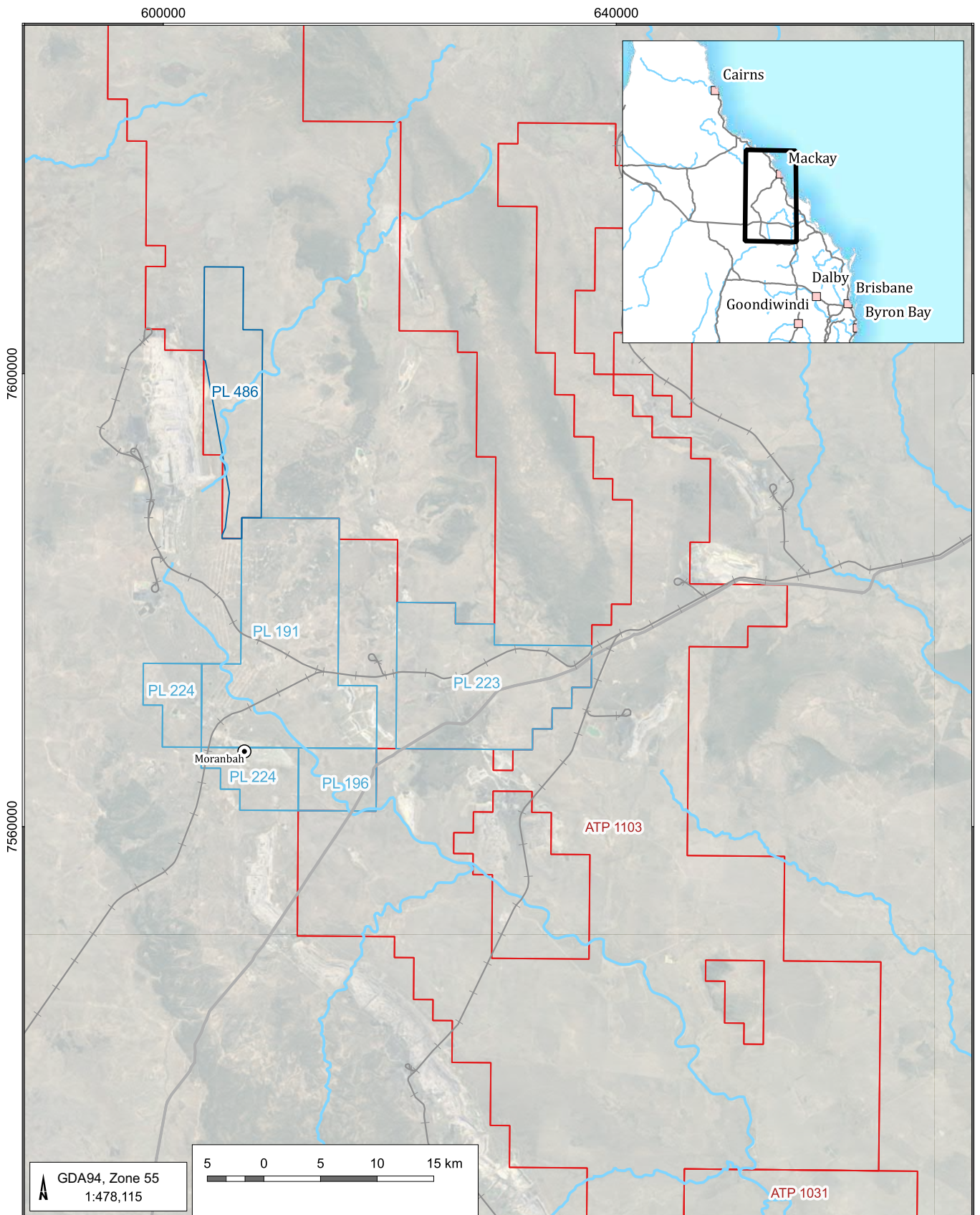
Pursuant to s. 370(3)(b) of the *Water Act (Qld) 2000*, the chief executive of the Department of the Environment, Tourism, Science and Innovation (DETSI) directed QPM Energy (MPG Upstream) Pty Ltd (QPME) to submit an Underground Water Impact Report (UWIR) related to water interference activities in Petroleum Leases (PLs) 191, 196, 223, and 224 associated with the Moranbah Gas Project (MGP). The previous 2022 UWIR (Arrow Energy, 2022) which related to activities associated with both the MGP and Bowen Gas Project (BGP) was approved with conditions by the Department of the Environment and Science (DES) and took effect on 2 August 2022. At the time Arrow Energy (Arrow) were identified as the responsible tenure holder (RTH) for both of these projects. However, following the acquisition of the MGP in September 2023, QPME, rather than Arrow Energy, have become the RTH and as such are now responsible for UWIR reporting and implementation requirements (e.g. monitoring and make good obligations) in accordance with the *Water Act (Qld) 2000*.

This UWIR report, which has been prepared by Australasian Groundwater and Environmental Consultants Pty Ltd (AGE) on behalf of QPME, is therefore intended to fulfill QPME's RTH responsibilities and provides information on the potential decline in water levels in aquifers due to the taking of water during QPME's coal seam gas (CSG) production activities as part of the MGP, as required by the *Water Act (Qld) 2000*.

1.2 Project Area

The MGP encompasses CSG production in Petroleum Leases (PLs) 191, 196, 223, and 224, the spatial distribution of which are shown in Figure 1.1. The MGP includes the following production activities between 2003 and 2024:

- approximately 235 production testing and production wells distributed over 49,225 hectares, which represents a reduction in wells relative to the previous UWIR (Arrow Energy, 2022);
- an existing gathering system consisting of approximately 267 kilometres of pipeline containing gas and water gathering lines from the well heads to relevant gas compression and water storage facilities; and
- five approved compressor facilities including the Moranbah Gas Processing Facility (MGPF) and the Node 1, 2, 3 and 4 compressor stations.



LEGEND

- ⊙ Populated place
- Major Drainage
- Arterial Roads
- QLD Rail Network
- PL (QPME)
- PL (Arrow)
- ATP (Arrow)

Bowen (BOW5001)

QPME tenements in the Bowen Basin



AGE

DATE
13/02/2025

FIGURE No:
1.1

1.3 Requirement for a UWIR

1.3.1 Cumulative management areas

The chief executive of DETSI may declare a cumulative management area (CMA) in areas of concentrated CSG development where the impacts on water levels caused by individual petroleum and gas projects overlap. In Queensland, the Surat CMA has been declared in the area of planned concentrated CSG development within the Surat Basin.

QPME's operations/project in the Bowen Basin falls outside of the Surat CMA, and under the *Water Act (Qld) 2000*, there is a requirement to prepare an UWIR. This requirement is addressed by this report.

1.3.2 This UWIR

This report forms the UWIR for QPME's CSG activities in the Bowen Basin, including CSG production and production testing wells, contained within the bounds of the QPME's production tenure.

The purpose of this report is to address Chapter 3, and in particular, s376 of the *Water Act (Qld) 2000* which stipulates that the UWIR must include:

- a) For the area to which the report relates:
 - (i) the quantity of water produced or taken from the area because of the exercise of any previous relevant underground water rights; and
 - (ii) an estimate of the quantity of water to be produced or taken because of the exercise of the relevant underground water rights for a 3-year period starting on the consultation day for the report.
- b) For each aquifer affected, or likely to be affected, by the exercise of the relevant underground water rights:
 - (i) a description of the aquifer;
 - (ii) an analysis of the movement of underground water to and from the aquifer, including how the aquifer interacts with other aquifers;
 - (iii) an analysis of the trends in water level change for the aquifer because of the exercise of the rights mentioned in paragraph (a)(i);
 - (iv) a map showing the area of the aquifer where the water level is predicted to decline, because of the taking of the quantities of water mentioned in paragraph (a), by more than the bore trigger threshold within 3 years after the consultation day for the report; and
 - (v) a map showing the area of the aquifer where the water level is predicted to decline, because of the exercise of relevant underground water rights, by more than the bore trigger threshold at any time.
- c) A description of the methods and techniques used to obtain the information and predictions under paragraph (b).
- d) A summary of information about all water bores in the area shown on a map mentioned in paragraph (b)(iv), including the number of bores, and the location and authorised use or purpose of each bore.
- e) A program for:
 - (i) conducting an annual review of the accuracy of each map prepared under paragraph (b)(iv) and (v); and
 - (ii) giving the chief executive a summary of the outcome of each review, including statement of whether there has been a material change in the information or predictions used to prepare the maps.
- f) A water monitoring strategy.
- g) A spring impact management strategy.

- h) If the responsible entity is the office:
 - (i) a proposed responsible tenure holder for each report obligation mentioned in the report; and
 - (ii) for each immediately affected area—the proposed responsible tenure holder or holders who must comply with any make good obligations for water bores within the immediately affected area.
- i) Other information or matters prescribed under a regulation.

1.4 Legislation

The primary legislative requirements for the management and development of groundwater for QPME's MGP activities are summarised below.

1.4.1 Petroleum and gas (Production and Safety) act 2004 and petroleum act 1923

The Petroleum and Gas (Production and Safety) Act 2004 (P&G Act, 2004) and the Petroleum Act 1923 regulate CSG activities and also govern groundwater management in relation to CSG development. Under the P&G Act, the petroleum tenure holder may take or interfere with water if taking or interference happens during the course of, or results from, the carrying out of another authorised activity for the tenure. These rights are subject to the tenure holder complying with the holder's underground water obligations (defined in the Water Act (Qld) 2000).

1.4.2 Water Act (Qld) 2000

Chapter 3 of the *Water Act (Qld) 2000* provides for the management of impacts on underground water caused by the exercise of underground water rights by petroleum tenure holders. This is achieved primarily by:

- providing a regulatory framework to:
 - require petroleum tenure holders to monitor and assess the impact of the exercise of underground water rights on water bores and to enter into 'make good' agreements with the owners of the bores;
 - requires the preparation of UWIRs that establish underground water obligations, including obligations to monitor and manage impacts on aquifers and springs;
 - manage the cumulative impacts from two or more petroleum tenure holders' underground water rights on underground water; and
- giving the chief executive and the office functions and powers for managing underground water.

If a water bore has an impaired capacity as a result of CSG activities, an agreement will be negotiated with the owner of the bore about the following:

- the reason for the bore's impaired capacity;
- the measures the holder will take to ensure the bore owner has access to a reasonable quantity and quality of water for the authorised use and purpose of the bore; and
- any monetary or non-monetary compensation payable to the bore owner for impact on the bore.

If an agreement relating to a water bore is made the agreement is taken to be a 'make good' agreement for the bore.

An UWIR will identify whether an 'immediately affected area' will result from CSG activities. An immediately affected area is defined as an area where the predicted decline in water levels within three years is at least:

- 5 m for a consolidated aquifer;
- 2 m for an unconsolidated aquifer; and
- 0.2 m for a spring.

UWIRs are published to enable comments from bore owners within the area. Submissions made by bore owners will be summarised by QPME, addressed as appropriate and provided to DETSI. UWIRs are submitted for approval by DETSI. The Office of Groundwater Impact Assessment (OGIA) may also advise DETSI about the adequacy of these reports.

DETSI will maintain a database of information collected under monitoring plans carried out by petroleum tenure holders in accordance with approved UWIRs. The database will also incorporate bore baseline data collected by petroleum tenure holders.

1.5 Summary of methods

This UWIR builds on information presented in the following documents:

- UWIR for PLs 191, 196, 223, 224 (Arrow Energy, 2012a);
- UWIR for ATP 1103 (Arrow Energy, 2012b);
- Bowen Gas Project Environmental Impact Statement (EIS) (Arrow Energy, 2012c);
- UWIR for ATP 1031 (Arrow Energy, 2014a);
- Bowen Gas Project Supplementary Report to the EIS (Arrow Energy, 2014b);
- UWIR for PL 191, 196, 223, 224 and ATP 644, 831, 742, 1031 and 1103 (Arrow Energy, 2016);
- UWIR for PL 191, 196, 223, 224 and ATP 644, 831, 742, 1031 and 1103 (Arrow Energy, 2019);
- UWIR for PL 191, 196, 223, 224 and ATP 644, 831, 742, 1031 and 1103 (Arrow Energy, 2022); and
- 2017, 2018, 2020, 2021 and 2022 Annual Reviews of the UWIR's for PL 191, 196, 223, 224 and ATP 644, 831, 742, 1031 and 1103.

Since the development of the previous UWIRs for PLs 191, 196, 223 and 224, the conceptual understanding of groundwater occurrence and processes in the MGP has been updated based on the collection and interpretation of the new data relating to the MGP area.

An assessment of impacts to groundwater due to the MGP field development plan was then undertaken comprising the following tasks:

- Task 1: Review and analysis of site-specific monitoring and assessment data;
- Task 2: Hydrogeological assessment and conceptualisation;
- Task 3: Numerical groundwater model development for making predictions of groundwater impacts;
- Task 4: Identification of potential impacts on groundwater; and
- Task 5: Review of the Water Monitoring Strategy (WMS) and Spring Impact Management Strategy (SIMP).

A summary of the reporting requirements as stipulated in the *Water Act (Qld) 2000* for this UWIR and relevant sections of this report in which they have been addressed is included in Table 1.1 below.

Table 1.1 Water Act (Qld) 2000 reporting requirements for this UWIR

UWIR reporting requirement	Report Section
s376	
a) For the area to which the report relates:	Section 2
(i) the quantity of water produced or taken from the area because of the exercise of any previous relevant underground water rights; and	
(ii) an estimate of the quantity of water to be produced or taken because of the exercise of the relevant underground water rights for a 3-year period starting on the consultation day for the report.	Section 2
b) For each aquifer affected, or likely to be affected, by the exercise of the relevant underground water rights:	Section 3
(i) a description of the aquifer;	
(ii) an analysis of the movement of underground water to and from the aquifer, including how the aquifer interacts with other aquifers;	Section 3, Section 5
(iii) an analysis of the trends in water level change for the aquifer because of the exercise of the rights mentioned in paragraph (a)(i);	Section 5
(iv) a map showing the area of the aquifer where the water level is predicted to decline, because of the taking of the quantities of water mentioned in paragraph (a), by more than the bore trigger threshold within 3 years after the consultation day for the report; and	Section 7
(v) a map showing the area of the aquifer where the water level is predicted to decline, because of the exercise of relevant underground water rights, by more than the bore trigger threshold at any time.	Section 7
c) A description of the methods and techniques used to obtain the information and predictions under paragraph (b).	Section 1, Section 3, Section 7
d) A summary of information about all water bores in the area shown on a map mentioned in paragraph (b)(iv), including the number of bores, and the location and authorised use or purpose of each bore.	Section 7
e) A program for:	Section 9
(i) conducting an annual review of the accuracy of each map prepared under paragraph (b)(iv) and (v); and	
(ii) giving the chief executive a summary of the outcome of each review, including statement of whether there has been a material change in the information or predictions used to prepare the maps.	Section 6, Section 7
f) A water monitoring strategy.	Section 4
g) A spring impact management strategy.	Not applicable to the Project Area. Refer to Section 8
h) If the responsible entity is the commission:	Not applicable to the Project Area
(i) a proposed responsible tenure holder for each report obligation mentioned in the report; and	
(ii) for each immediately affected area (IAA) – the proposed responsible tenure holder or holders who must comply with any make good obligations for water bores within the IAA.	Not applicable to the Project Area
i) Other information or matters prescribed under a regulation.	No matters identified

UWIR reporting requirement	Report Section
s378 a) Water Monitoring Strategy: (i) Strategy for monitoring the quantity of water produced. (ii) Strategy for monitoring changes in water level. b) Rationale for the strategy. c) Timetable for implementing the strategy. d) Program for reporting the implementation of the strategy.	Section 4 and MGP Baseline Assessment Plan included in Appendix D
2. Strategy must include:	
a) the parameters to be measured;	
b) locations for taking the measurements; and	
c) frequency of the measurements.	
3. A program for a baseline assessment for each bore that is:	
a) outside the tenure, within an immediately or long term affected area; and	
b) within the area shown on the map prepared under section 376(b)(v).	

2 Existing and forecast water production

Historical actual water production data since the last UWIR has been compiled for both production and production testing wells to confirm the quantity of water taken and allow for comparison against the modelled historical and forecast volumes for the MGP.

As reported in Arrow Energy (2022), the volumes of water produced from existing MGP wells are measured using progressive cavity pumps (PCPs) in both the gas production and production testing (appraisal) wells. These pumps work by rotating an eccentric screw which pushes the inflowing water in the well upwards. Consequently, the pumping rate (expressed as a volume/time) is proportional (based on an 'efficiency factor') to the rate of rotation of the pump (i.e. there is a direct correlation between a given number of revolutions per minute (rpm) and a corresponding pumping rate). A flow test is undertaken to calculate the volume of water produced from the PCPs (i.e. the pump rate and time for a known volume of water to be pumped is used to calculate the 'efficiency factor'). This is applied to a record of the pumps operating rpm to calculate the volume of water pumped. Flow tests are undertaken regularly to maintain the accuracy of the flow calculation. In addition, the total volume of water pumped into dams constructed to hold the pilot test water is used as a check on this calculation.

Existing water production rates are presented in Section 2.1. Forecasts of future water production for the MGP are presented in Section 2.2. All the historical and future forecast water production presented in Section 2.1. and Section 2.2 is from the Moranbah Coal Measures, as the Fort Cooper Coal Measures and Rangal Coal Measures have only been targeted during production testing.

2.1 Existing water production summary

The total volume of water taken for the period of 1 January 2022 to 31st August 2024 (hereafter referred to as the 'UWIR reporting period') in the MGP Area during production and production testing is presented in Table 2.1 along with historical water production rates for the period 2003 to 2021. It should be noted that whilst PLs 191, 196, 223 and 224 make up the MGP, production has only been undertaken in PLs 191, 196 and 224 (not including production testing).

As indicated in Table 2.1, the water production in the UWIR reporting period totalled 542 ML from production and 0 ML from production testing. This is slightly higher than the forecast production reported in the previous 2022 UWIR (Arrow Energy, 2022) for the period 2022 to 2024 of 522 ML.

A time series of annual actual production volumes from PLs 191, 196 and 224 is shown in Figure 2.1 to illustrate the proportion of water extracted historically from the petroleum leases that make up the MGP. As shown in Figure 2.1, the annual water production volume in the MGP PLs ranges between 162 and 205 ML for the UWIR reporting period.

Table 2.1 Historical water production and production testing volumes

Period	Total production volume (ML)	Production testing volume (ML)
2003 - 2021	5,502	70
2022 - 2024	542	0

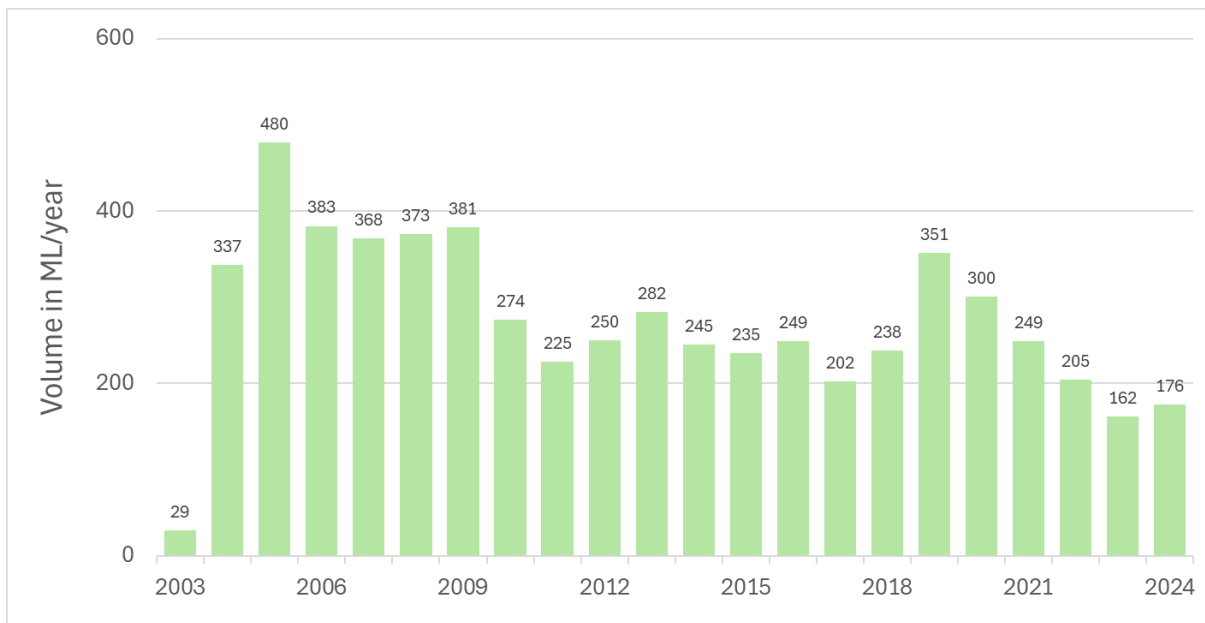


Figure 2.1 Total water produced from MGP production wells on PL191, PL196 and PL224

2.2 Forecast water production

Total forecast water production forecast for the MGP for the next 3 years (UWIR reporting interval) commencing 1 January 2025 is expected to be 318 ML (equivalent annual extract rate of 106 ML/yr).

The MGP is expected to remain operational until the end of 2028. No future production testing has been planned for the MGP. Field development of PLs 191, 196 and 224 are on-going and any updates to the forecast production will be incorporated into future annual review reporting.

3 Existing conceptual model

The conceptual hydrogeological model was described in the previous UWIRs for PLs 191, 196, 223, 224 (Arrow Energy, 2012a) and the 2016, 2019 and 2022 Bowen UWIR (Arrow Energy, 2016; Arrow Energy, 2019 and Arrow Energy, 2022). This model was based initially predominantly on a desktop review of available hydrogeological information including data from neighbouring coal mines, hydrogeological reports and records obtained from the DES and DNRME.

A summary of the conceptual hydrogeological model (see Figure 3.4), including geology and aquifers is provided in the following sections. In general, the geology and hydrogeology of the Bowen Basin which hosts the MGP is well understood and ongoing operation of MGP has not identified any significant deviations from the basic conceptual model described in previous UWIRs.

3.1 Geological summary

As reported in previous UWIRs (Arrow Energy, 2016; Arrow Energy, 2019 and Arrow Energy, 2022), the Bowen Basin covers an area of approximately 200,000 km², and spans over 600 km from Collinsville in the north to Rolleston in the south. It contains a sedimentary sequence of Permo-Triassic clastics, which attain a maximum thickness of 9,000 m in the depocentre of the Taroom Trough.

Deposition in the Bowen Basin commenced during an Early Permian extensional phase, with fluvial and lacustrine sediments and volcanics being deposited in a series of half-grabens in the east while in the west a thick succession of coals and non-marine clastics were deposited. Following rifting there was a thermal subsidence (sag) phase extending from the Early to Late Permian, during which a basin-wide transgression allowed deposition of deltaic and shallow marine, predominantly clastic sediments as well as extensive coal measures. Foreland loading of the basin spread from east to west during the Late Permian, resulting in accelerated subsidence, which allowed the deposition of very thick successions of Late Permian marine and fluvial clastics, again with coal and Early to Middle Triassic fluvial and lacustrine clastics. Sedimentation in the basin was terminated by the Middle to Late Triassic (Geoscience Australia, 2008).

The surface geology mapped across the MGP is presented in Figure 3.2, showing PL224, PL196 and the southwestern portion of PL191 are predominantly covered by Late Tertiary and Quaternary colluvium, which typically comprises poorly sorted clay, silt, sand and gravel.

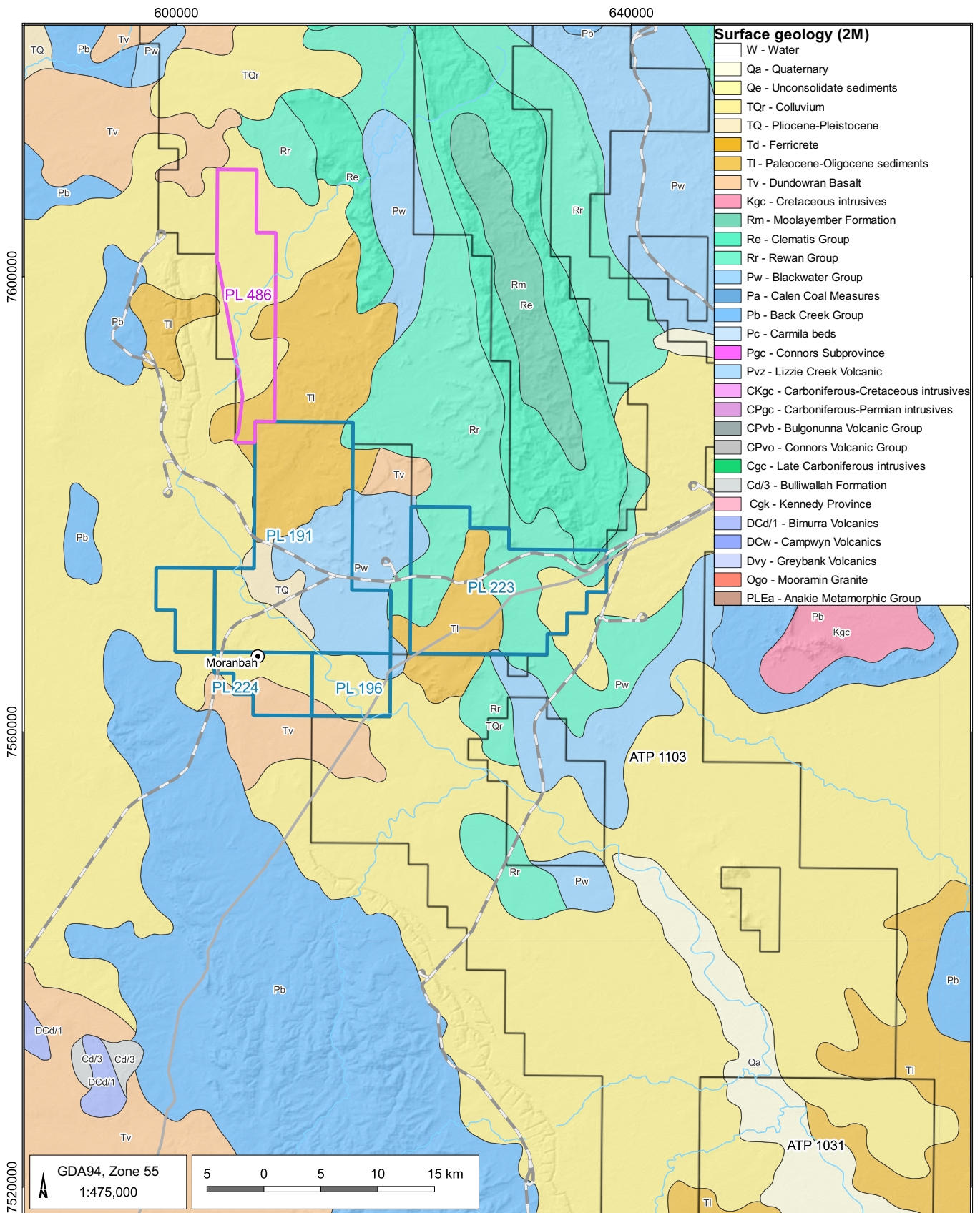
Areas of Tertiary sediment cover include the Dundowran Basalt in the southern part of PL 224 and Paleocene-Oligocene sediments in the northern portion of PL 191 and central portion of PL223. Where present the Tertiary cover in the Bowen Basin typically comprises thick, clay-rich laterite, a result of the lateritisation of Permian units during the Tertiary period, and includes paleochannel deposits and basalt flows (Arrow Energy, 2022).

Outcrops of Triassic-aged and Permian-aged consolidated formations are confined to the central and eastern portion of the MGP area, and include the Late Permian Blackwater Group (Fort Cooper Coal Measures, Moranbah Coal Measures and Rangal Coal Measures) in the central and north-eastern portion of the MGP area and the Early Triassic Rewan Group in the eastern portion of the MGP area.

The stratigraphy of the Bowen Basin is summarised in Figure 3.1. The Late Permian Blackwater Group comprises (from oldest to youngest) the Moranbah Coal Measures (MCM), the Fort Cooper Coal Measures (FCCM), and the Rangal Coal Measures (RCM).

Period	Stratigraphic Unit			Description	
Quaternary	Alluvium Alluvium, colluvium and other sediments in floodplains, alluvial fans, and high terraces			Clay, silts, sand, gravel, floodplain alluvium	
Tertiary	Suttor Formation			Clay, silt, sand, gravel, colluvium, fluvial and lacustrine deposits including cross-bedded quartz sandstone, conglomerate, claystone	
	Basalt			Olivine rich weathered basaltic sands, weathered basalt, and fresh basalt flows	
	Duaringa Formation			Mudstone, sandstone, conglomerate, siltstone, oil shale, lignite and basalt	
Triassic	Mimosa Group	Moolayember Formation		Mudstone, lithic sandstone, interbedded siltstone, mudstone, sandstone and thin coal seams.	
		Clematis Sandstone		Cross-bedded quartz sandstone, some quartz conglomerate and minor red-brown mudstone.	
		Rewan Formation		Green lithic sandstone, pebble conglomerate, red and green mudstone	
Permian	Late	Blackwater Group	Rangal Coal Measures		Coal seams, carbonaceous shale and mudstone, tuff, siltstone and mudstone
			Fort Cooper Coal Measures	Burngrove Formation	Coal, brown and green sandstone, conglomerate, carbonaceous shale, tuff
				Fairhill Formation	Labile sandstone, quartzose sublabile sandstone, siltstone, mudstone, calcareous and tuffaceous sandstone, volcanic conglomerate, carbonaceous mudstone, coal
			Moranbah Coal Measures	MacMillan Formation	Quartzose to sublabile, locally argillaceous sandstone, siltstone, mudstone, carbonaceous mudstone and coal
				German Creek Formation	
	Early to Middle	Back Creek Group			Quartzose to lithic sandstone, siltstone, carbonaceous shale, minor coal and sandy coquinite

Figure 3.1 Regional stratigraphy of the Bowen Basin (Arrow Energy, 2022)



Bowen (BOW5001)

Surface geology of the Bowen Basin



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FIGURE No:
3.2

3.1.1 Target geological formations

The targeted coal seams for CSG production wells within the MGP are the Moranbah Coal Measures. Production testing in PL191 and PL 223 prior to 2018 has also targeted the Fort Cooper Coal Measures and Rangal Coal Measures, but no extraction is planned from these units in the future. A description of each of these coal measure units is provided below.

3.1.1.1 Moranbah Coal Measures

The Moranbah Coal Measures (MCM) form part of the Late Permian “Group III” coals deposited in the third and final phase of the formation of the Bowen Basin. The MCM consist of coals, sandstones, siltstones and mudstones and average from 250 m to 300 m in thickness. They are characterised by several laterally persistent, relatively thick coal seams interspersed with several thin minor seams. The predominant target seams in order of importance are the Goonyella Middle (GM), P, Q and Goonyella Middle Lower (GML) seams. The typical thicknesses of these seams are:

- The Q seam is split into three main plies, the QA1 (3.5 m thick), QA2 (3 m thick), and QB (1.75 m thick).
- The P seam is the second most targeted source of coal seam methane within the MGP Area. The P seam consists of 3 plies, the GR (3 m thick), PL1 (1.5 m thick), PL2 (0.5 m thick) and averages about 5 m in total thickness.
- The GM seam is the primary target seam within the MGP. The seam averages 5 m in thickness but thins towards the southeast as a result of seam splitting.
- The GML seam also forms part of the MCM and in relatively small local pockets, the seam can reach thicknesses of up to 6.5 m.

3.1.1.2 Fort Cooper Coal Measures

The Fort Cooper Coal Measures (FCCM) conformably overlies the MCM and are approximately 400 m thick. Along with the coal seams, sediments of the FCCM include green lithic sandstone, conglomerate, mudstone, carbonaceous, shale, coal, and thin beds of greyish white cherty tuff containing abundant leaf impressions (Jensen, 1968). The FCCM are characterised by up to seven formations (6 – 60 m thick) rich in carbonaceous mud and thin coal seams, and its distinctive tuff beds. These formations are interbedded with 10 m to 30 m thick siltstone and sandstone sequences. The potential target seam of the FCCM is the Girrah Seam. This seam marks the roof of the FCCM (Burngrove Formation) and is one of the few identifiable horizons. The seam is approximately 30 m in thickness with numerous stone bands and a notable radioactive tuff band.

3.1.1.3 Rangal Coal Measures

The final phase of coal deposition in the Bowen Basin in the Late Permian resulted in the formation of Group IV coals. These include, from north to south, the Rangal Coal Measures (RCM), Baralaba Coal Measures and the Bandanna Formation. The coals in this group are the most diverse in terms of quality, and also the most widely distributed within the basin. Group IV coals were deposited under fluvial, lacustrine and paludal conditions (Mutton, 2003) and comprise sandstones, calcareous sandstone, carbonaceous shale, mudstone, coal, volcano-clastics (tuff), and concretionary limestone.

3.1.1.4 Geological model cross-section

Figure 3.3 presents a southwest to northeast orientated section through the MGP based on Arrow’s geological model for the northern Bowen Basin, which was developed based on all available geological information, including gas well exploration and testing drilling information, mine drilling and water user data. The section in Figure 3.3 shows the coal measures of the RCM, FCCM and MCM at outcrop in the west (around 4 km west from the MGP production areas) and dipping to depths of up to 1 km towards the east of the MGP at PL 223 (at coordinate 40,000 in Figure 3.3). The Quaternary and Tertiary cover is not visible in Figure 3.3 due to the large depth scale to represent the regional geology of the coal measures and overlying Rewan Group which thickness exceeds 500m in the eastern portion of the MGP. As shown in Figure 3.3, the coal seams of the MCM that are targeted by the MGP occur at depths ranging from 200 to 500 meters.

Faults shown by the black lines in Figure 3.3 affect the lateral continuity of the coal seams and at 10 km east of MGP PL 223 (at coordinate 52,000 in Figure 3.3) a large regional fault system is present where coal seams of the RCM, FCCM and MCM are laterally disconnected due to a large regional fault system with fault throws exceeding 500 meters. East of this large regional fault system the Rewan thickness is drastically reduced and the RCM, FCCM and MCM coal measures are present at much shallower depths.

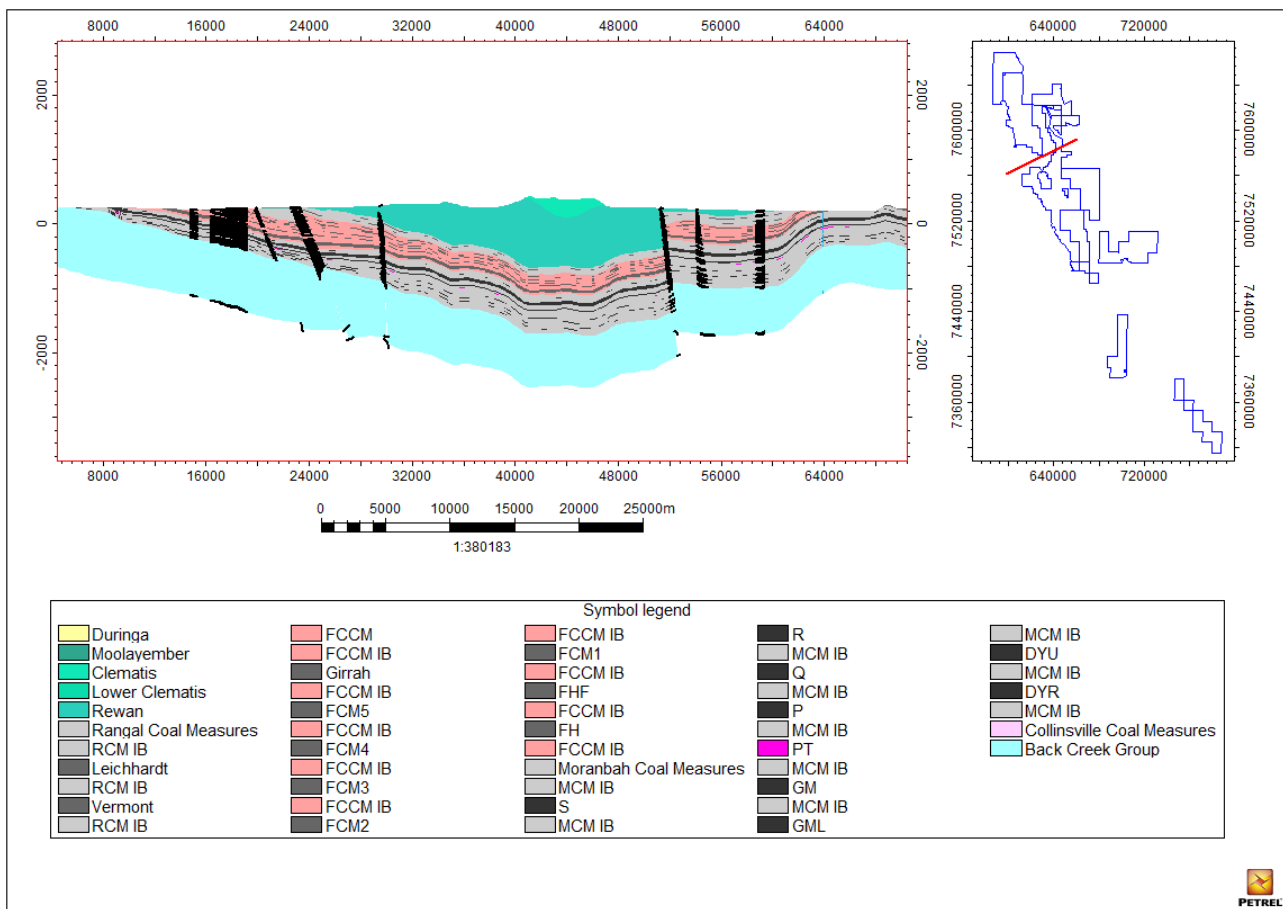


Figure 3.3 Stratigraphy underlying the MGP Area (Arrow Energy, 2022)

3.2 Conceptual hydrogeological model

A summary of the hydrostratigraphy of the Bowen Basin, including identification of the key aquifer units, is provided in Table 3.1 and a schematic conceptual section is presented in Figure 3.4. As shown other than the coal seams themselves, which tend to be relatively permeable, the main aquifer units present in the Bowen Basin are Quaternary alluvium, Tertiary basalts and the Clematis Sandstone. The remainder of the units present are predominantly considered to be aquitards. Further descriptions of each are provided below in Sections 3.2.1 to 3.2.5 based on Arrow Energy (2022).

Table 3.1 Hydrostratigraphy of the Bowen Basin (Arrow Energy, 2022)

Age	Stratigraphic Unit		Lithology	Typical thickness (m)	Aquifer Type
Quaternary	Alluvium		Clay, silts, sand, gravel, floodplain alluvium	15-35	Unconfined (resource aquifer)
Tertiary	Suttor Formation		Clay, silt, sand, gravel, colluvium, fluvial and lacustrine deposits including cross-bedded quartz sandstone, conglomerate, claystone	0-120	Aquitard
	Basalt		Olivine-rich weathered basalt remnants, moderately weathered and fresh basalts	0-80	Unconfined (resource aquifer); fractured rock aquifer
	Duaringa Formation		Mudstone, sandstone, conglomerate, siltstone, oil shale, lignite and basalt	0-50	Aquitard
Triassic	Moolayember Formation		Mudstone, lithic sandstone, interbedded siltstone, mudstone, sandstone and thin coal seams.	0-200	Confining unit - GAB
	Clematis Sandstone		Cross-bedded quartz sandstone, some quartz conglomerate, minor reddish brown mudstone	0-300	Confined GAB aquifer
	Rewan Formation		Green lithic sandstone, pebble conglomerate, red and green mudstone, siltstone	200-800	Confining unit
Late Permian	Rangal Coal Measures (RCM) and equivalents		Coal seams, carbonaceous shale and mudstone, tuff, siltstone and mudstone	25-200	Confined aquifer (coal) and confining unit (interburden)
	Fort Cooper Coal Measures (FCCM) and equivalents		Coal, brown and green sandstone, conglomerate, carbonaceous shale, tuff	100-600	Confined aquifer (coal) and confining unit (interburden)
	Moranbah Coal Measures (MCM)		Coal, sandstone, siltstone, mudstone, carbonaceous mudstone	100-700	Confined aquifer (coal) and confining unit (interburden)
Middle Permian	Back Creek Group		Sandstone, siltstone, carbonaceous shale, minor coal and sandy coquinite	400-1200	Confining unit

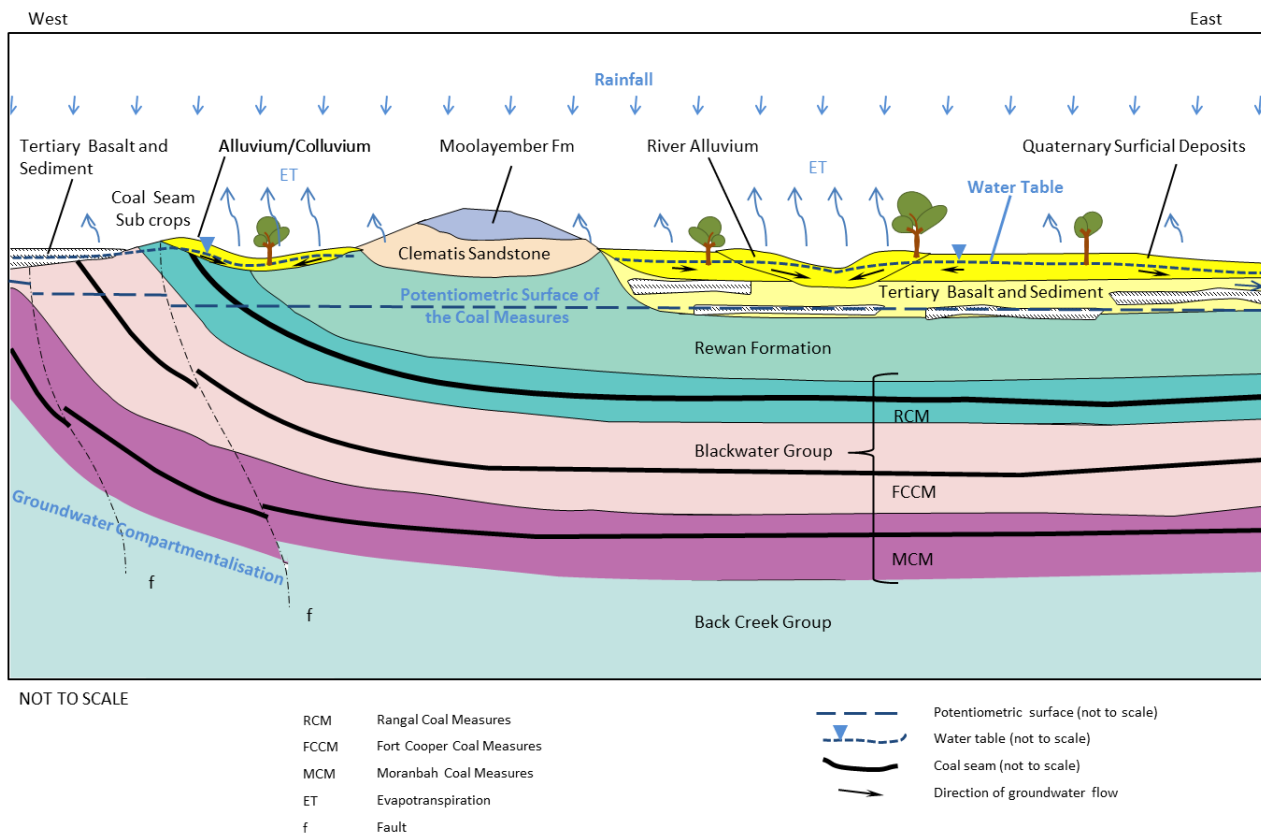


Figure 3.4 Conceptual Hydrogeological Model (Arrow Energy, 2012c)

3.2.1 Quaternary alluvium aquifers

Quaternary alluvium aquifers form the shallow-most aquifers in the Bowen Basin and are generally associated with major creek and river systems. As reported in Arrow Energy (2022), these alluvium aquifers typically occupy an area within the river valley which is generally about 500 m wide. Due to the semi-arid climate, the ephemeral nature of the stream flow, and discontinuity of the more permeable gravel and sand layers groundwater resources in the Quaternary alluvium in the Bowen Basin are not abundant, and groundwater only occurs in isolated areas. As shown in Figure 3.2, no alluvium aquifers are mapped within 20 kilometres (km) of the MGP area (i.e. PLs 191, 196 and 224).

Key alluvium aquifer characteristics are:

- groundwater levels fluctuate between 6 to 10 meters below ground level (mbgl);
- may not be fully saturated all year;
- are of variable permeability being characterised by relatively high permeability riverbed sands and relatively low permeability riverbank sediments;
- recharge mainly through direct infiltration of rainfall, overland flow and surface water flow;
- discharge is generally through evapotranspiration from vegetation, infiltration and recharge to underlying older formations;
- groundwater quality is highly variable ranging from brackish to saline; and
- groundwater use is erratic, and no significant extraction areas are recognised from the alluvium aquifers in and surrounding the MGP (Arrow Energy, 2022).

3.2.2 Tertiary sedimentary aquifers

The undifferentiated Tertiary sediments and Suttor Formation occurs extensively throughout the northern portion of the Bowen Basin and MGP area, although outcrops are not continuous, and much of the Tertiary sequence is concealed by younger, overlying Quaternary alluvium and colluvium. The Tertiary sediments generally consist of lenses of paleochannel gravels and sands separated by sandy silts, sandy clays and clays. Potential for groundwater exists within the more permeable sand and gravel sections of the Tertiary sediments.

Key aquifer characteristics are:

- the average groundwater level around 52 mbgl;
- lenses of saturated sand and gravel are limited in extent and separated by sandy silts and clays;
- highly variable in permeability and porosity and limited in lateral and vertical extent;
- recharge mainly through direct infiltration of rainfall, overland flow in outcrop areas and vertical seepage from overlying Quaternary alluvium;
- discharge is generally through evapotranspiration from vegetation, infiltration and recharge to underlying older formations;
- groundwater quality is classed as fresh to brackish; and
- groundwater use is sparse, and no significant extraction areas are recognised from the Tertiary sediment aquifers in the MGP area (Arrow Energy, 2022).

3.2.3 Tertiary basalt aquifers

The spatial distribution of the Tertiary basalt is sporadic within the Bowen Basin. The largest mass occurs to the west of Dysart with several other masses occurring near Moranbah, west of Nebo and northeast of Middlemount (Pearce and Hansen, 2006). Near the MGP the Tertiary basalt is present within and south of tenures PL 224 and PL 196 and northeast from PL191. Groundwater is principally stored and transmitted in the fractures, joints and other discontinuities within the rock mass.

Key aquifer characteristics are:

- groundwater levels range between 17 to 38 mbgl;
- vesicular basalt acts as localised, discontinuous aquifers;
- permeability and porosity is highly variable depending on degree of weathering and interconnectedness of jointing and/or fracturing;
- recharge mainly through direct infiltration of rainfall, overland flow and surface water flow in rock outcrop areas where no substantial clay barriers exist in the shallow subsurface and vertical seepage from overlying aquifers;
- discharge is generally through flow into adjacent or underlying older formations and evapotranspiration;
- groundwater quality is variable ranging from brackish to saline; and
- considered unlikely to represent a significant groundwater supply given the isolated and sporadic occurrence of groundwater and highly variable permeability and porosity.

3.2.4 Triassic aquifers

The Triassic aquifer refers to the Clematis Sandstone. The Moolayember Formation is a recognised aquitard generally overlying and confining parts of the Clematis Sandstone. The distribution of the Clematis Sandstone and Moolayember Formation has mostly eroded but a few remnants occur as outcrops northeast of the MGP. These two formations form part of the basal section of GAB recharge beds (Pearce and Hansen, 2006). The Triassic Rewan Formation, present in the eastern portion of the MGP area, is considered to be a regional-scale confining unit (aquitard) along most of the central axis of the Bowen Basin but is absent from the east and west flanks of the Bowen Basin.

Key aquifer characteristics are:

- Rewan Formation:
 - the average groundwater level at around 25 mbgl;
 - highly variable in permeability and porosity and limited in lateral and vertical extent;
 - groundwater quality collected from the one monitoring bore in the Rewan Formation classed the groundwater as saline;
 - recharge is localised and mainly through direct infiltration of rainfall, overland flow and surface water flow in outcrop areas;
 - discharge is localised and generally via through flow into adjacent or underlying older formations and evapotranspiration; and
 - groundwater use in the MGP area is unknown and given the limited extent of this aquifer, groundwater supply is likely to be isolated.
- Clematis Sandstone:
 - the average groundwater level is around 52 mbgl;
 - highly variable in permeability and porosity and limited in lateral and vertical extent;
 - Clematis Sandstone aquifer has a localised presence to only a few small outcrops in the Project Area;
 - the Clematis Sandstone aquifer has moderate to good permeability;
 - recharge is localised and mainly through direct infiltration of rainfall, overland flow and surface water flow in outcrop areas;
 - discharge is localised and generally via through flow into adjacent or underlying older formations and evapotranspiration; and
 - groundwater use targeting the sandstone is unknown.

3.2.5 Permian aquifers

The two dominant Permian formations within the MGP Area are the Blackwater Group and the Back Creek Group. Coal seams within these two groups tend to be more permeable than the other strata present and hence at a regional scale these units typically form aquitards. Coal seams of the Blackwater Group, which include the RCM, FCCM and MCM, are continuous across the MGP and have been extensively mined along the western margin of the Bowen Basin, in particular the Goonyella Middle (GM) seam within the MCM which is also the primary target seam for the MGP (see Section 3.1.1.1).

Key aquifer characteristics are:

- Blackwater Group:
 - the recorded pressures associated with the Back Creek Group indicate artesian groundwater pressures;
 - low to moderately permeable coal seams;
 - recharge is limited and generally via direct infiltration of rainfall and overland flow as well as downward seepage from overlying aquifers where no clay barriers exist in outcropping/ subcropping areas;
 - discharge is generally through flow into adjacent (outcropping or sub-cropping coal seams) aquifers or seepage into underlying aquifers (via structural discontinuities) and groundwater extraction (CSG, incidental mine gas management, and mine dewatering activities);
 - groundwater quality is generally poor, however varies from being fresh to saline;
 - groundwater resources associated with the Blackwater Group are typically contained in porous sandstones and fractured shale and siltstones; and
 - confined by low permeability overburden and interburden as well as the overlying Rewan Formation where it exists.

- Back Creek Group:
 - low to moderately permeable coal seams;
 - recharge is limited and generally via direct infiltration of rainfall and overland flow as well as downward seepage from overlying aquifers where no clay barriers exist in outcropping / subcropping areas;
 - discharge is generally through flow into adjacent (outcropping or sub-cropping coal seams) aquifers or seepage into underlying aquifers (via structural discontinuities) and groundwater extraction (CSG, incidental mine gas management, and mine dewatering activities);
 - confined by low permeability overburden and interburden as well as the overlying Rewan Formation where it exists; and
 - groundwater quality is generally poor, however varies from being fresh to saline.

4 Water monitoring strategy

4.1 Groundwater monitoring program

A water monitoring strategy (WMS) is required for the MGP UWIR, which incorporates the development of a groundwater monitoring program to undertake the following:

- site and regional groundwater level monitoring data in the deeper aquifers;
- site and regional groundwater level and quality monitoring data in the shallow aquifers;
- assessment of site aquifer parameters for shallow and deep aquifers through model calibration;
- characterisation of interconnectivity of aquifers underlying the site; and
- characterisation of surface water – groundwater interaction (particularly with Isaac River on-site).

To meet the WMS objectives, a groundwater monitoring program has been implemented that includes a representative suite of bores in the shallow and deep groundwater systems (Figure 4.1). The major groundwater systems that are monitored include:

- shallow groundwater systems (water-table) comprised of:
 - Quaternary and Tertiary colluvium and alluvium;
 - Tertiary basalt and other Tertiary sediments; and
 - Triassic outcrop areas (i.e. Rewan Formation).
- deep groundwater systems that include confined aquifers in the following Permian units:
 - Blackwater Group at the CSG target depths, and
 - Blackwater Group sub-crops including the Rangal Coal Measures, Fort Cooper Coal Measures and Moranbah Coal Measures.

The MGP groundwater monitoring program is discussed in more detail in Sections 4.1.1 to 4.1.6 of this report.

4.1.1 Groundwater monitoring network

A regional aquifer groundwater monitoring network has been developed and implemented for the MGP UWIR, the purpose of which is to monitor the any observed decline in groundwater level and establish baseline groundwater level and groundwater quality data. As shown in Figure 4.1 and summarised in Table 4.1 the monitoring network comprises a total of 20 monitoring points installed at 17 locations. No additional monitoring points have been added since the previous UWIR for the MGP (Arrow Energy, 2022).

As shown in Table 4.1 the monitoring network comprises ten monitoring points in the shallow aquifer system, including Quaternary alluvium, Tertiary basalt, Tertiary sediments, weathered FCCM and the Triassic Rewan Formation. The deep monitoring network comprises ten monitoring points at seven monitoring bore locations in the FCCM, MCM and Back Creek Group and includes three nested monitoring sites (sites M313W, M314W and M324W). Further details regarding the shallow and deep monitoring network are provided in Section 4.1.1.1 and Section 4.1.1.2, respectively.

To meet the monitoring objectives of the MGP WMS, the monitoring bores listed in Table 4.1 are subject to measurement of groundwater levels and testing of water quality parameters. Monitoring details, including monitoring frequency, monitoring procedure and tested parameters are described in further detail in Section 4.1.2 to Section 4.1.6.

4.1.1.1 Shallow monitoring network

The current shallow groundwater monitoring network includes six groundwater monitoring bores to monitor groundwater levels in the Quaternary alluvium and Tertiary units within PL 191. These bores are located in areas where sensitive ecosystems exist in association with the Isaac River where long term drawdowns exceeding 5 m were previously predicted in the underlying MCM due to the MGP operations (Arrow Energy, 2022). Shallow formations (alluvium and Tertiary basalt) at these locations have a high environmental value and are more likely to be used as a groundwater source. Whilst impacts greater than the bore trigger threshold are not predicted to occur in these shallow formations (Arrow Energy, 2022), groundwater monitoring has been undertaken in these bores to ensure that an adequate baseline dataset has been established and to monitor any potential impacts.

The remaining two shallow monitoring bores are located within PL 224 and PL223 to monitor the weathered FCCM and shallow part of the Rewan Formation, respectively.

Shallow monitoring point M230W (targeting the weathered Tertiary Basalt) was replaced in late 2021 with monitoring point M300W, as the groundwater level decline observed in M230W between Q3 and Q4-2017 are considered to have been influenced by the nearby Anglo underground mining operations. As discussed in the 2016 UWIR (Arrow Energy, 2016) a similar decline was observed in shallow monitoring point M340W which has been dry since July 2017.

4.1.1.2 Deep monitoring network

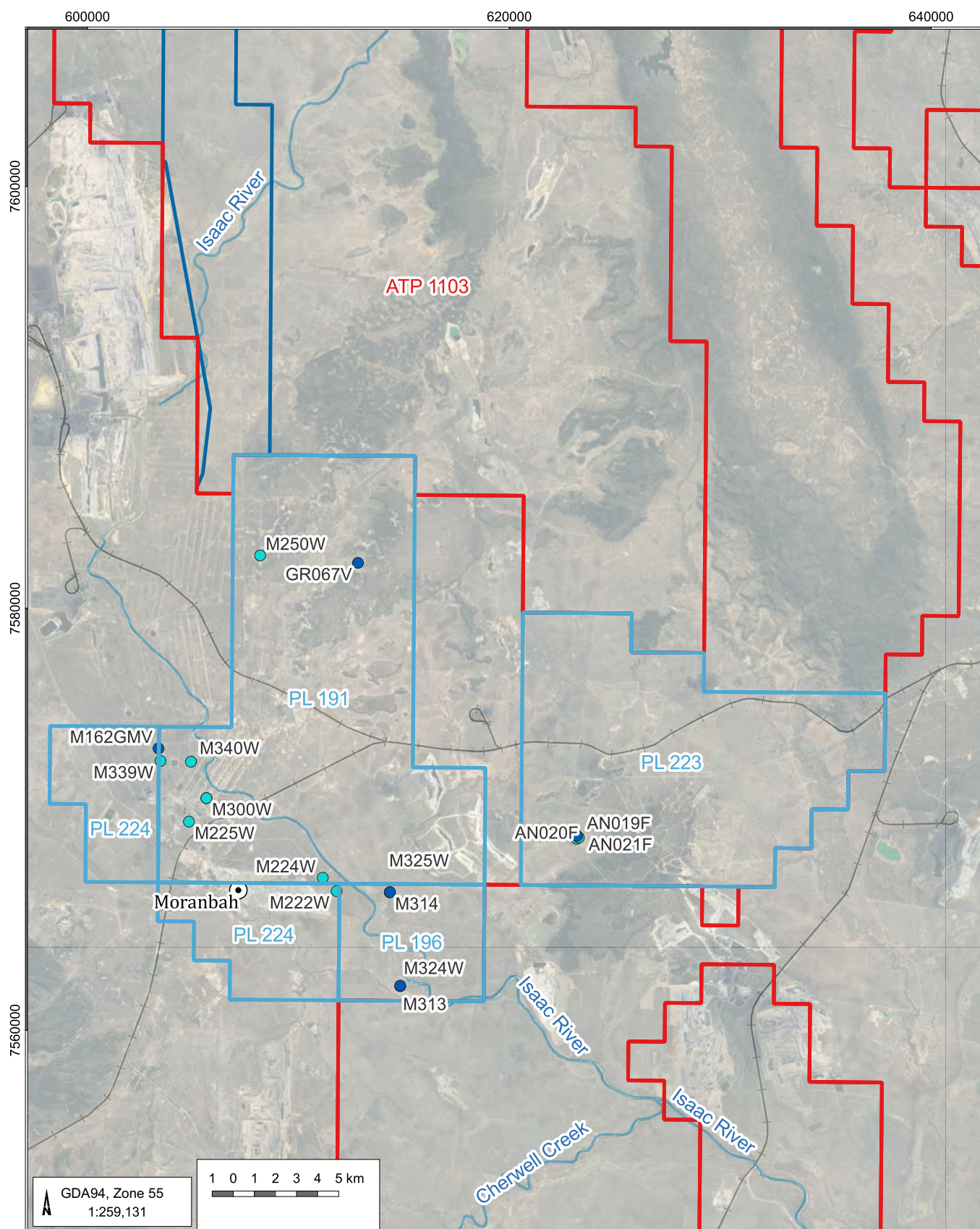
Based on previous groundwater impact predictions in the 2012 EIS (Arrow Energy, 2012a) and predicted IAA and LAA areas for the MGP reported in previous UWIRs (Arrow Energy, 2016; Arrow Energy, 2019 and Arrow Energy, 2022), four deep groundwater bores have been installed within PLs 191, 196 and 224 to monitor the FCCM, MCM (coal measures targeted by the MGP) and the underlying Back Creek Group. One further deep monitoring bores (AN019F) was installed, together with two shallow monitoring points AN020F and AN021F, to monitor potential impacts on existing landholder bores on PL 223 and to provide background monitoring at locations which are not expected to experience any CSG related drawdown.

Table 4.1 MGP groundwater monitoring network

Bore	Monitoring point	Shallow/Deep	Monitoring target	Development area
M339W	M339W	Shallow	Weathered Tertiary basalt	PL191
M225W	M225W	Shallow	Weathered Tertiary basalt	PL191
M340W	M340W	Shallow	Weathered Tertiary basalt	PL191
M230W (replaced by M300W) ¹	M230W	Shallow	Weathered Tertiary basalt	PL191
M300W	M300W	Shallow	Weathered Tertiary basalt	PL191
M250W	M250W	Shallow	Tertiary Sediment	PL191
M224W	M224W	Shallow	Quaternary Alluvium	PL191
M222W	M222W	Shallow	Weathered Fort Cooper Coal Measures	PL224
M313W (nested)	m313_gm_1p	Deep	Moranbah Coal Measures (QA Seam)	PL196
	m313_bk_1p	Deep	Back Creek Group	PL196
M314W (nested)	m314_gm_1p	Deep	Moranbah Coal Measures (QA Seam)	PL196
	m314_gm_1p	Deep	Back Creek Group	PL196

Bore	Monitoring point	Shallow/Deep	Monitoring target	Development area
M324W (nested)	m324_fl_1p	Deep	Fort Cooper Coal Measures	PL196
	m324_qa_1p	Deep	Moranbah Coal Measures (QA Seam)	PL196
M325W	M325W	Deep	Fort Cooper Coal Measures	PL196
GR067V	GR067V	Deep	Moranbah Coal Measures	PL191
M162V	M162V	Deep	Moranbah Coal Measures	PL224
AN019F	AN019F	Deep	Fort Cooper Coal Measures	PL223
AN020F	AN020F	Shallow	Rewan Formation	PL223
AN021F	AN021F	Shallow	Tertiary Sediment	PL223

Note: ¹M230W was replaced by M300W due to mining impact impacting the water level.



- ⊙ Populated place
- Major water course
- Rail
- Deep monitoring wells
- Shallow monitoring wells
- ATP (Arrow, BGP)
- PL (QPME, MGP)
- PL (Arrow, BGP)

Bowen (BOW5001)

Groundwater monitoring network – MGP



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FIGURE No:
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4.1.2 Groundwater monitoring frequency

Groundwater monitoring frequencies for existing MGP WMS bores are summarised in Table 4.2.

Table 4.2 MGP WMS groundwater monitoring frequency

Bore	Shallow/Deep	Monthly Water Level	6 Monthly Water Quality	6 Monthly Water Level	Annual Water Quality
M339W	Shallow	June 2012 to January 2016		January 2016 Onwards	
M225W	Shallow	June 2012 to January 2016		January 2016 Onwards	
M340W	Shallow	June 2012 to January 2016		January 2016 Onwards	
M230W	Shallow	June 2012 to January 2016		January 2016 to June 2021	
M300W	Shallow	June 2012 to January 2016		November 2021 Onwards	
M250W	Shallow	June 2012 to January 2016		January 2016 Onwards	
M224W	Shallow	June 2012 to January 2016		January 2016 Onwards	
M222W	Shallow	July 2014 to January 2016		January 2016 Onwards	
M313W (nested)	Deep	July 2014 to January 2016		January 2016 Onwards	
M314W (nested)	Deep	July 2014 to January 2016		January 2016 Onwards	
M324W (nested)	Deep	July 2014 to January 2016		January 2016 Onwards	
M325W	Deep	November 2015 to November 2016		January 2016 Onwards	No Water Quality Monitoring
GR067V	Deep	November 2015 to November 2016		December 2016 Onwards	
M162V	Deep	November 2015 to November 2016		December 2016 Onwards	
AN019F	Deep	November 2015 to November 2016		December 2016 Onwards	
AN020F	Shallow	November 2015 to November 2016		December 2016 Onwards	
AN021F	Deep	June 2012 to January 2016		January 2016 Onwards	No Water Quality Monitoring

Consistent with the previous 2022 UWIR (Arrow Energy, 2022), groundwater quality monitoring is proposed to be undertaken on a six-monthly basis for a period of 12 months for any new WMS bores for the MGP (none proposed in this UWIR) and thereafter groundwater quality monitoring is proposed to be undertaken annually for the remainder of the CSG operations.

The groundwater monitoring frequency is based on:

- limited groundwater level variation from climatic or seasonal fluctuations due to the depth of these confined formations (low recharge) and low permeability – for determining baseline levels;
- length of time over which groundwater level impacts develop as a result of the CSG development;
- stability of groundwater quality in these low permeability formations, and the delayed impact of CSG development on groundwater quality (if there is any impact on groundwater quality) relative to impact on groundwater levels (as change in groundwater quality is dependent on inducing flow); and
- data will be reviewed on an annual basis and presented in the annual review report to DETSI as prescribed in Section 9. This review will include a comparison of groundwater data to groundwater model predictions.

Following the establishment of baseline groundwater quality, the frequency of sampling and analyses may be modified for some or the entire suite of chemical parameters.

4.1.3 Groundwater monitoring procedure

Groundwater monitoring will be conducted in accordance with the following guidelines and standards:

- DES's 2018 Monitoring and Sampling Manual (DES, 2018);
- AS/NZS 5667.1:1998 Water quality - Sampling - Guidance on the design of sampling programs, sampling techniques and the preservation and handling of samples; and
- AS/NZS 5667 series water quality sampling Australian Standards and the Groundwater Sampling and Analysis – A Field Guide (Geoscience Australia, 2009).

During monitoring events, visual inspections will be undertaken by field staff to provide an assessment on bore integrity. Any observed bore defects will be noted and reported with follow up maintenance actions proposed. This aims to ensure that each monitoring point is maintained and in a secured and operating condition.

4.1.4 Groundwater monitoring parameters

The proposed field parameters and the laboratory analytical schedule for groundwater samples are listed in Table 4.3 and Table 4.4 below respectively.

Table 4.3 Field parameters monitoring suite

Parameter	
Temperature (°C)	Redox Potential (Eh)
Electrical Conductivity (EC)	Dissolved Oxygen (DO)
pH	-

Table 4.4 Chemical parameters monitoring suite

Parameter	
EC and Total Dissolved Solids (TDS)	Calcium (Ca ²⁺)
Total Alkalinity	Sodium (Na ⁺)
Bicarbonate/Carbonate HCO ₃ ⁻ /CO ₃ ²⁻	Potassium (K ⁺)
Fluoride (F ⁻)	Magnesium (Mg ²⁺)
Strontium (Sr)	Nitrite (NO ₂ ⁻), Nitrate (NO ₃ ⁻), Ammonia (NH ₄ ⁺)
Chloride (Cl ⁻)	Total Phosphorous (PO ₄ ³⁻)
Sulphate (SO ₄ ²⁻)	Total and Dissolved organic carbon (TOC/DOC)
Dissolved Methane (CH ₄)	Metals (dissolved): arsenic (As), barium (Ba), boron (B), chromium (Cr), cobalt (Co), Copper (Cu), Iron (Fe), Lead (Pb), manganese (Mn), molybdenum (Mo), nickel (Ni), zinc (Zn)

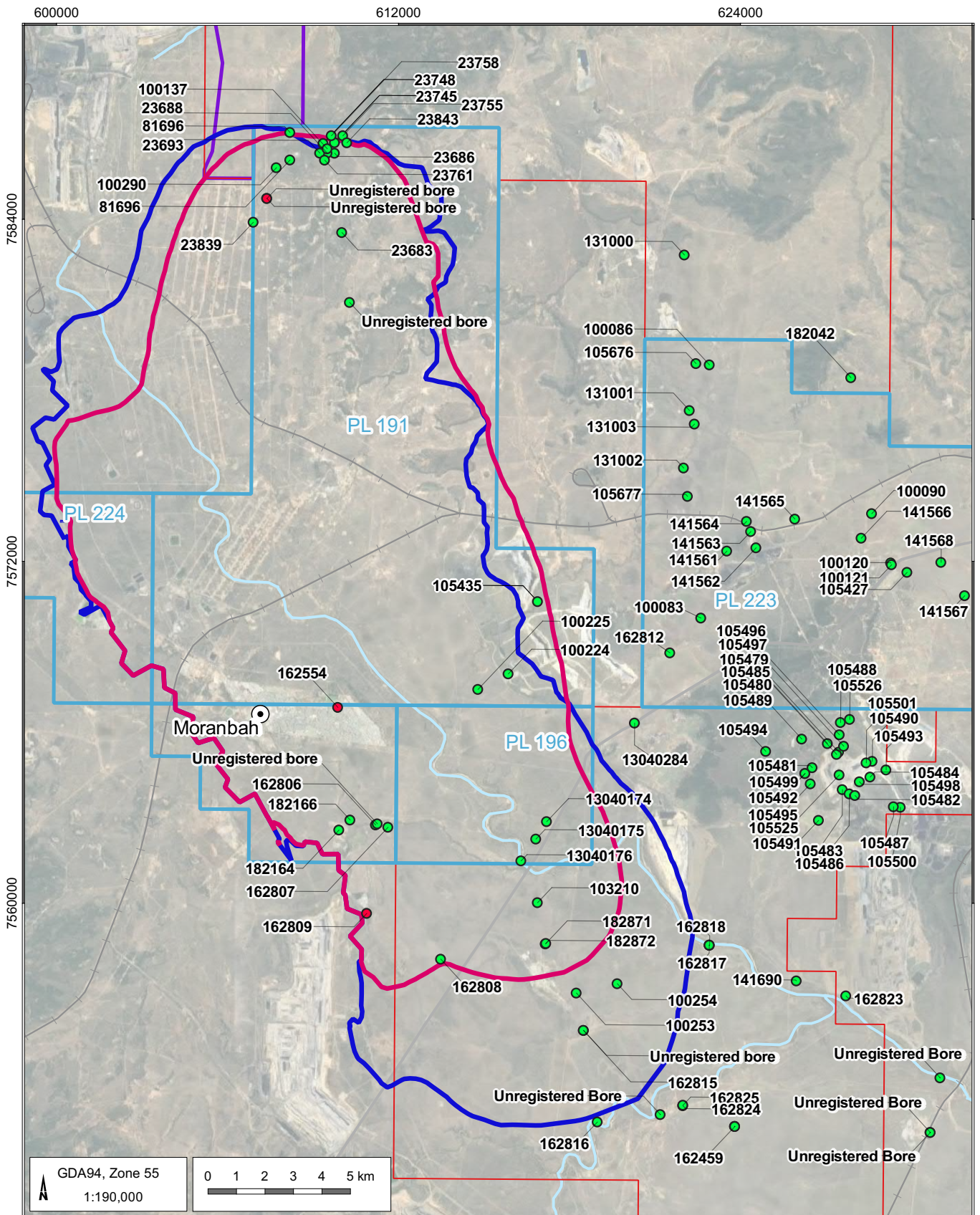
4.1.5 Assessment of aquifer parameters

Groundwater pressure data collected as part of the WMS will provide the basis for future groundwater model updates. As part of this, re-calibration of the numerical groundwater model using transient groundwater level data will enable the refinement of parameterisation of hydraulic property values.

4.1.6 Baseline assessment parameters

Under section 397 of the *Water Act (Qld) 2000* petroleum tenure holders are required to develop and implement an appropriate baseline assessment program. To fulfill these obligations as the new tenure holder for the MGP, QPME has prepared a revised baseline assessment plan (BAP). This plan was approved separately by DETSI on 3 March 2026 and is included in Appendix D.

Figure 4.2 presents the priority baseline assessment and LAA area (i.e. the areas where more than 5 m of drawdown is anticipated in the MCM in the long term) and identifies those landholder bores for which a baseline assessment has already been completed by the previous tenure holder and lodged with OGIA. The BAP identifies three additional bores (Registered bore RN162554, Registered bore RN162809 and unregistered bore AEN1300) which had not been previously assessed. The BAP therefore includes a commitment that baseline assessments at these bores will be undertaken as soon as possible, i.e. by 30 April 2026.



LEGEND

- Populated place
- Qld rail network (DERM)
- Arterial roads (Qld)
- Major drainage
- Long-term Affected Area (LAA)
- Priority area for MGP baseline assessment

- PL (QPME, MGP)
- PL (Arrow, BGP)
- ATP (Arrow, BGP)

- MGP baseline assessment bores**
- Baseline assessment undertaken
 - Baseline assessment not undertaken

Bowen (BOW5001)

Priority area for the MGP baseline assessment and baseline assessment bores



AGE

DATE
17/03/2026

FIGURE No:
4.2

4.2 Water production monitoring

The quantity of water taken during production of CSG will be monitored according to the process described in Section 2.

5 QPME monitoring results

Groundwater monitoring has been undertaken by QPME in accordance with the UWIR WMS groundwater monitoring network described in Section 4.1.1 at the locations shown in Figure 4.1. Groundwater monitoring results are presented in more detail in the following sections. Since the previous UWIR (Arrow Energy, 2022), three years of additional data (groundwater levels and water quality) have been collected and have been reviewed to identify any locations where the recent data are inconsistent with the current conceptual model and/or numerical model predictions.

5.1 Groundwater levels

5.1.1 Shallow UWIR monitoring data summary

Groundwater level monitoring has been undertaken in 10 shallow groundwater monitoring points which form part of the 2022 Bowen UWIR groundwater monitoring network for the MGP area. Further details of each monitoring point are provided in Table 5.1. Data are available for the following periods for each monitoring point:

- monitoring since June 2012 for monitoring points M339W, M225W, M340W, M230W, M250W, M224W, M222W;
- monitoring since March 2016 for monitoring points AN020F and AN021F; and
- monitoring since November 2021 for monitoring M300W.

Table 5.1 Shallow groundwater monitoring points

Point ID	Total Constructed Depth (m)	Screen Interval (mbgl)	Screened Formation
M339W	41.0	35.0 – 41.0	Weathered Tertiary Basalt
M225W	34.0	23.0 – 34.0	Weathered Tertiary Basalt
M340W	27.3	19.3 – 27.3	Weathered Tertiary Basalt
M230W ¹	32.0	29.0 – 32.0	Weathered Tertiary Basalt
M300W	30.0	24.0 – 30.0	Weathered Tertiary Basalt
M250W	56.5	44.5 – 56.5	Tertiary Sediment
AN021F	27.0	20.0 – 22.0	Tertiary Sediment
M224W	32.5	26.5 – 32.5	Quaternary Alluvium
M222W	30.2	20.0 – 26.0	Weathered Fort Cooper Coal Measures
AN020F	77.0	70.0 – 72.0	Rewan Formation

Notes: ¹M230W was replaced by M300W due to underground coal mining impact impacting the water level.

²Screened interval could not be determined due pumping infrastructure.

The groundwater level monitoring results for the shallow groundwater monitoring points are shown in Appendix A. Hydrographs are presented in Figure 5.1 and Figure 5.2 and are discussed below.

As shown in Figure 5.1, observed groundwater levels in the shallow aquifer system range from:

- 200 to 209 m Australian Height Datum (AHD) in the weathered Tertiary Basalt aquifer;
- 233 to 243 m AHD in the Tertiary sediment aquifer;
- 208 to 212 m AHD in the Quaternary alluvium aquifer;
- 202 to 206 m AHD in the weathered FCCM; and
- 236 to 239 m AHD in the Rewan Formation.

These observed ranges have not significantly changed since the previous 2022 UWIR and no significantly different temporal trends are observed in Figure 5.1 based on the updated monitoring records presented in this UWIR, except for monitoring data for bore M300W (replacement point for 230W which was impacted by underground mining).

Reported data for M300W only comprised one measurement in the previous UWIR (Arrow, 2022). Updated records for M300W now comprise three years of monitoring data showing groundwater levels between 200 and 204 mAHD which is within the observed groundwater range at other monitoring points installed in the Tertiary Basalt (see Figure 5.2). Whilst a decline of 3.4 m can be observed in M300W between June 2022 and November 2023 recent observed levels at the monitoring point remain above the initial reading. Furthermore, as would be expected for a shallow monitoring point the available data show a similar pattern of variation to the CRD curve which suggest that the recent decline is a reflection of relatively dry conditions which prevailed during 2022 and 2023.

Consistent, with the previous UWIR for the MGP (Arrow Energy, 2022), the monitoring data in Figure 5.1 do not suggest any impacts of CSG production to groundwater levels in the shallow groundwater system including the Quaternary alluvium, weathered Tertiary basalt, Tertiary sediment, shallow weathered FCCM and Rewan Formation. This data does not suggest any changes to the conceptual model presented in Arrow Energy (2022) and generally supports the updated groundwater impact predictions presented in Section 7.3. These predictions show no predicted IAA or LAA for unconsolidated aquifers related to extraction from the MGP as modelled drawdown does not exceed the bore trigger threshold of two metres.

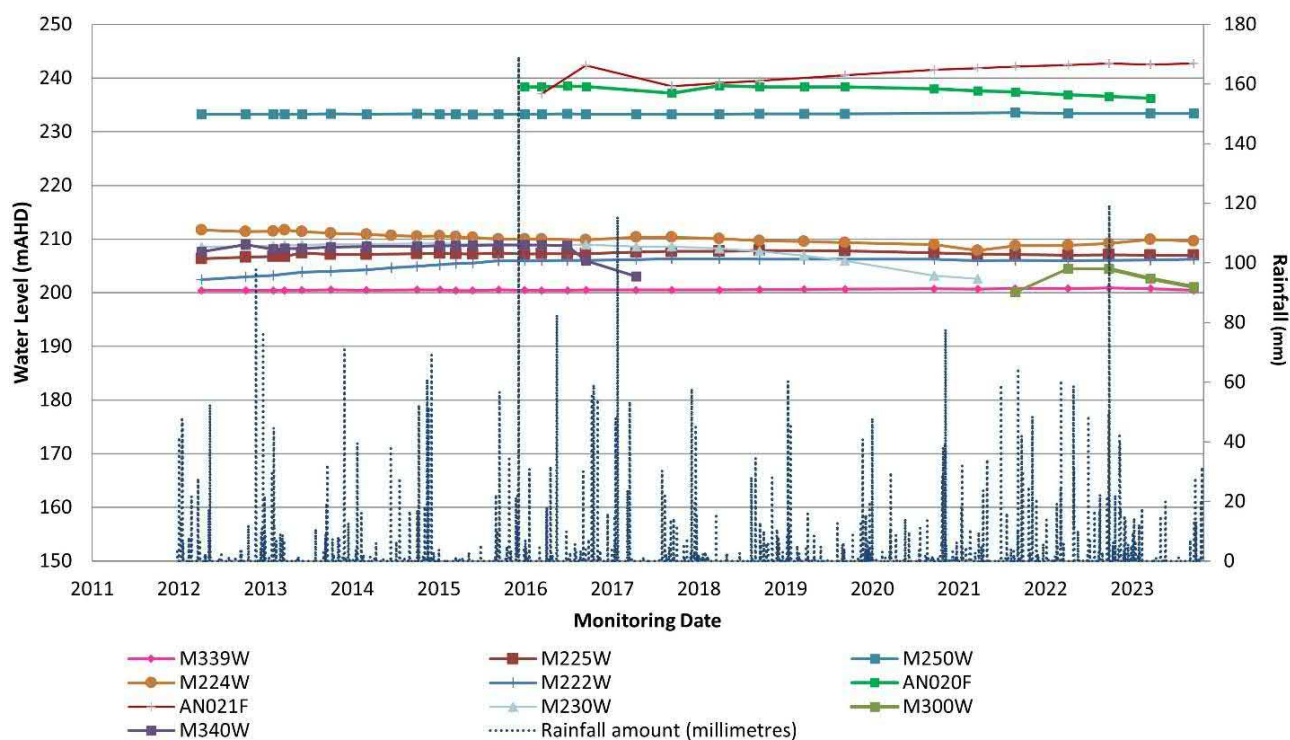


Figure 5.1 Shallow Bores Water Level Monitoring Results – MGP

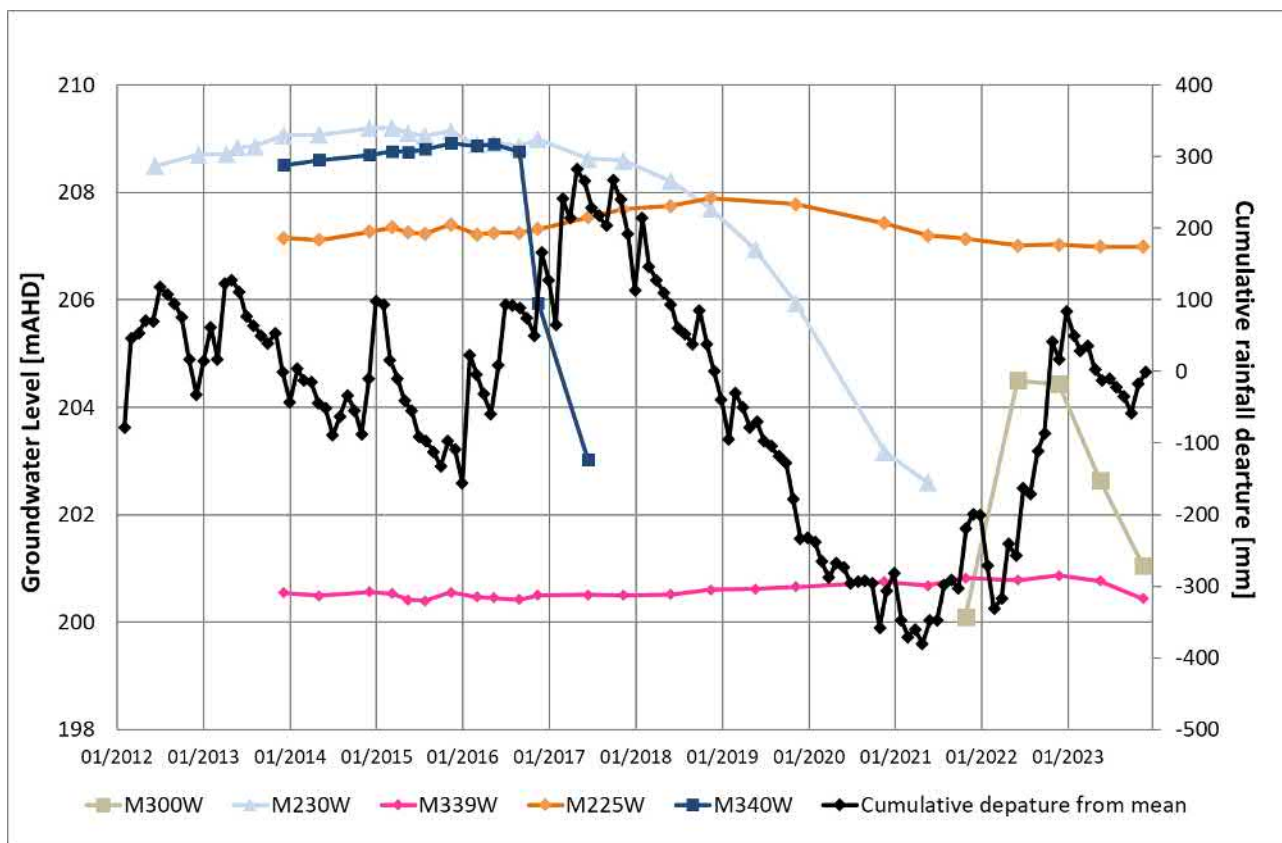


Figure 5.2 Cumulative rainfall departure and groundwater levels for weathered Tertiary Basalt

5.1.2 Deep UWIR monitoring data summary

Groundwater level monitoring has been undertaken in nine deep groundwater monitoring points which form part of the 2025 MGP UWIR groundwater monitoring network. Table 5.2 provides additional details for these points. Data are available for the following periods for each bore/monitoring point:

- monitoring since September 2014 for bores M313W, M314W, M324W;
- monitoring since February 2015 for bore M325W;
- monitoring since November 2015 for bores AN019F
- monitoring since December 2015 for bore M162V; and
- monitoring since February 2016 for bore GR067V.

Table 5.2 Deep groundwater monitoring points

Bore ID	Monitoring ID	Total Constructed Depth (m)	Screen Interval (mbgl)	Screened Formation
M313W	m313_gm_1p	532.4	313.0 – 316.5	Moranbah Coal Measures (QA Seam)
	m313_bk_1p		507.0 – 510.0	Back Creek Group
M314W	m314_gm_1p	560.5	210.5 – 213.5	Moranbah Coal Measures (QA Seam)
	m314_bk_1p		551.5 – 553.5	Back Creek Group
M324W	m324_fl_1p	240.0	163.0 – 166.0	Fort Cooper Coal Measures
	m324_qa_1p		187.0 – 190.0	Moranbah Coal Measures (QA Seam)
M325W	M325W	202.3	180.5 – 182.0	Fort Cooper Coal Measures
AN019F	GR067V	290.0	269.0 – 271.0	Fort Cooper Coal Measures
M162V	M162V	276.0	252.0 – 256.0	Moranbah Coal Measures
GR067V	AN019F	610.9	543.2 – 610.9	Moranbah Coal Measures

All observed groundwater level data for the deep groundwater monitoring network are shown in Figure 5.3. Based on Figure 5.3 the following deep monitoring points show relatively low groundwater levels were discussed in the previous UWIR (Arrow, 2022):

- Water levels at GR067V of as low as -150 mAHD are noted in April and August 2016, which are due to depressurisation activities associated with the conversion of the bore to a monitoring point. The recovery curve has subsequently stabilised and a standing water level of 204 mAHD is evident.
- Monitoring data from M325W in the FCCM has exhibited a consistently increasing groundwater level trend since monitoring commenced in 2014. As the starting water level of the bore is unknown and cannot be determined, including the ongoing increase in water level in the bore, the bore trigger threshold has not been applied to the monitoring bore.
- Monitoring bore M162V shows groundwater levels ranging between 60 and 100 mAHD and is located around 470 m from the current production well M134GMV within the MCM, as such this drawdown is expected and water levels will likely continue to decline in this monitoring point as production continues.

Given the large observed groundwater level range due to the observed data for GR067V, M325W and M162V, the observed groundwater levels for the deep groundwater monitoring network are also presented in Figure 5.4 to better display observed groundwater level trends between 130 mAHD and 220 mAHD.

Based on Figure 5.3 and Figure 5.4, observed groundwater levels range from:

- 206 to 216 m AHD in the Back Creek Group;
- 50 to 205 m AHD in the FCCM when considering all data, and showing a range between 196 and 204 mAHD when excluding results from M325W (see also Figure 5.5); and
- -129 to 204 m AHD in the MCM when considering all data and showing a range between 65 mAHD and 204 m AHD when excluding the early low groundwater level measurements at GR067V due to bore conversion.

Additional data for the deep monitoring network does not show significant changes compared to the results presented and discussed in the previous UWIR (Arrow Energy, 2022) and suggests that CSG impacts due to the MGP are contained within the MCM and FCCM. Compared to the previous UWIR (Arrow Energy, 2022), no additional monitoring points were identified where more than 5 m of drawdown can be observed. As reported in Arrow Energy (2022), data for the following monitoring points show water level declines of 5 m or more:

- Data for nested monitoring location M314W shows a decline of up to 9.5 m in the Back Creek Group (see M314W Back Creek in Figure 5.4). At this monitoring location a decline of 4.3 m is observed in the monitoring point in the upper portion of the MCM (Qa seam) (see M314W Moranbah CM in Figure 5.4), which decline can be attributed due to the nearby production at GM050V, which is located 660 m south of M314W. As the observed drawdown in the MCM, which is the formation targeted by the MGP, is greater than the observed drawdown in the Back Creek Group, it is considered unlikely that the observed drawdown in the Back Creek Group is caused by CSG activities.
- Data for M313W and M324W in the MCM show groundwater declines of 60 and 6 m respectively due to CSG activities at nearby production well GM052V, located 300 m to the southwest of these bores.
- Data for monitoring point M162V in the MCM, shows a steady groundwater level decline of 35 m since 2015 which is attributed to nearby extraction at CSG well M134GMV which located around 470 m to the north. Groundwater levels in this monitoring point are therefore expected to continue to decline due to ongoing CSG production activities.
- As mentioned earlier, drawdown of more than 5m is observed in monitoring bores GR067V and M325W, which are due to other causes than impacts from CSG extraction activities.

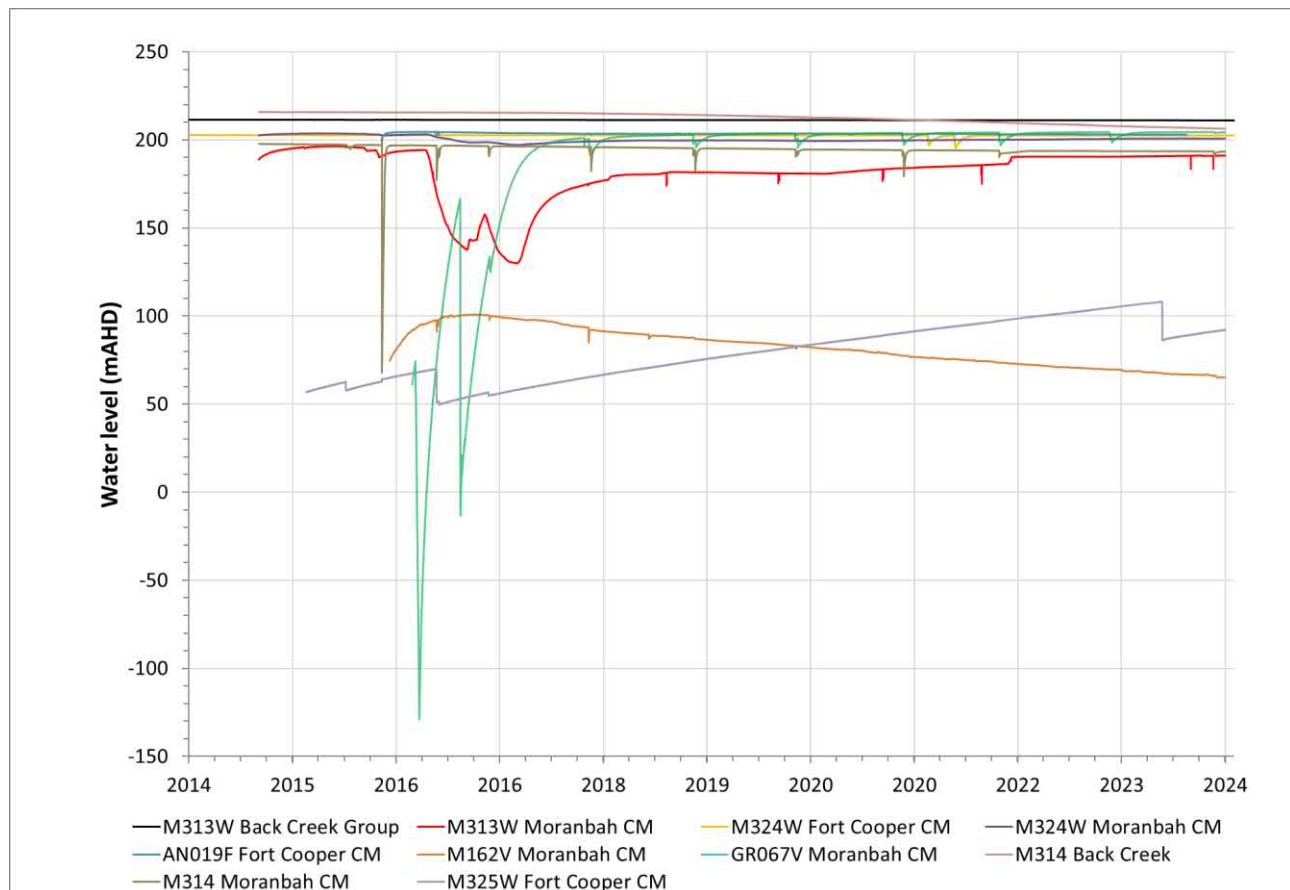


Figure 5.3 Water pressure monitoring results, deep monitoring points

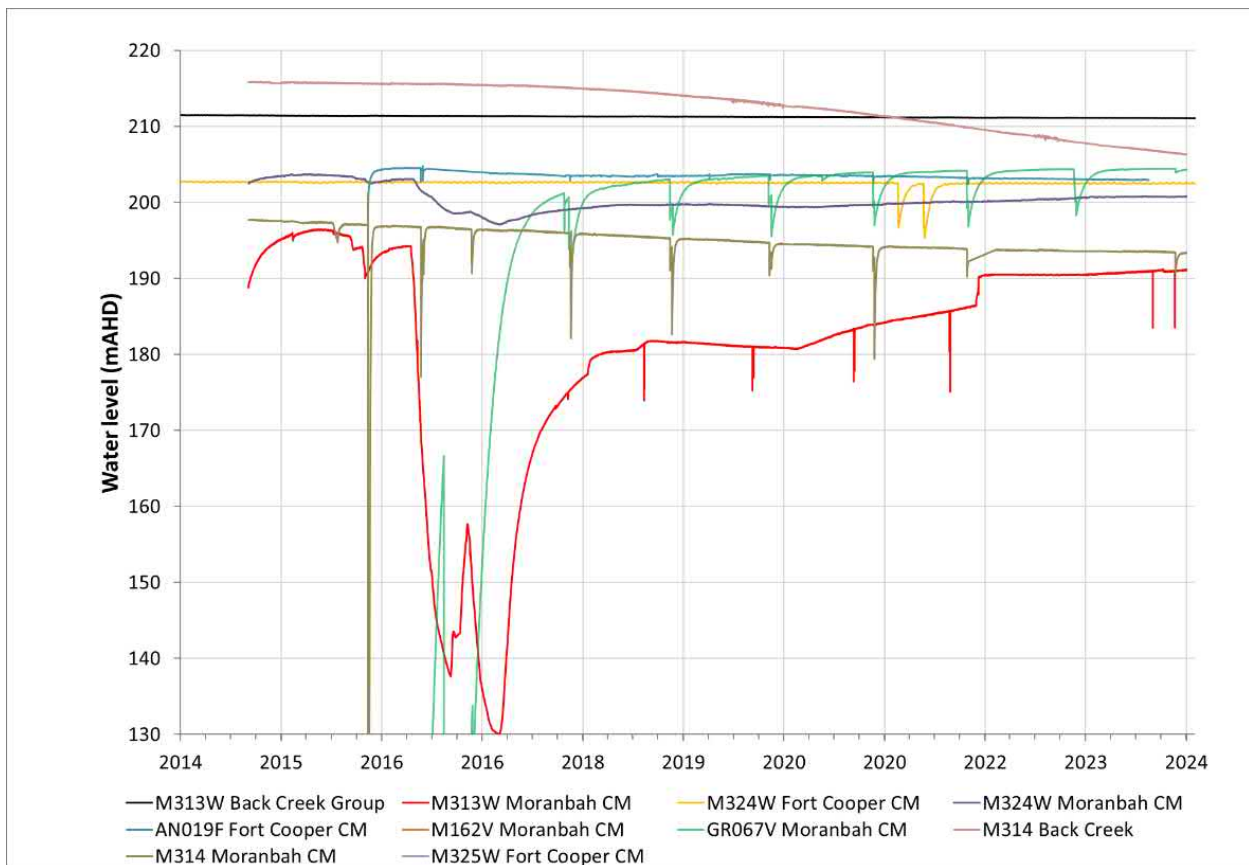


Figure 5.4 Water pressure monitoring results, deep monitoring points – clipped observation range

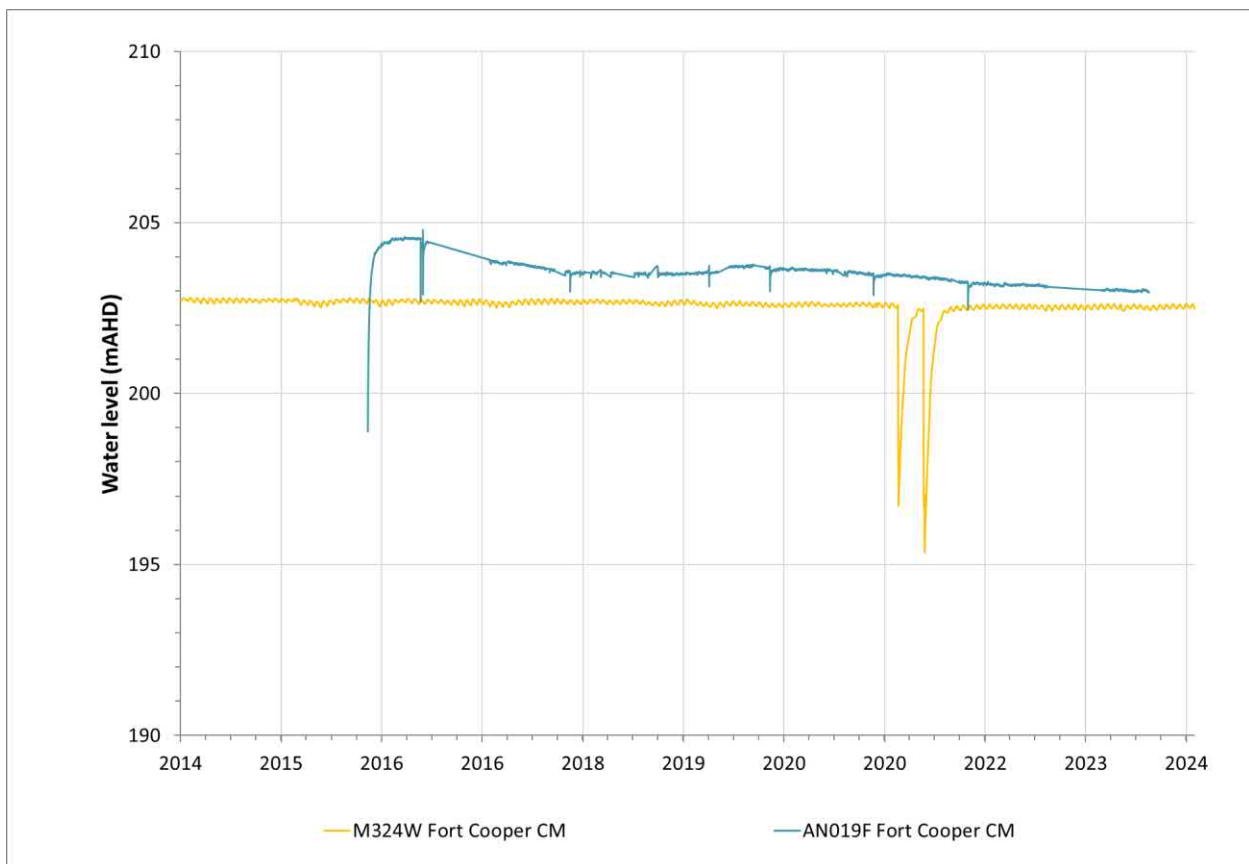


Figure 5.5 Water pressure monitoring results, FCCM (M324W and AN019F)

5.2 Groundwater flow

As described below, a review of vertical hydraulic gradients was also undertaken for two areas within MGP tenure where data is available from monitoring points in different hydrogeological formations that are in relative close proximity to one another.

5.2.1 Area 1

Area 1 comprises the following monitoring points which are listed from deepest to shallowest:

- Back Creek Group (M314W);
- Moranbah Coal Measures (M314W);
- Fort Cooper Coal Measures (M325W); and
- Shallow monitoring bores located approximately 3 km northwest from M314W and M325W, which are installed in the weathered Fort Cooper Coal Measures (M222W) and Quaternary Alluvium (M224W).

The monitoring points listed above are within active CSG production areas in the southern portion of the MGP and within 1 km of the Isaac River. Figure 5.6 shows the observed groundwater levels for Area 1 to review vertical groundwater level gradients in this region. The following can be noted for Area 1:

- as mentioned in Section 5.1.2 groundwater levels at bore M325W in the FCCM, exhibits relative low groundwater levels due to equilibration of groundwater levels at this monitoring location and does likely not reflect rest groundwater levels in this unit;
- a decline in water levels have been observed in M314W within MCM and the Back Creek Group, drawdown in the MCM at this location is thought to be related to nearby CSG operations (see Section 5.1.2);
- groundwater levels around 193 mAHD for the MCM, showing heads that are 13 m lower compared to the underlying Back Creek Group; and
- groundwater levels of 210 mAHD and 206 mAHD for shallow monitoring bores M224W (Quaternary alluvium) and M222W (shallow weathered FCCM) which are around 13 to 17 m higher compared to the observed groundwater levels in the MCM.

The groundwater levels reviewed for Area 1 suggest an apparent hydraulic gradient with potential for flow towards the MCM from the Back Creek Group and shallow formations, which is consistent with the fact that the MCM are the target coal seams for the MGP which are being depressurized as part of its CSG operations.

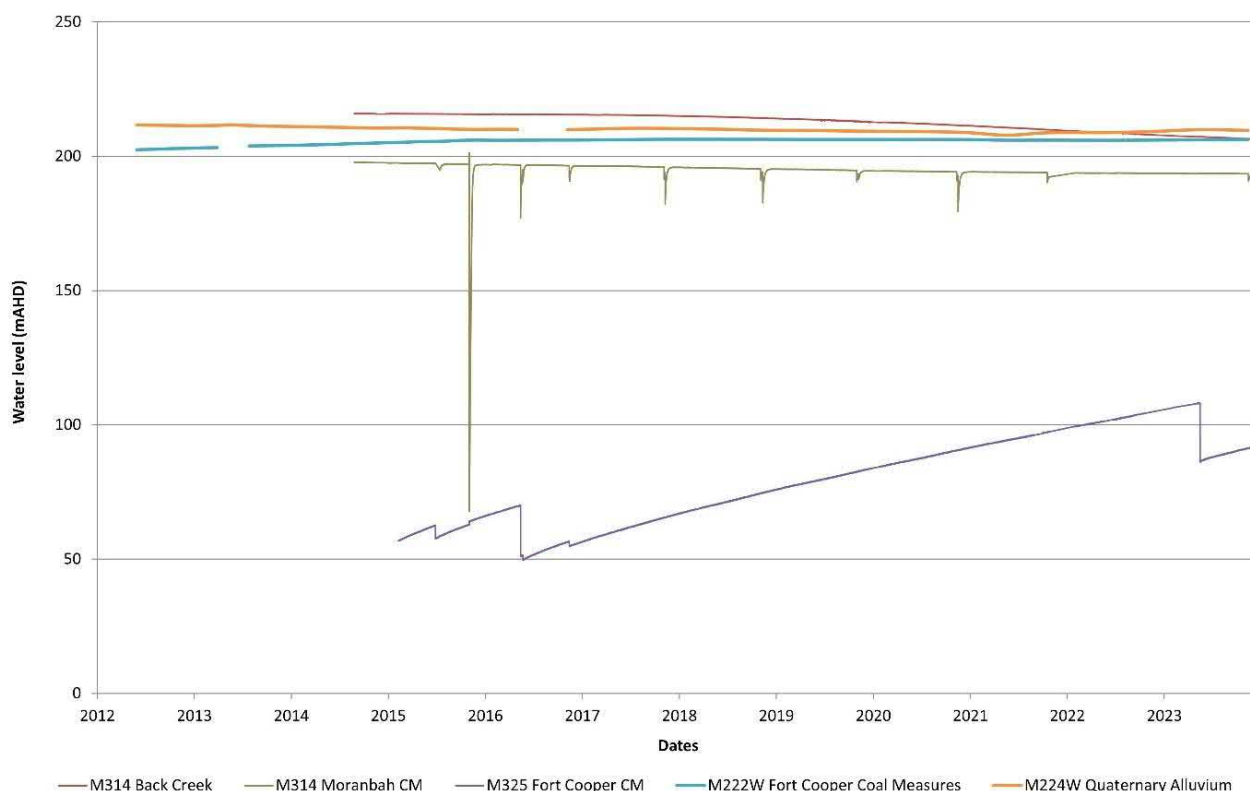


Figure 5.6 Observed groundwater levels at monitoring area 1

5.2.2 Area 2

Monitoring area 2, located near CSG production well GM052V in the southern portion of PL 226, includes the following monitoring points listed from deepest to shallowest formation:

- Back Creek Group (M313W);
- Moranbah Coal Measures (M313W);
- Moranbah Coal Measures (M324W); and
- Fort Cooper Coal Measures (M324W).

Figure 5.7 presents the selected groundwater level data for Area 2, for which the following observations can be made:

- drawdown due to nearby CSG extraction from the MCM aquifer is evident at monitoring points M313W and M324W, but since local production ceased in CSG well GM052V in April 2017 (Arrow Energy, 2022) recent water level recovery is evident at both monitoring points; and
- monitoring data for the FCCM and Back Creek Group in this area indicate a slight decline in water levels.

As reported in Arrow Energy (2022), the decline in water levels noted for the FCCM monitoring point at M324W was observed to correlate to the water production in CSG wells and consequential drawdown in the underlying MCM, which suggests that there is some transmission of impacts from the MCM to the overlying FCCM. Whilst there is some decline in observed water levels in the deeper Back Creek Group aquifer at monitoring location M313W, it does not clearly correlate to the water production in the CSG wells (Arrow Energy, 2022) and ongoing monitoring will confirm this.

Overall, based on the vertical hydraulic gradient analysis for Area 1 and Area 2, monitoring data suggests that impacts are predominantly contained within the MCM and FCCM, which is consistent with the impact predictions presented in Section 7.3.

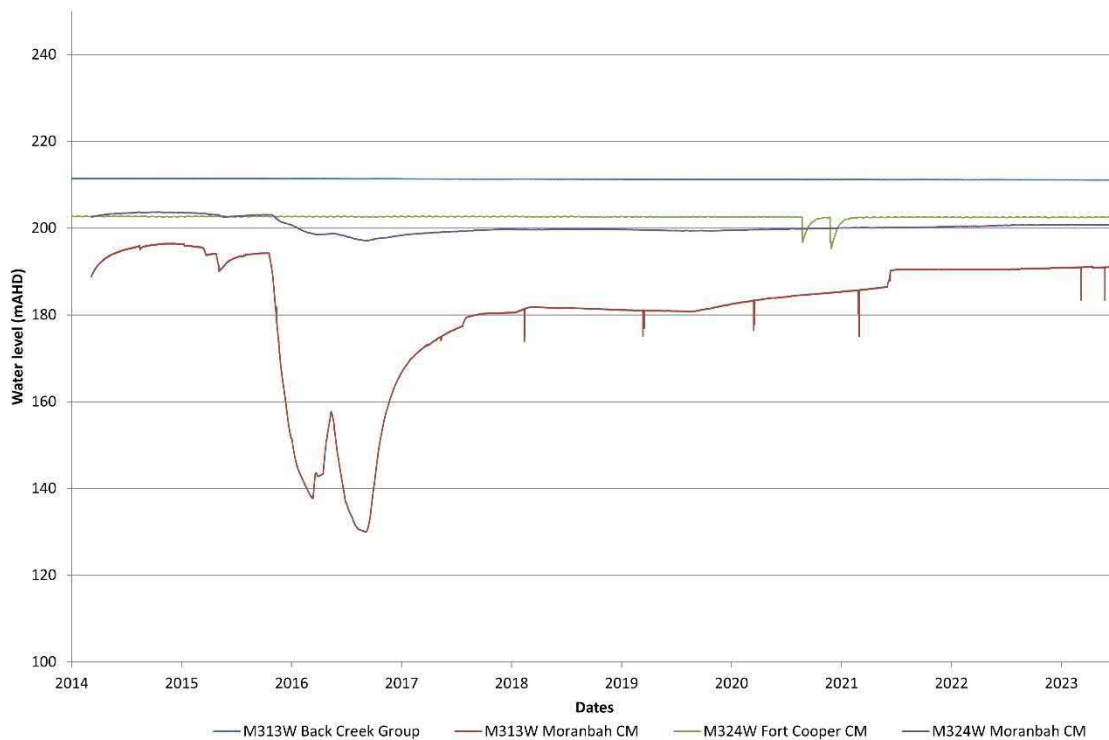


Figure 5.7 Observed groundwater levels at monitoring area 2

5.3 Groundwater quality

The purpose of the groundwater quality monitoring network is to determine the baseline groundwater quality in each aquifer and detect any unexpected changes in groundwater quality which could be attributed to CSG extraction. Results obtained via the shallow and deep monitoring networks are discussed below in Sections 5.3.1 and 5.3.2. Detailed groundwater quality results are included as Appendix B.

5.3.1 Shallow aquifer quality

Groundwater quality monitoring for PL 191, 196, 223 and 224 has been undertaken in eight shallow groundwater monitoring bores since June 2012. It should be noted that due to sampling difficulties at AN021F discussed in Arrow Energy (2016), an adjacent bore AN020F was drilled and completed into the Rewan Formation, which has been sampled since 13 May 2016 as a replacement (Arrow Energy, 2016). Summary statistics based on data collected for the eight shallow monitoring points (M339W, M225W, M340W, M230W, M250W, M224W, M222W and AN020F) are presented in Table 5.3.

No significant changes are observed in the updated water quality data for this UWIR, relative the previous UWIR (Arrow, 2022). As such, water quality ranges for each parameter and aquifer type remain similar compared to the previous UWIR and salinity ranges (as defined by the Environmental Protection Agency of South Australia) for the shallow hydrogeological units can be described as follows:

- groundwater quality of the quaternary alluvium varies from brackish to saline;
- groundwater quality of the tertiary basalt aquifer varies from brackish to saline;
- groundwater quality of the tertiary sediment aquifer is fresh to brackish;
- groundwater quality of the weathered coal measures is saline; and
- groundwater quality of the Rewan Formation is saline.

The shallow groundwater quality monitoring results are shown in Appendix B.

Table 5.3 Water quality – shallow monitoring points

Parameter	Units	Quaternary Alluvium		Tertiary Basalt		Tertiary Sediment		Weathered Coal Measures		Rewan Formation	
		Min	Max	Min	Max	Min	Max	Min	Max	Min	Max
Field pH	-	5.73	7.48	6.28	8.49	5.42	7.8	5.92	8.16	6.02	7.58
Electrical Conductivity	µS/cm	4,240	31,600	5,300	42,769	2,170	2650	9,090	11,700	9,590	11,200
Total Dissolved Solids	mg/L	2,360	27,000	3,000	29,000	1,300	2200	5,190	9,990	6,210	9,070
Hydroxide Alkalinity (OH-) as CaCO ₃	mg/L	<1	<5	<1	<5	<1	0	<1	<5	<1	<1
Carbonate Alkalinity as CaCO ₃	mg/L	<1	<5	<1	94	<1	0	<1	<5	<1	<1
Bicarbonate Alkalinity as CaCO ₃	mg/L	101	360	380	827	53	116	243	457	3	126
Total Alkalinity as CaCO ₃	mg/L	101	360	380	827	53	116	243	457	5	126
Sulphate, SO ₄	mg/L	541	6200	60	1140	28	106	78	196	<1	1
Chloride, Cl	mg/L	1,020	14,000	1,490	17,000	660	794	3,140	4,140	3,750	4,030
Calcium - Dissolved	mg/L	172	1,000	55	362	12	20	290	452	51	460
Magnesium - Dissolved	mg/L	107	1,400	85	808	<1	52	340	529	147	203
Sodium - Dissolved	mg/L	543	6,200	891	13,000	344	510	932	1,400	1,450	2,160
Potassium - Dissolved	mg/L	5	17	12	150	9	13	9	14	21	29
Arsenic-Dissolved	mg/L	<0.001	0.008	<0.001	0.003	<0.001	<0.001	<0.001	0.011	<0.001	<0.001

Parameter	Units	Quaternary Alluvium		Tertiary Basalt		Tertiary Sediment		Weathered Coal Measures		Rewan Formation	
		Min	Max	Min	Max	Min	Max	Min	Max	Min	Max
Beryllium-Dissolved	mg/L	<0.0005	0.193	<0.0005	<0.005	<0.0005	<0.001	<0.0005	<0.001	<0.001	<0.001
Barium-Dissolved	mg/L	0.045	0.2	0	0.283	0.047	1.06	0.184	3.9	3.42	5.34
Cadmium-Dissolved	mg/L	<0.0001	0.0002	<0.0001	0.7	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Chromium-Dissolved	mg/L	<0.001	0.015	<0.001	0.014	<0.001	0.076	<0.001	0.002	<0.001	<0.001
Cobalt-Dissolved	mg/L	<0.001	0.027	<0.001	0.005	<0.001	0.005	<0.001	0.002	<0.001	0.001
Copper-Dissolved	mg/L	<0.001	0.063	<0.001	0.094	<0.001	0.145	<0.001	0.036	<0.001	0.005
Lead-Dissolved	mg/L	<0.001	<0.01	<0.001	<0.005	<0.001	0.112	<0.001	<0.001	<0.001	<0.001
Manganese-Dissolved	mg/L	0.313	8.1	<0.005	0.611	0.003	0.095	1.1	2.03	1.17	2.28
Molybdenum	mg/L	<0.001	0.004	0.002	0.008	<0.001	0.152	0.002	0.004	<0.001	0.007
Nickel-Dissolved	mg/L	<0.05	0.17	0.005	0.361	0.006	0.088	<0.001	0.125	<0.001	0.006
Selenium	mg/L	<0.01	<0.05	<0.01	0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Strontium	mg/L	<0.01	14	1.52	11.1	0.69	0.91	6.67	10.4	11	11.3
Vanadium-Dissolved	mg/L	<0.001	0.002	<0.001	0.042	<0.001	<0.01	<0.001	<0.01	<0.01	<0.01
Zinc-Dissolved	mg/L	0.008	0.302	<0.005	2.27	<0.005	0.131	<0.005	0.719	<0.005	0.014
Boron	mg/L	0.13	0.55	0.42	2.96	0.13	0.78	0.3	0.38	0.09	0.2
Iron	mg/L	0.2	14.2	<0.05	0.59	<0.05	0.43	0.05	22.2	1.68	14.3
Mercury-Dissolved	mg/L	<0.00005	<0.0001	<0.00005	0.001	<0.00005	<0.0001	<0.00005	<0.0001	<0.0001	<0.0001
Fluoride, F	mg/L	0.2	0.9	0.09	2	0.04	0.6	0.4	1	<0.1	0.1
Phosphate as P in water	mg/L	<0.005	0.79	0.026	12.6	<0.005	1.3	<0.005	2.09	<0.01	0.11

5.3.2 Deep aquifer quality

Table 5.4 provides a summary of water quality results obtained from monitoring points targeting the deep aquifers (M313W, M314W, M324W, M325W, AN019F, GR067V, M162V, M134GMV). This provides an indication of water quality ranges for each parameter analysed based on aquifer type. No significant changes are observed in water quality ranges for the MCM and FCCM, relative to the previous UWIR (Arrow, 2022). As such the review of this data indicates no notable changes to the hydrogeochemical characteristics for the FCCM and MCM, which is discussed in Arrow Energy (2022) and characterizes these units as follows:

- groundwater quality of the FCCM aquifer is fresh to saline (as defined by the Environmental Protection Agency of South Australia); and
- groundwater quality of the MCM is fresh to saline.

Table 5.4 Background water quality – deep monitoring points

Parameters	Units	Fort Cooper Coal Measures		Moranbah Coal Measures	
		Min	Max	Min	Max
Field pH	-	6.79	11.8	7.27	9.42
Electrical Conductivity	µS/cm	1,170	15,700	1,710	16,000
Total Dissolved Solids	mg/L	707	9,910	1,160	9,810
Hydroxide Alkalinity (OH-) as CaCO ₃	mg/L	<1	456	<1	<1
Carbonate Alkalinity as CaCO ₃	mg/L	<1	157	<1	456
Bicarbonate Alkalinity as CaCO ₃	mg/L	<1	1,380	159	2,380
Total Alkalinity as CaCO ₃	mg/L	222	1,380	159	2,420
Sulphate, SO ₄	mg/L	<1	68	<1	134
Chloride, Cl	mg/L	188	4,920	198	5,850
Calcium - Dissolved	mg/L	<1	276	2	209
Magnesium - Dissolved	mg/L	<1	256	<1	62
Sodium - Dissolved	mg/L	199	2,590	212	3,490
Potassium - Dissolved	mg/L	10	73	6	1,450
Arsenic-Dissolved	mg/L	<0.001	0.005	<0.001	0.013
Beryllium-Dissolved	mg/L	<0.001	<0.001	<0.001	<0.001
Barium-Dissolved	mg/L	0.005	12.2	0.236	23
Cadmium-Dissolved	mg/L	<0.001	<0.001	<0.001	0.001
Chromium-Dissolved	mg/L	<0.001	0.004	<0.001	0.018
Cobalt-Dissolved	mg/L	<0.001	0.004	<0.001	0.01
Copper-Dissolved	mg/L	<0.001	0.582	<0.001	7.08
Lead-Dissolved	mg/L	<0.001	0.459	<0.001	2.19
Manganese-Dissolved	mg/L	<0.001	0.304	0.007	0.446
Molybdenum	mg/L	0.006	0.114	0.001	0.091
Nickel-Dissolved	mg/L	<0.001	0.02	<0.001	0.05
Selenium	mg/L	<0.01	<0.01	<0.01	<0.01
Strontium	mg/L	0.406	8.18	1.18	10.8
Vanadium-Dissolved	mg/L	<0.01	<0.01	<0.01	0.02

Parameters	Units	Fort Cooper Coal Measures		Moranbah Coal Measures	
		Min	Max	Min	Max
Zinc-Dissolved	mg/L	<0.005	2.16	<0.005	0.568
Boron	mg/L	0.24	1.17	0.46	2.4
Iron	mg/L	<0.05	2.94	0.07	3
Mercury-Dissolved	mg/L	<0.0001	0.42	<0.0001	0.87
Fluoride, F	mg/L	0.2	4.5	0.4	2.6
Phosphate as P in water	mg/L	<0.01	0.62	<0.01	17.4

5.4 Groundwater use

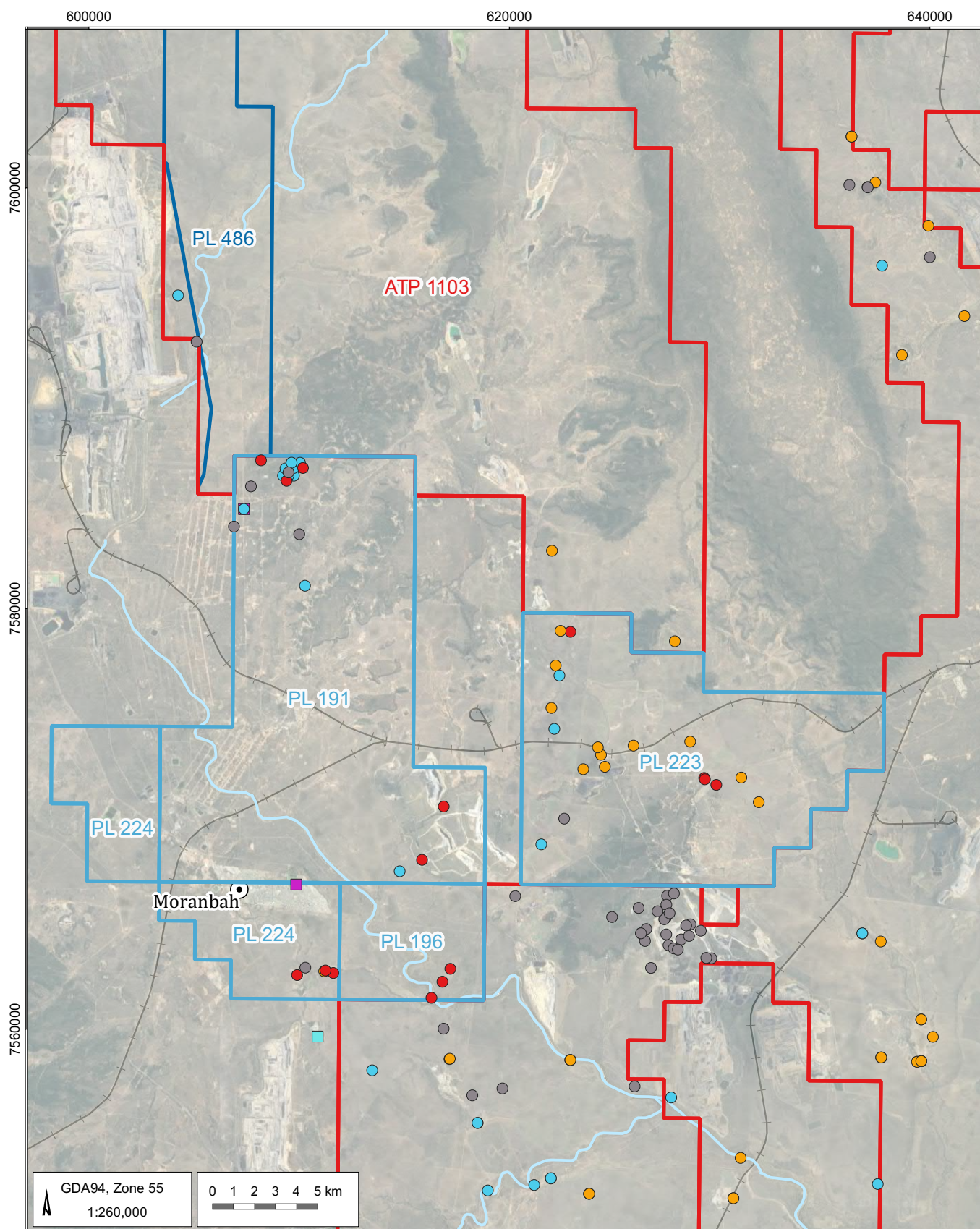
Baseline assessment results from both Arrow Energy and QPME have been analysed to identify groundwater bores and their current use within the MGP area. To date, baseline assessments have been completed in 50 landholder bores —comprising 47 registered and 3 unregistered bores. These assessments identified the following status for the bores:

- 7 bores could not be found (14%): These include sites where the landowner was unaware of a bore at the specified location or where physical inspections found no evidence of a bore.
- 15 bores were abandoned and destroyed (30%).
- 13 bores were abandoned but are still useable (26%).
- 15 bores were verified as existing (30%).

All bores in the baseline assessments were classified in accordance with the status as defined on the Queensland Globe, with exceptions made for those that could not be located during the baseline assessment. The bores classified as 'could not be found' included those where the identified bore owner was not aware of the existence of any bore at that location or where a physical site inspection did not find any evidence of the bore in the specified location.

As detailed in Section 4.1.6, three bores within the MGP baseline assessment area still require assessment: AEN1300 (classified as "abandoned but still useable"), RN162809 (classified as "abandoned but still useable") and RN162554 (classified as "existing").

The locations and status of the bores with and without a baseline assessment are shown in Figure 5.8, which indicates that the majority of existing bores are situated within PL 223. Based on the most recent baseline assessment data, all identified bores are understood to be used by local landholders for stock and domestic purposes and therefore no bores in this area are utilised for industrial or municipal (town) water supply. The landholder bores in and around the MGP can exceed depths of 500 meters as these include old gas exploration wells that are installed within the MCM. Details of individual bores that are predicted to be impacted by the MGP are provided in Sections 7.3.1.1, 7.3.1.2 and 7.3.2.1.



LEGEND

- Populated place
- Major drainage
- Rail
- ATP (Arrow, BGP)
- PL (QPME, MGP)
- PL (Arrow, BGP)

MGP baseline assessment bore status

- Abandoned and destroyed
- Abandoned but still useable
- Can't find
- Existing

Bores without baseline assessment

- Abandoned but still useable
- Existing

Bowen (BOW5001)

Completed baseline assessments for the MGP



AGE

DATE
17/03/2026

FIGURE No:
5.8

5.4.1 Future baseline assessments

Ongoing assessments will be carried out as outlined in the MGP BAP provided in Appendix D.

6 Updated conceptual hydrogeological model

A conceptual hydrogeological model was initially developed as part of the EIS (Arrow Energy, 2012c) and the SREIS (Arrow Energy, 2014b) and was subsequently updated based on data available at the time of the previous 2016, 2019 and 2022 UWIRs (Arrow Energy, 2016; Arrow Energy, 2019 and Arrow Energy, 2022) which related to the MGP. This section presents a review of the current conceptual hydrogeological model as reported in the 2022 UWIR (Arrow Energy, 2022) against the revised groundwater data presented above in Sections 4 and 5.

6.1 Water levels and flow

Data obtained from groundwater monitoring bores making up the WMS provide site specific observations on groundwater levels/pressures and interconnectivity. The table below provides a comparison of this data to the existing conceptual model. Overall, the existing conceptual model as presented in Section 3 remains valid and remains unchanged relative to the previous UWIR (Arrow Energy, 2022). Whilst site specific data is provided in Table 6.1 below, on a regional scale groundwater levels, flow and quality will vary.

Table 6.1 Data comparison

Existing Conceptual Model	Change since previous UWIR and supporting data
Shallow aquifers are recharged mainly through direct infiltration of rainfall, overland flow and surface water flow. The extent of recharge to water table aquifers from rainfall, overland flow and surface water are site and location specific.	No change
Shallow aquifers are hydraulically connected to surface water systems. The assumption has been made that water table aquifers in some locations are in connection with rivers/streams (generally losing stream).	No change
Rewan Formation is considered to be a regional-scale confining unit (aquitard). The coal seams are further confined by low permeability overburden and interburden.	Impacts within the coal measures have now been observed in monitoring bores located 660 m of existing production wells, but this is not considered to be a significant change
The pressure data presents evidence of limited interconnectivity between deep aquifers.	
Depressurisation impacts notable within the coal measures in monitoring bores located within 350 m of existing production wells.	
Propagation of impacts within the coal measures not readily identifiable in monitoring bores located 4.5 km from existing production wells, thus suggesting low permeability target formations.	
Coal seams are low to moderately permeable (relative to other coal seams targeted by CSG operations).	No change
Water pressure recovery data suggests that the permeability of the coal seams is low to very low.	
Water quality of the coal seam aquifers is highly variable indicating spatial heterogeneity of the hydrogeological system.	
Groundwater quality of the Quaternary Alluvium aquifer is highly variable ranging from brackish to saline.	No change
Groundwater quality of the Tertiary Basalt aquifer is variable ranging from brackish to saline.	No change
Groundwater quality of the Tertiary sediment aquifer is considered fresh to brackish.	No change
Groundwater quality of the Permian aquifers is considered to range from fresh to saline.	No change

6.2 Groundwater users

Baseline assessments have been undertaken by QPME and/or Arrow Energy as discussed in Section 4.1.6. This data provides information on groundwater users within the MGP and suggests that groundwater use is limited in the MGP area.

6.3 Conclusion

The updated groundwater monitoring information for the MGP for this UWIR do not show significant changes compared to the previous UWIR and does not suggest any that any changes to the existing conceptual model conceptual hydrogeological model presented in Section 3 of this report are required.

Given that no changes to the conceptual model are required then, as described in Section 3, the existing groundwater flow model used to quantify impacts in the previous UWIR (Arrow Energy, 2022) has been re-calibrated based on the updated information presented above in Sections 2 to 5. No other changes have been made to the model, other than minor changes required to extend the calibration period and generate revised predictions.

7 UWIR numerical groundwater model update

As mentioned in Section 6.3 as part of this UWIR, revised groundwater impact predictions are made for the MGP by extending and recalibrating an existing numerical groundwater model which was used for the previous UWIR (Arrow Energy, 2022). Further details of the groundwater model update undertaken by AGE are provided in Appendix C, a brief summary is provided below in Section 7.1. Section 7.2 shows the MGP field development plan simulated by the model and revised impact predictions are reported in Section 7.3, including predicted IAA and LAA areas related to the MGP and the combined (or cumulative) impact predictions related to operation of the MGP and BGP.

7.1 Model construction

7.1.1 Model history

The Northern Bowen Basin numerical groundwater model used for the assessment was originally developed for Arrow by Ausenco and Norwest (Ausenco and Norwest, 2012) to assess the impacts of CSG activities in the Bowen Basin related to the MGP and BGP. The model was developed initially using MODFLOW-SURFACT™. For the 2019 Bowen UWIR (Arrow Energy, 2019), AGE converted the Ausenco and Norwest Bowen model to MODFLOW-USG in order to increase the resolution of the model mesh around the MGP area and better delineate groundwater structures (AGE, 2018). For the 2022 Bowen UWIR (Arrow Energy, 2022), the groundwater model was further updated by AGE, including further mesh refinement, a revised stress-period setup, revision of specific storage values and presenting revised predictions based on update MGP and BGP field development plans (AGE, 2021).

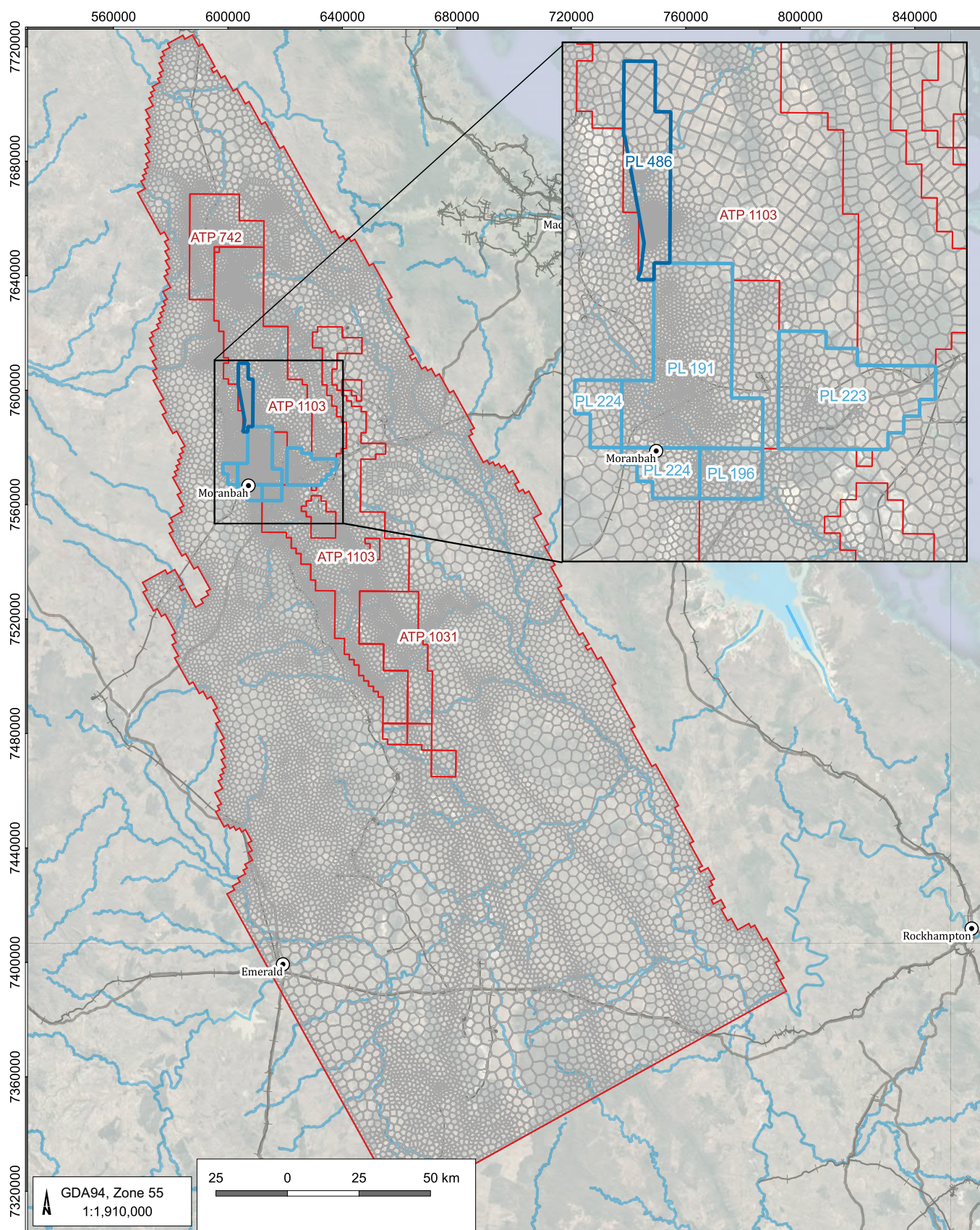
7.1.2 Summary of changes

Relative to the previous version of the model used for the previous MGP UWIR (Arrow Energy, 2022) the following changes have been made to the groundwater model:

- extension of the model calibration period from January 2018 to January 2024;
- update the MODFLOW well (WEL) package based on actual historic CSG related water extraction data provided for BGP and MGP by Arrow Energy;
- update the MODFLOW recharge (RCH) package based on updated historic actual climate records from Bureau of Meteorology (BoM) SILO website;
- model re-calibration using the updated groundwater level data presented in Section 5;
- generate revised predictions based on revised calibrated model parameters; and
- revised MGP and BGP future field development plans provided by Arrow Energy and QPME.

7.1.3 Model domain, mesh and layering

The model domain is approximately 157 km wide (west to east direction) and 395 km long (north to south direction) as shown in Figure 7.1. This area has been discretised and arranged into 22 layers comprising up to 18,082 cell nodes in each layer with the dimensions of the cells varying to best represent CSG production areas, faults, surficial aquifer systems (e.g. basalt), major drainage systems and monitoring wells. Overall, the model comprises 188,516 cells across the 22 layers (see Table 7.1). Model layer elevations were based on a regional geological model previously developed by Arrow Energy and have not been revised during this UWIR iteration.



LEGEND

- Populated place
- AGE mesh
- AGE model outline
- Major drainage
- Road
- Qld rail network (DERM)
- PL (QPME, MGP)
- PL (Arrow, BGP)
- ATP (Arrow, BGP)

Bowen (BOW5001)

Model domain



AGE

DATE
13/02/2025

FIGURE No:
7.1

Table 7.1 Groundwater model layering

Model layer	Primary Formation/Group	Unit
1	Quaternary Alluvium, weathered materials	Surficial Coverage
2	Tertiary sediments (Duringa), Basalts (Anakie) & Moolayember	Tertiary, Triassic
3	Clematis Sandstone	Triassic
4	Rewan/Rangal Coal Measures	Triassic
5	Rangal Coal Measures (RCM)	Leichardt seam
6		Interburden
7		Vermont seam
8	Fort Cooper Coal Measures (FCCM)	FCCM
9		FCCM
10		FCCM
11	Moranbah Coal Measures (MCM)	Q Seam
12		Interburden
13		P seam
14		Interburden
15		GM seam
16		Interburden
17		GML seam
18		Interburden
19		DYU seam
20		Interburden
21		DYR seam
22	Collinsville, Back Creek Group	Permian basement

7.1.4 Model calibration

The updated groundwater model was calibrated through use of a pre-development steady state run and a transient run (2000 to 2024) and using available groundwater level records and historical CSG production rates for the MGP and BGP.

As per the previous calibration of the Bowen UWIR model (AGE, 2018) a total of 6,705 model parameters were estimated. Initial parameter values were primarily based on previously calibrated parameters, other than specific storage where the initial values were adjusted to avoid exceeding the upper bound values reported in Rau et al. (2018).

Transient calibration was undertaken with reference to updated data for 38 monitoring points for which time series groundwater level data are available, including monitoring data provided by QPME and Arrow for both MGP and BGP tenures. The steady state part of the calibration uses data for a substantially larger number of 481 monitoring points and includes single time of drilling readings for a large number of landholder monitoring points. Figure 7.3 presents the observation bores that were used in the calibration.

For both the steady-state simulation and transient simulation a relatively high level of agreement between observed and modelled levels has been achieved through model calibration, as shown in Figure 7.2 and evident from the calibration performance metrics presented in Appendix C. In particular, the scaled root mean square (SRMS) discrepancy between transient observed and simulated groundwater level of 2.9% is substantially better than equivalent statistics related with either previous iteration of the model, which were 5.2 % for the 2019 UWIR model (AGE, 2018) and 13.7 % for the 2022 UWIR model (AGE, 2021). Comparisons of observed and modelled head time series at each transient monitoring point used for model calibration are presented in Appendix A of the modelling report (Appendix C).

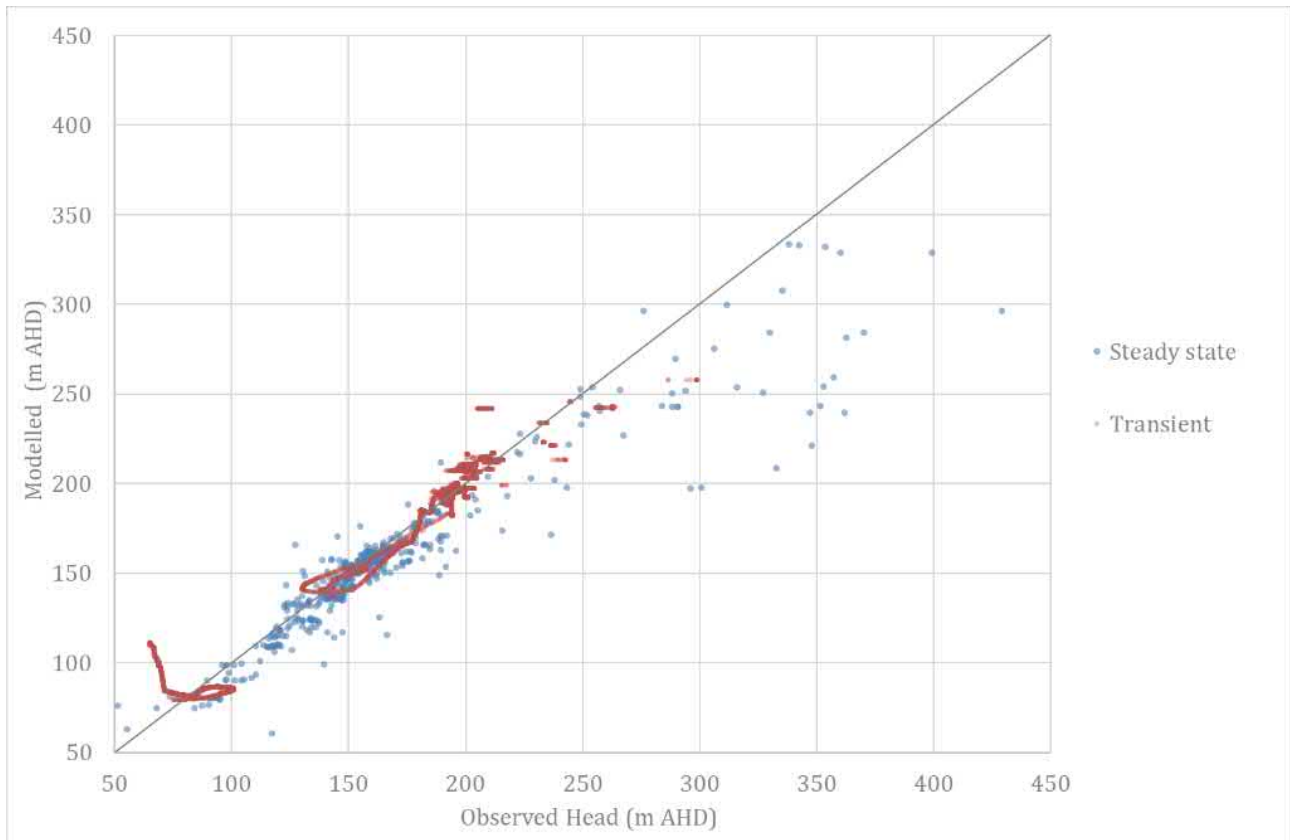
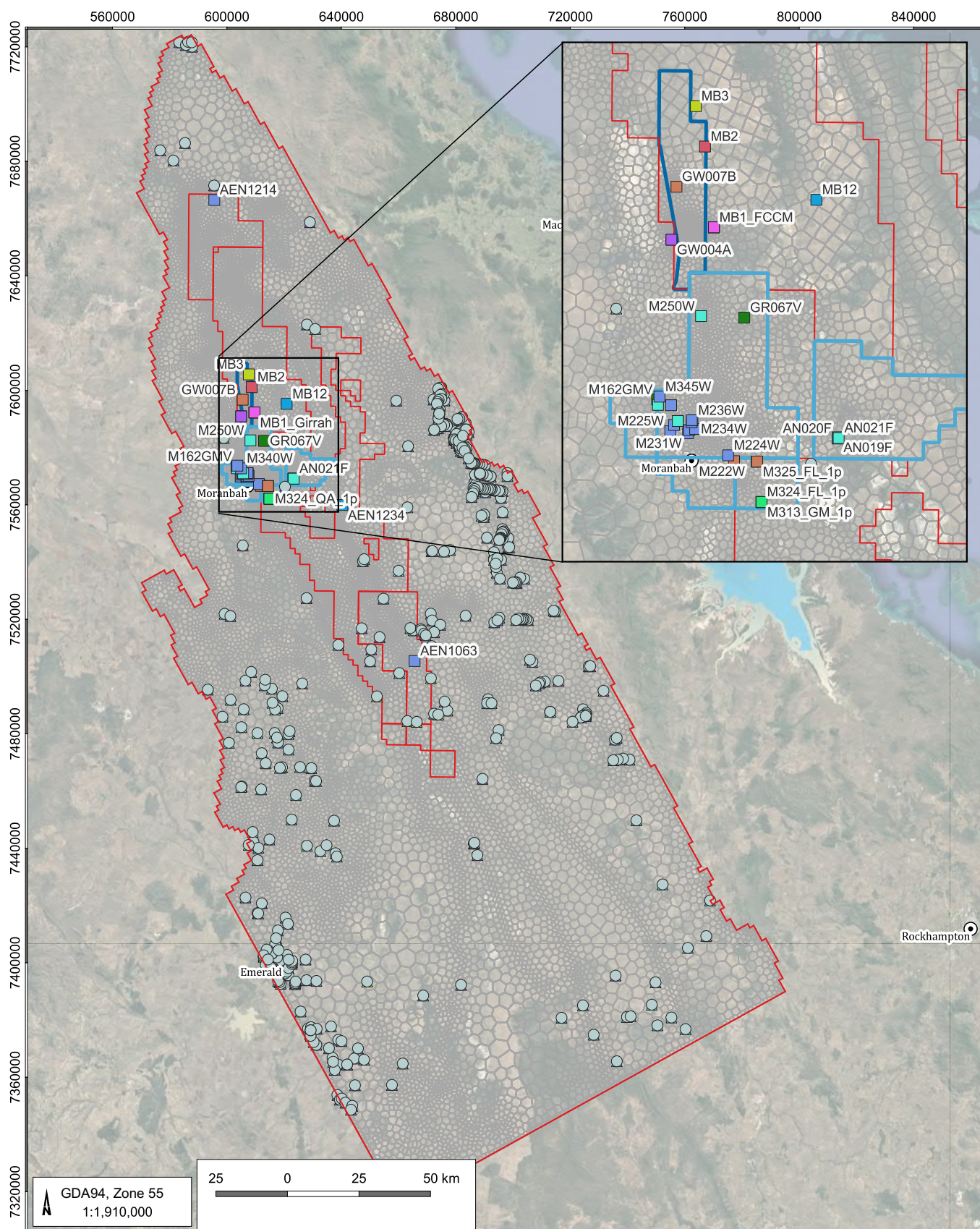


Figure 7.2 Scattergram measured vs. simulated groundwater levels - 2025 Bowen UWIR model



LEGEND

- Populated place
- AGE mesh
- AGE model outline
- PL (QPME, MGP)
- PL (Arrow, BGP)
- ATP (Arrow, BGP)
- Steady state Targets
- Transient Targets
 - lay 1- Quaternary
 - lay2 - Tertiary
 - lay 4 - Rewan
 - lay 5 - Leichardt seam
 - lay 8 - Fort Cooper Coal Measures
 - lay 9 - Fort Cooper Coal Measures
 - lay 10 - Fort Cooper Coal Measures
 - lay 11 - Q seam
 - lay 13 - P seam
 - lay 15 -GM seam
 - lay 16 - Interburden
 - lay 18 - Interburden
 - lay 22 - Permian basement

Bowen (BOW5001)

Observation locations used for model calibration



AGE

DATE
18/02/2025

FIGURE No:
7.3

7.2 Field development plan

Simulated historical and future MGP extraction locations are shown in Figure 7.5. The future field development plan (FDP) for the MGP has not changed since the previous UWIR. A timeseries of simulated production rates over time is shown in Figure 7.4 for both the MGP and BGP.

As is shown in Figure 7.4, the MGP is expected to be active until December 2028, whilst production scale extraction from the BGP (based on a revised FDP provided by Arrow Energy) is not expected to commence until 2045.

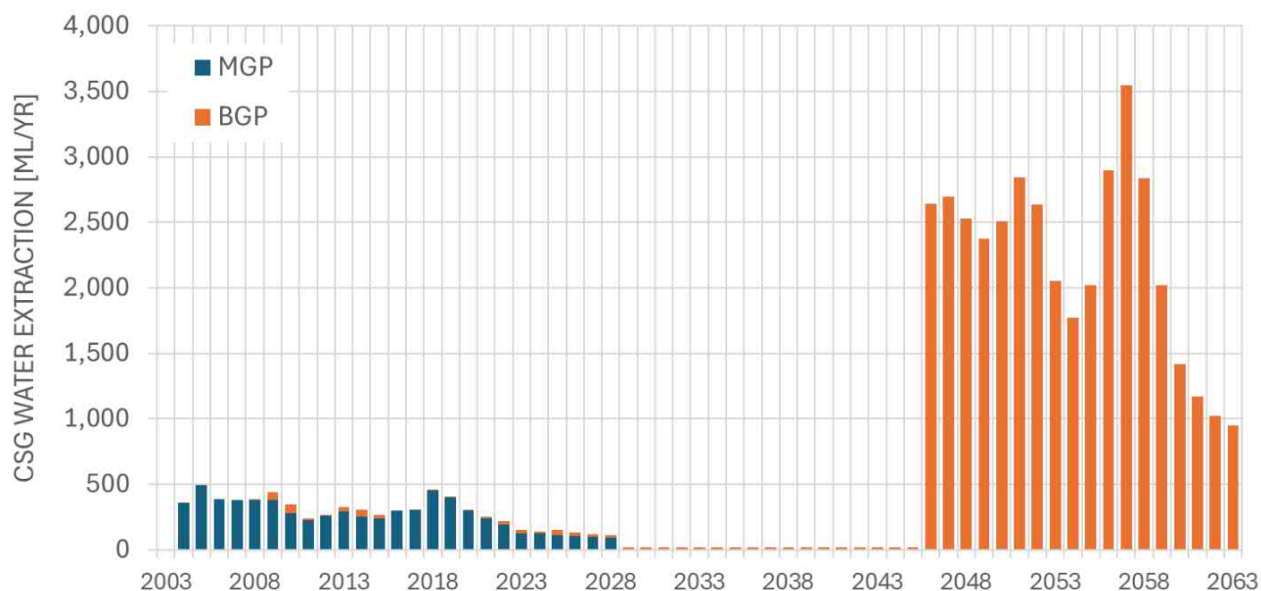
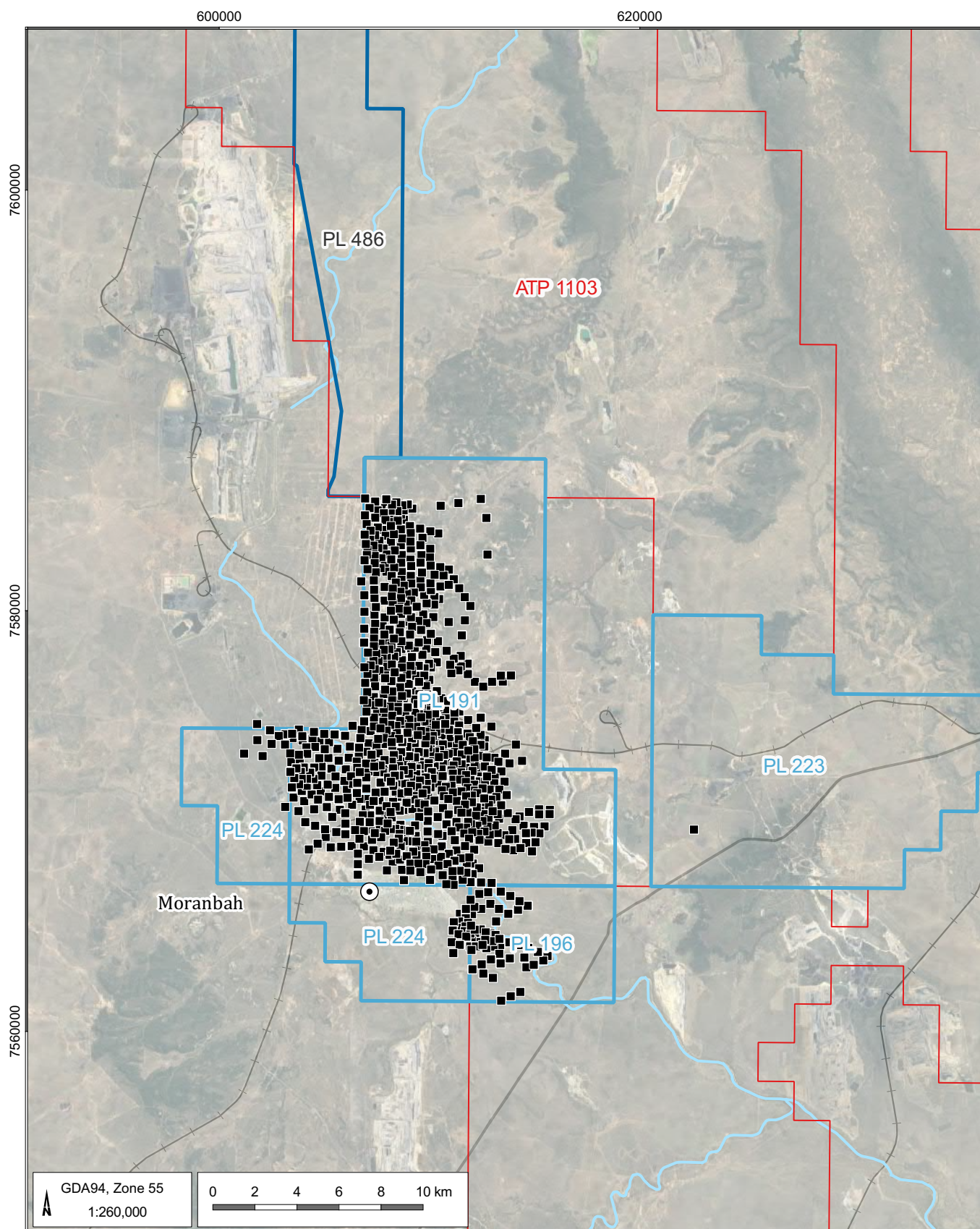


Figure 7.4 2025 FDP – timeseries of simulated CSG extraction rates for the MGP and BGP



LEGEND

- ⊙ Populated place
- Simulated MGP extraction locations
- Qld rail network (DERM)
- Arterial roads (Qld)
- Major drainage
- PL (QPME, MGP)
- PL (Arrow, BGP)
- ATP (Arrow, BGP)

Bowen (BOW5001)

Simulated field development extraction locations



AGE

DATE
17/03/2026

FIGURE No:
7.5

7.3 Prediction of impacts

The following three predictive model scenarios were undertaken for the purposes of estimating the cumulative impacts of the MGP and BGP as well as the individual contribution of the MGP:

1. A baseline or **No CSG scenario** which does not include any CSG related extraction.
2. An **MGP only scenario** which assumes that there is no extraction from CSG wells associated with the BGP project, note that any recorded actual extraction from BGP pilot wells is also excluded from this scenario.
3. A **Cumulative scenario** which includes actual historic and proposed future water extraction from the MGP and BGP projects at the rates shown in Figure 7.4.

Based on outputs from these three scenarios predicted drawdown impacts have been estimated as follows:

- cumulative drawdowns associated with the MGP and BGP have been calculated by subtracting the simulated heads in the 'Cumulative scenario' from the 'No CSG scenario' heads; and
- drawdowns associated with the MGP only have been calculated by subtracting the simulated heads in the 'MGP only scenario' from the 'No CSG scenario'.

For this UWIR four primary predictions are required based on the updated groundwater flow modelling outputs, these being the estimated extent of the immediately and long-term affected areas, the baseline assessment area and potentially impacted springs and other GDEs in each aquifer. In the case of the MGP UWIR these primary predictions can be further defined as follows:

- IAA (Immediately Affected Area) – areas where maximum cumulative and/or MGP only drawdown impacts exceed 5 m in consolidated units or 2 m in unconsolidated units within the next 3 years (i.e. January 2028);
- LAA (Long term Affected Area) – areas where maximum cumulative and/or MGP only drawdown impacts exceed 5 m in consolidated units or 2 m in unconsolidated units at any time in the future;
- identification of baseline assessment areas in relevant aquifers (i.e. those areas where more than 1 m of drawdown is expected within the next 3 years (used for baseline assessment program planning); and
- springs and other GDEs where drawdown impacts of more than 0.2 m are predicted at any point in the future.

Since the MCM and RCM span multiple model layers, drawdown impact results for these units were generated by processing drawdown for each coal seam layer (i.e. layers 11, 13, 15, 17, 19 and 21 for the MCM and layers 5 and 7 for the RCM) within the associated coal measure. These results were then subsequently combined and used to obtain a spatial composite of the maximum predicted drawdown in any of the modelled coal seam layers.

It should be noted that the predictions made in the groundwater model will be validated against future monitoring data as part of the annual review process. This will provide confirmation of predicted impacts against actual impacts occurring, if any.

7.3.1 Immediately Affected Area (IAA)

Predicted IAAs related to the MGP only are shown in Figure 7.6. As shown since limited vertical propagation of impacts into overlying units is predicted then an IAA has only been predicted in the MCM (i.e. in the target coal measures). Drawdowns of less than the bore trigger threshold are predicted in all other units within the next three years. As shown the predicted MGP only IAA is predominantly confined to the MGP project area (i.e. PLs 191, 196 and 224) although does extend around 4 km south into Arrow Energy's ATP 1103 tenure area.

Table 7.2 lists all the usable landholder bores within the MGP only MCM IAA, identifying five existing bores and a further four abandoned bores that are still useable. Six of these bores are within the MGP tenure area (see detailed discussion in Section 7.3.1.1), while the remaining three bores are located on Arrow Energy's ATP 1103 (see Section 7.3.1.2).

7.3.1.1 IAA bores within MGP tenures

Based on the most recent baseline assessment undertaken by Arrow Energy, the six bores within QPME's MGP tenure are used by local landholders for stock and domestic purposes. These include three unregistered bores (AEN 1300, AEN1010 and AEN 1012) and two registered bores (AEN2112 and AEN1182). Additionally, Registered bore RN162554 is listed as an existing bore on the Queensland Globe, for which no baseline assessment has yet been undertaken (refer to Section 4.1.6 and the BAP in Appendix D).

Bore construction details are available for bores AEN1012 and AEN1182 (both abandoned but still useable) and RN162554 (existing bore). A comparison of the recorded bore depth against the estimated depth to the top of the MCM coal measures at these three bore locations indicates the following:

- AEN1182 (RN 100225): This bore likely tap into the MCM as it is recorded as being 505 m deep (based on bore sign when visiting the bore as part of the baseline assessment), whilst the top of the MCM is understood to be 280 m below ground level (mbgl). As such predictions suggest that this bore could experience drawdown of more than 5 m within the next three years.
- AEN1012 (unregistered): Baseline assessment results indicate that this bore is approximately 43 m deep and hence unlikely to be affected by predicted drawdown in the MCM, the top of which is estimated to be at around 325 mbgl at this location.
- RN162554: Bore construction details from QLD Globe show that this bore is around 18 m deep. This bore is unlikely to be affected by predicted drawdown in the MCM, as the top of the MCM is estimated to be at around 132 mbgl at this location.

No depth information is available for the remaining three bores (AEN1300, AEN1010 and AEN2112). These bores could experience more than 5 m of drawdown if they are deep enough to intersect the MCM. The top of the MCM is estimated at 273 mbgl at AEN1010, 273 mbgl at AEN1300 and 91 mbgl at AEN2112.

7.3.1.2 IAA bores outside MGP tenures

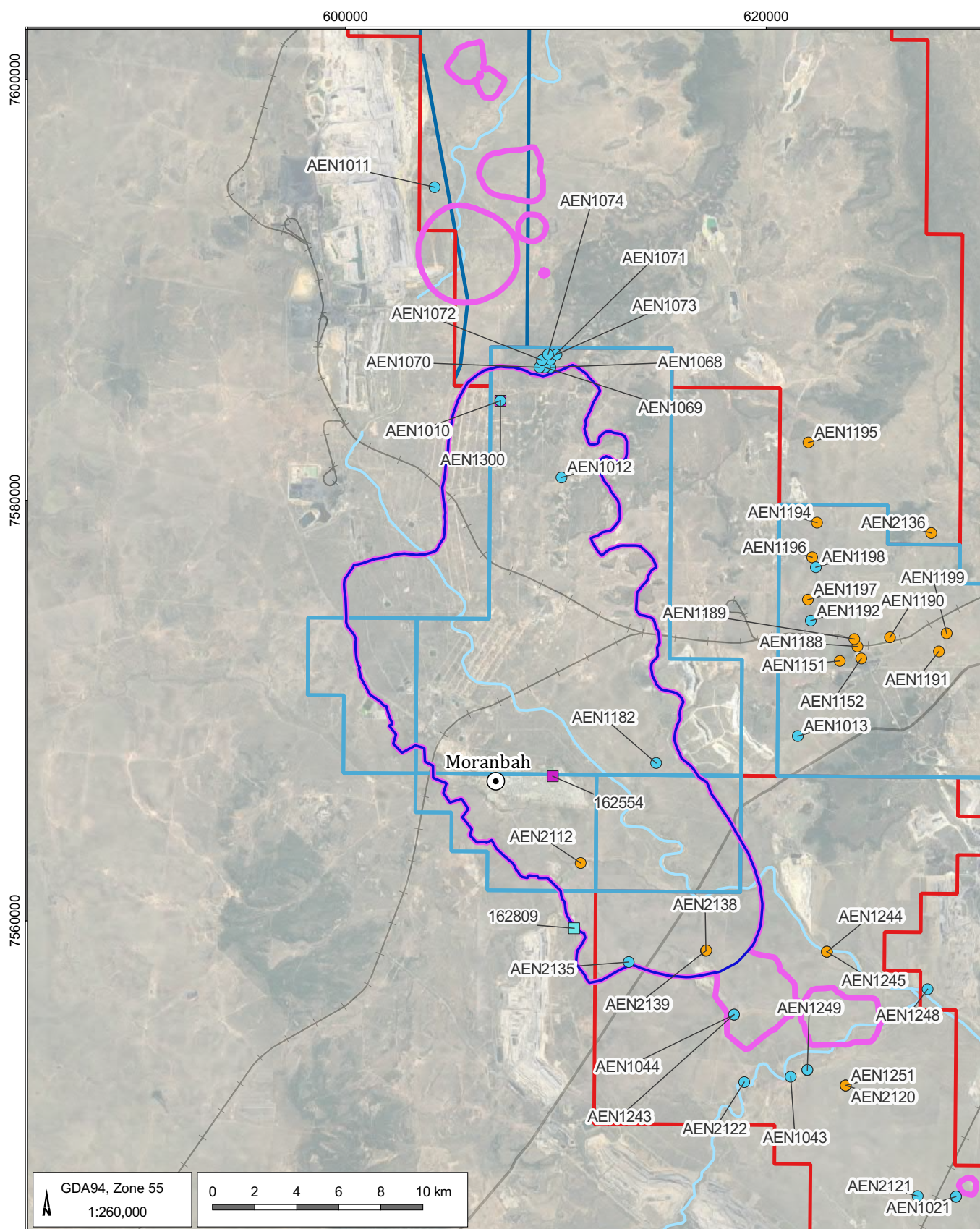
The three remaining bores that fall within the predicted MCM IAA area are located on Arrow Energy's ATP 1103. A comparison of bore depths with the estimated depth to the top of the MCM at these locations suggest the following:

- AEN2138: Baseline assessment results indicate a bore depth of 60 m and hence this bore is unlikely to be affected by predicted drawdown in the MCM, the top of which is estimated to be at approximately 273 mbgl at this location;
- AEN2139: Baseline assessment results suggest that this bore is around 50 m deep and hence this bore is unlikely to be affected by predicted drawdown in the MCM, the top of which is estimated to be at around 273 mbgl at this location; and
- AEN2135: No depth information is available for this bore. It is currently not known if this bore intersects the MCM, which is estimated to be at approximately 92 mbgl at this location.

Table 7.2 Existing and abandoned but still useable landholder bores located within the MGP MCM IAA

Bore ID	Latitude	Longitude	Bore depth (m)	Depth to top of MCM (m) ¹	Likely to experience more than 5 m of drawdown?	Drill date	Tenure (tenure holder)	Plan	RN	Status	Use type	Baseline assessment undertaken
AEN1300	148.039	-21.838	Unknown	273	Unknown, no depth information	-	PL 191 (QPME)	18SP208194	-	Existing	Stock & domestic	No
AEN2112	148.077	-22.036	Unknown	91	Unknown, no depth information	01/01/1950	PL 224 (QPME)	RP616987	162806	Existing	Stock & domestic	Yes
RN162554	148.064	-21.999	18	132	No, bore base is around 110 m above the MCM	24/04/2016	PL224 (QPME)	4CP847481	162554	Existing	Stock & domestic	No
AEN1010	148.039	-21.839	Unknown	273	Unknown, no depth information	-	PL 191 (QPME)	18SP208194	-	Abandoned but still useable	Stock & domestic	Yes
AEN1012	148.067	-21.871	43	325	No, bore base is around 280 m above the MCM	-	PL 191 (QPME)	RP904445	-	Abandoned but still useable	Stock & domestic	Yes
AEN1182	148.112	-21.993	506	280	Possibly, bore extends below top of the MCM	10/10/1994	PL 191 (QPME)	SP192459	100225	Abandoned but still useable	Stock & domestic	Yes
AEN2135	148.010	-22.079	Unknown	92	Unknown, no depth information	01/01/1950	ATP 1103 (Arrow)	SP260061	162808	Abandoned but still useable	Stock & domestic	Yes
AEN2138	148.135	-22.074	60	273	No, bore base is around 210 m above the MCM	07/07/2021	ATP 1103 (Arrow)	GV148	182871	Existing	Stock & domestic	Yes
AEN2139	148.136	-22.074	50	273	No, bore base is around 220 m above the MCM	08/07/2021	ATP 1103 (Arrow)	GV148	182872	Existing	Stock & domestic	Yes

Note: ¹Estimated based on 2025 Bowen groundwater model.



LEGEND

- Populated place
- Qld rail network (DERM)
- Arterial roads (Qld)
- Major drainage

Predicted IAAs

- MGP Only - Moranbah Coal Measures
- MGP and BGP - Moranbah Coal Measures

- PL (QPME, MGP)
- PL (Arrow, BGP)
- ATP (Arrow, BGP)

MGP baseline assessment bore status

- Abandoned but still useable
- Existing

Bores without baseline assessment

- Abandoned but still useable
- Existing

Bowen (BOW5001)

Extent of the Immediately Affected Areas



AGE

DATE
17/03/2026

FIGURE No:
7.6

7.3.2 Long-term Affected Area (LAA)

The LAA of an aquifer is the area within which water levels are predicted to decline by more than the trigger thresholds at any time in the future. The trigger thresholds are specified in the *Water Act (Qld) 2000*. They are 5 m for consolidated aquifers (such as sandstone) and 2 m for unconsolidated aquifers (such as sands). Model simulations for this assessment cover the period 2000 to 2181; consequently, the LAA calculations are based on the maximum predicted drawdown over this 181-year timeframe.

Predicted LAAs related to the MGP only and the MGP and BGP are presented in Figure 7.7. Given that extraction from the MGP is expected to cease in 2028 (i.e. at the end of the current UWIR cycle) then the predicted MGP only LAA for the MCM is similar in extent to the predicted IAA (Figure 7.6). No LAAs are predicted for aquifers other than the MCM.

7.3.2.1 LAA bores

In addition to the eight landholder bores located within the MCM IAA (see Table 7.2), six additional landholder bores are located within the MCM LAA: AEN1068, AEN1069, AEN1070, AEN1071, AEN1072 and RN162809. Details for these additional bores are provided in Table 7.3. All these bores are located on PL 191, except for bore RN162809, which is located off tenure to the west of Arrow Energy's ATP 1103.

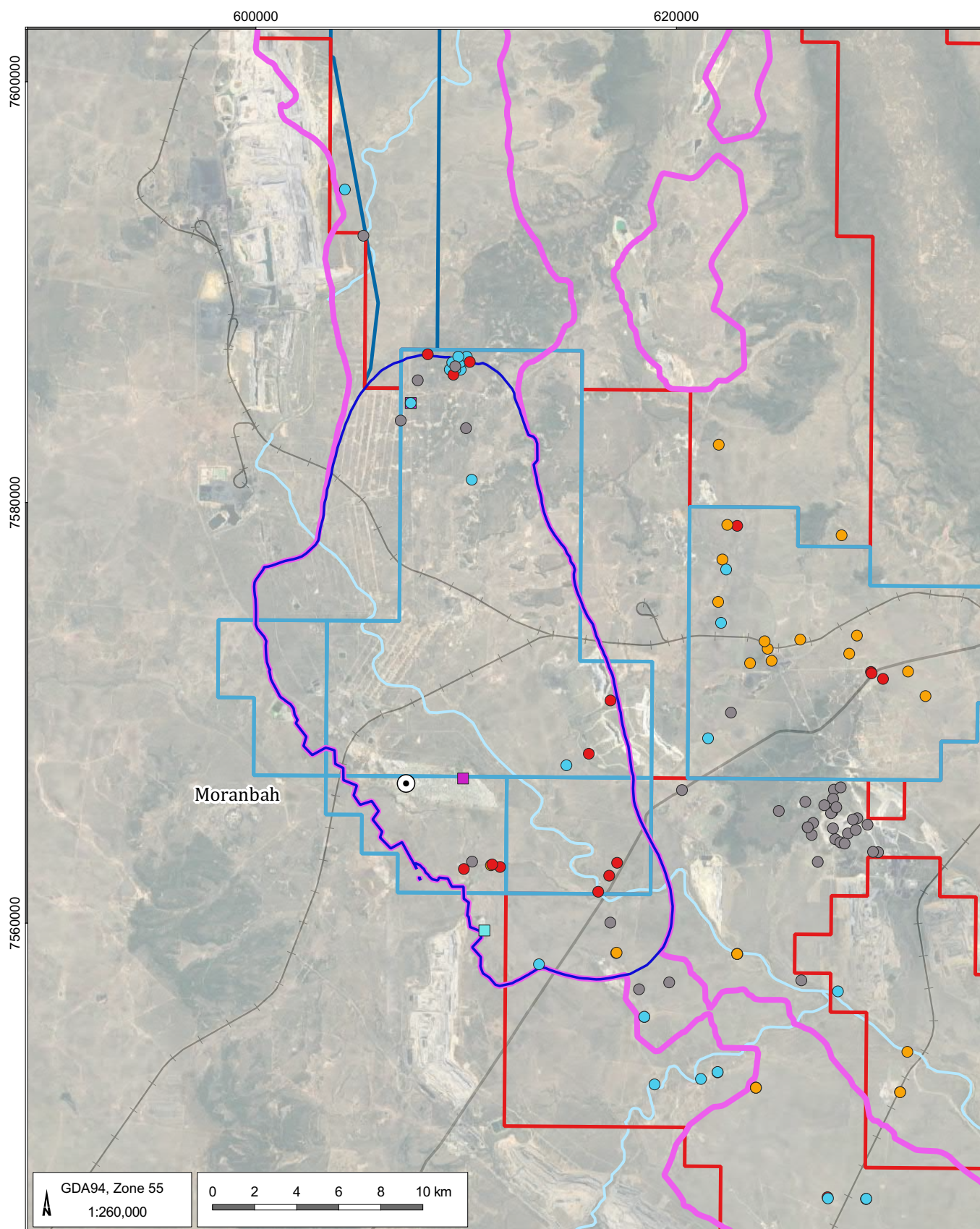
Based on available bore information, these six LAA bores are classified as abandoned but still useable. Five of these bores (AEN1068, AEN1069, AEN1070, AEN1071, and AEN1072) may intersect the MCM as these were originally drilled for gas and petroleum exploration (Queensland Globe website, visited on 17 February 2025). Currently each of these six bores is classified as stock and domestic water supply bore based on the most recent baseline assessments undertaken by Arrow Energy.

As discussed in Section 4.1.6 and the BAP (Appendix D), no baseline assessment has yet been completed for the remaining sixth LAA bore (registered bore RN162809). According to the 2025 Bowen groundwater model (Appendix C) the MCM is relatively shallow at this location and hence this bore could be deep enough to intersect the MCM. However, the bore depth is currently unknown since a baseline assessment has not been completed for this bore and no bore construction details are available via the Queensland Globe. Without this bore depth information it cannot be assessed whether this bore could be affected by predicted drawdown in the MCM due to the MGP.

Table 7.3 Additional landholder bores located within the MCM only LAA

Bore ID	Latitude	Longitude	Bore depth (m)	Depth to top of MCM (m) ¹	Likely to experience more than 5 m of drawdown?	Drill date	Tenure (tenure holder)	Plan	RN	Status	Use type	Baseline assessment undertaken
AEN1068	148.0619	-21.8236	513	358	Possibly, converted gas well which extends below top of the MCM	17/08/1987	PL 191 (QPME)	SP208194	23686	Abandoned but still useable	Stock & domestic	Yes
AEN1069	148.0594	-21.8236	506	385	Possibly, converted gas well which extends below top of the MCM	23/08/1987	PL 191 (QPME)	SP208194	23688	Abandoned but still useable	Stock & domestic	Yes
AEN1070	148.0569	-21.8236	491	385	Possibly, converted gas well which extends below top of the MCM	30/08/1987	PL 191 (QPME)	SP208194	23693	Abandoned but still useable	Stock & domestic	Yes
AEN1071	148.0619	-21.8203	544	372	Possibly, converted gas well which extends below top of the MCM	15/02/1988	PL 191 (QPME)	SP208194	23745	Abandoned but still useable	Stock & domestic	Yes
AEN1072	148.058	-21.8206	564	385	Possibly, converted gas well which extends below top of the MCM	24/02/1988	PL 191 (QPME)	SP208194	23748	Abandoned but still useable	Stock & domestic	Yes
RN162809	148.075	-22.0645	Unknown	50	Unknown, no depth information	01/01/2002	Off tenure (closest tenure ATP1103)	17GV130	162809	Abandoned but still useable	Water supply	No

Note: ¹Estimated based on 2025 Bowen groundwater model.



LEGEND

- ⊙ Populated place
- Qld rail network (DERM)
- Arterial roads (Qld)
- Major drainage

Predicted LAAs

- ▭ MGP Only - Moranbah Coal Measures
- ▭ MGP and BGP - Moranbah Coal Measures

- ▭ PL (QPME, MGP)
- ▭ PL (Arrow, BGP)
- ▭ ATP (Arrow, BGP)

MGP baseline assessment bore status

- Abandoned and destroyed
- Abandoned but still useable
- Can't find
- Existing

Bores without baseline assessment

- ▭ Abandoned but still useable
- ▭ Existing

Bowen (BOW5001)

Extent of the Long-term Affected Areas



AGE

DATE
17/03/2026

FIGURE No:
7.7

8 Environmental values

This section identifies and describes the groundwater related environmental values relevant to the MGP based on previous EIS and UWIR reporting for the MGP and BGP (Arrow Energy, 2012c; Arrow Energy, 2014b; Arrow Energy, 2016; Arrow Energy, 2019 and Arrow Energy, 2022) which are related to the MGP. It then assesses the potential for future and or historic groundwater level drawdown impact at those environmental values.

8.1 Requirements

In central Queensland groundwater is used for a variety of uses and can potentially support groundwater dependent ecosystems and have cultural value. The enhancement of these values and the protection of groundwater are required in the Environmental Protection Policy (EPP) (water). The EPP (water) provides a framework for identifying the environmental values. For the purposes of this assessment the environmental values as defined in the EPP (water) are those groundwater systems within the potential impact area that are sufficiently important to require protection or enhancement.

This section therefore addresses the following legislative requirements under the *Water Act 2000*:

- a description of the impacts on environmental values that have occurred, or are likely to occur, because of any previous exercise of underground water rights; and
- an assessment of the likely impacts on environmental values that will occur, or are likely to occur, because of the exercise of underground water rights:
 - during the period mentioned in paragraph (a)(ii); and
 - over the projected life of the resource tenure.

8.2 Environmental values in the area

During the EIS/SREIS process (Arrow Energy, 2012c and Arrow Energy, 2014b) the groundwater related environmental values that were assessed included:

- biological integrity of aquatic ecosystems;
- suitability for recreational use (primary recreation);
- suitability for minimal treatment before supply as drinking water;
- suitability for use in primary industries; and
- cultural and spiritual values.

8.2.1 Aquatic and other GDEs

Section 379 of the Water Act 2000 defines a potentially impacted spring, as a spring overlying an aquifer affected by underground water rights if:

- the water level in the aquifer is predicted, in an underground water impact report or final report, to decline by more than the spring trigger threshold at the location of the spring at any time; and
- the cause of the predicted decline is, or is likely to be, the exercise of the underground water rights.

The spring trigger threshold for an aquifer is defined as a decline in the water level of the aquifer of 0.2 m. Hence, an assessment of potentially affected springs and other groundwater dependent ecosystems (GDEs) is based on identifying points or areas where the long term predicted impact on groundwater levels in the source aquifer exceeds 0.2 m.

GDEs in and around the MGP area, based on data which forms part of the BoM GDE Atlas (BOM, 2024) are shown in Figure 8.1. As reported in previous UWIRs for the MGP, many of these sites have been studied in detail through the completion of field surveys including those completed in 2011 by KCB (KCB, 2012a; KCB, 2012b) and the Queensland Herbarium (Queensland Herbarium, 2012).

Based on previous UWIR reporting (Arrow Energy, 2012a; Arrow Energy, 2016; Arrow Energy, 2019 and Arrow Energy, 2022) there are no spring vents or spring complexes that are fed by the deep groundwater system near the MGP, as the closest mapped springs are more than 200 km from the MGP. Therefore, the only GDEs assessed in this UWIR for the MGP, include the terrestrial and aquatic GDEs shown in Figure 8.1 that are fed by the shallow aquifer system. No wetlands (lacustrine GDEs) classified as Matters of National Environmental Significance (MNES wetlands) are impacted by the MGP, as the nearest MNES wetland Lake Elphinstone is located more than 32 km from the MGP LAA area in the MCM.

8.2.2 Recreational use

The category of suitability for recreational use is not applicable to in-situ groundwater. As noted above there are also no registered groundwater springs in the area. Groundwater seepage from the alluvium into water courses can provide short duration baseflow into rivers and creeks immediately after heavy rains of flooding, however, after large flood events the suitability of these water for recreation will be limited by other factors.

8.2.3 Drinking water

Fresh groundwater occurs in discrete locations with limited extent within the Bowen Basin associated with basalts, alluvial deposits and water courses, specifically the alluvium of Cooper Creek, Denison Creek, Funnel Creek and Connors River which are located more than 40 km east from MGP production areas. Such water is accessed by groundwater bores. In addition, the Braeside bore field, which is located more than 30 km from MGP production areas, supplies water to coal mines, the Coppabella township and several rural properties. The remaining aquifer areas are generally too saline and/or sodic for use as drinking water with minimal treatment. Drinking water with minimal treatment in alluvial aquifers or basalts is therefore not an environmental value that is impacted by the MGP, as these areas are located at more than 30 km from MGP production areas and fall well outside the predicted LAA for the MCM.

8.2.4 Primary industry

Water bores may be used for agricultural uses such as stock watering where water quality permits. In the Bowen Basin water quality suitable for stock watering is generally found in basalts and alluvial systems. Other shallow groundwater is generally too saline for most agricultural uses. Similarly, groundwater in deep aquifers including the coal measures is also saline and therefore not suitable for most uses. Areas of alluvium and basalts in the Bowen Basin therefore represent the primary areas with potential for this environmental value.

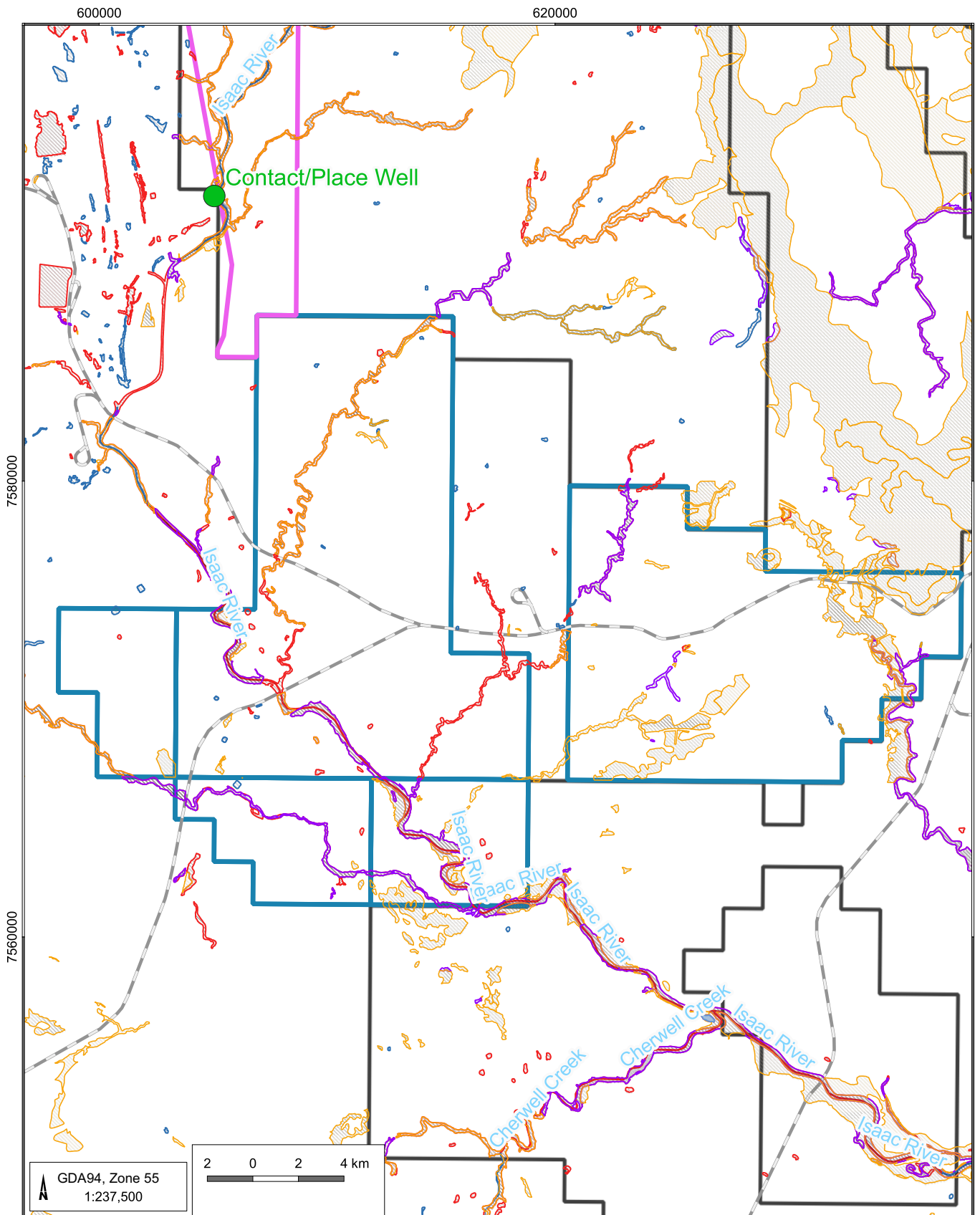
8.2.5 Cultural and spiritual value

Based on previous EIS and UWIR reporting (Arrow Energy, 2012c; Arrow Energy, 2014b; Arrow Energy, 2016; Arrow Energy, 2019 and Arrow Energy, 2022), there are no registered groundwater springs or seeps that supply surface water bodies in the Project area. Cultural heritage studies were carried out for the MGP and BGP, which identified four significant sites with potential association with groundwater, based on their description as 'wells'. One of these sites is located 5 km north of the MGP at the western margin of Arrow's PL482.

From the above discussion it is concluded the environmental values with potential to exist in the MGP UWIR area include:

- Biological integrity of aquatic ecosystems in or dependent upon alluvial aquifers;
- Drinking water with minimal treatment in alluvial aquifers or basalts;
- Agricultural uses such as stock watering; and
- Cultural and Spiritual Value.

The potential for activity reported in the Bowen Basin UWIR to have impacted or to impact these environmental values in the future is discussed below.



LEGEND

- Populated place
- Rail_CLIP
- Arterial Road (QLD)
- Major watercourses
- PL (Arrow, BGP)
- PL (ARROW, BGP)
- ATP (ARROW, BGP)
- Cultural site of significance
- MSES high ecological significance wetlands
- Aquatic GDEs**
 - Known GDE
 - High potential GDE
 - Moderate potential GDE
- Terrestrial GDEs**
 - Known GDE
 - High potential GDE
 - Moderate potential GDE

Bowen (BOW5001)

GDE and sites of cultural and spiritual significance



AGE

DATE
17/02/2025

FIGURE No:
8.1

8.3 Potential Impacts to Environmental Values

The potential for impacts to environmental values to have occurred or to occur are discussed below.

8.3.1 Aquatic and other GDEs

As specified in Section 8.2.1, in the absence of any known springs which may be sourced from deeper units, all GDEs present in and around the MGP area, including terrestrial, aquatic and lacustrine GDEs, are likely to be sourced from shallow systems including Quaternary alluvium and Tertiary basalts which are present at outcrop. As such in terms of assessing potential drawdown impacts then predicted drawdown at the water table is most relevant. However, consistent with the LAA maps presented previously (Figure 7.7) MGP only impacts are largely confined to the MCM at depths ranging from 60 to 500 m and as such there are no areas where more than the 0.2 m trigger threshold is predicted at the water table.

Based on the information above there is negligible to minimal risk for potential CSG impacts to have occurred or to occur at these environmental values and therefore a Spring Impact Management Strategy will not be prepared as part of this UWIR.

8.3.2 Drinking water

As outlined above (Section 8.3.1) there are no areas where more than the 0.2 m trigger threshold is predicted at the water table and hence no impacts are expected in any of the near surface aquifers which can support drinking water supplies in the area. As such there is negligible to minimal risk for potential impacts to have occurred or to occur to this environmental value.

8.3.3 Primary Industry

Areas where Quaternary alluvium and/or Tertiary basalt aquifers are present at outcrop also represent areas which could support intensive agriculture or other industries. However, as discussed above (Sections 8.3.1 and 8.3.2) there are no areas where more than the 0.2 m is predicted at the water table. Furthermore, as discussed previously in Sections 7.3.1 and 7.3.2 none of the bores located within the LAA area are used for primary industry. In the event that existing bores which source water for primary industry are identified within the baseline area shown in Figure 4.2 then they would be subject to baseline assessments initially and ultimately 'made good' if found to be actually impaired.

8.3.4 Cultural and Spiritual Value

Cultural heritage studies were carried during previous EIS and UWIR studies for the MGP (Arrow Energy, 2012c; Arrow Energy, 2014b; Arrow Energy, 2016; Arrow Energy, 2019 and Arrow Energy, 2022), which identified one significant site with potential association with groundwater based on their description as 'wells'. This site is located 5 km north of the MGP at the western margin of Arrow's PL482 and is not predicted to be impacted by the MGP as there are no areas where more than the 0.2 m trigger threshold is predicted at the water table.

8.4 Subsidence

The potential for subsidence due to CSG that could occur in areas of significant depressurisation are discussed below based upon previous EIS and UWIR reporting (Arrow Energy, 2012c; Arrow Energy, 2014b; Arrow Energy, 2016; Arrow Energy, 2019 and Arrow Energy, 2022).

Subsidence was assessed based on ground movement data collected over the MGP area. Interpreted ground movement from satellite interferometry data showed movement over most of the study area was less than 10 mm (uplift or subsidence). Isolated cases with a greater rate of movement were identified and found to be consistent with site surface features in most cases. Average downward movement of 10 to 20 mm was identified in one area that correlated with both CSG extraction and coal mining activity.

The subsidence interpreted from satellite interferometry indicated the magnitude of the surface ground movement associated with CSG extraction in the MGP is small, within the lower range of calculations used to estimate subsidence, broadly distributed so therefore less likely to induce differential subsidence and significantly less than that likely to occur from longwall coal mining.

Based on the subsidence assessment above, there is minimal risk from subsidence due to CSG to have impacted or to impact any environmental values.

9 Annual data review

This report will be reviewed annually, which will consider the following:

- new hydrogeological data that significantly alters the conceptual model;
- whether new production testing or production has been undertaken or is planned; and
- whether the predictions made in Section 7.3 have materially changed.

The program for the implementation of the strategy will be reported to DETSI on an annual basis as part of the annual review. The annual review will provide progress on the implementation of the WMS. In addition to the annual review, the UWIR will be updated every three years. As required under section 378(1)(d) of the *Water Act (Qld) 2000*, an annual update will also be provided to the OGIA about the implementation of the WMS.

10 Glossary

Term	Meaning
Alluvium	Unconsolidated deposits such as sands, gravels and clays deposited by flowing water such as rivers and streams.
Anisotropy	The property of being directionally dependent, as opposed to isotropy, which implies homogeneity in all directions.
Aquatic ecosystems	The abiotic and biotic components, habitats and ecological processes contained within rivers and their riparian zones and reservoirs, lakes, wetlands and their fringing vegetation.
Aquifer	A saturated geological layer or formation that is permeable enough to yield economic quantities of water.
Aquitard	A geological formation having low (but not zero) permeability to water, such as a silty or clayey layer.
Artesian aquifer	A confined aquifer with the potentiometric level above ground level.
Baseflow	Sustained flow of a stream in the absence of direct run-off, due to groundwater discharge.
Bore	A hole drilled in the ground to obtain samples of soil or rock, intersect groundwater for extractive use, monitoring or investigation, or for a range of other purposes. In Australia is also a commonly used term for a constructed groundwater well.
Brackish	Water containing moderate salt concentrations significantly less than sea water, with Total Dissolved Solids typically between 1,000 and 10,000 mg/L. (Compare Fresh, Saline and Brine).
Brine	Saline water with a total dissolved solids concentration greater than 40,000 mg/L or coal seam gas water after it has been concentrated through water treatment processes and/or evaporation.
Calcareous	Containing significant proportions of calcium carbonate.
Catchment	An area which discharges to a common point.
Coal Seam Gas water	Groundwater that is necessarily or unavoidably brought to the surface in the process of coal seam gas exploration or production. Coal seam gas water typically contains significant dissolved salts, has a high sodium adsorption ratio (SAR) and may contain other components that have the potential to cause environmental harm if released to land or waters through inappropriate management. Coal seam gas water is a waste, as defined under the section 13 of the Environment Protection Act. (DEHP, 2011).
Colluvium	Sedimentary deposit formed primarily by gravity forces, typically at the base of a slope or a cliff.
Confined aquifer	An aquifer in which groundwater is confined under pressure.
Confining layer	Geological material through which significant quantities of water cannot move, located below unconfined aquifers, above and below confined aquifers.
Drawdown	The drop in the watertable or potentiometric level when water is being pumped from a well.
Ecosystem	A system made up of the community of living things (animals, plants, and microorganisms) which are interrelated to each other and the physical and chemical environment in which they live.
Fault	A structural discontinuity in a rock mass or geological formation.
Fluvial	Pertaining to a river or stream.
Fluvio-lacustrine	Pertaining to a combined environment involving a river or stream and lake conditions.
Formation	A geological structure such as a rock mass or layer.
Fresh water	Water containing low salt concentrations, typically less than 1,000 mg/L. (Compare Brackish, Saline and Brine).

Term	Meaning
Groundwater dependent ecosystems (GDEs)	ecosystems that need access to groundwater to meet all or some of their water requirements to maintain their communities of plants and animals, ecological processes and ecosystem services.
Groundwater	Any sub-surface water, generally present in an aquifer or aquitard.
Groundwater flow	The movement of water in an aquifer.
Hydraulic conductivity	A standard measure of the permeability of a geological formation or its ability to transmit groundwater flow.
Hydraulic gradient	The slope of the water table in an unconfined aquifer, or the potentiometric surface in a confined aquifer.
Hydraulic Head	A measure of the pressure head of water in aquifer, commonly measured as the elevation to which water will rise in a constructed well.
Hydrogeology	The study of the inter-relationships of geologic materials and processes with water, especially groundwater.
Lateritisation	A process of weathering, dissolution and leaching resulting in a hard crust dominated by iron and aluminium oxides.
Lithology	The physical composition of a rock.
Paleochannel	Unconsolidated sediments or semi-consolidated sedimentary rocks deposited in ancient, currently inactive river and stream channel systems.
Permeability	The ability to transmit fluids through a porous medium.
Recharge	Addition of water to or flow into an aquifer (generally) from rain. Also used to describe water entering an aquifer from surface water, groundwater, or artificial means.
Saline water	Water containing high levels of dissolved salts, typically between 10,000 and 40,000 mg/L. (Compare Fresh, Brackish and Brine).
Saturated zone	The zone in which the voids in the rock are completely filled with water. The water table represents the top of the saturated zone in an unconfined aquifer.
Specific yield	The ratio of the volume of water a rock will release by gravity drainage to the bulk volume of the rock.
Spring	The land to which water rises naturally from below the ground and the land over which the water then flows.
Unconfined aquifer	An aquifer with no confining layer between the water table and the ground surface where the water table is free to rise and fall.
Vertical Anisotropy	Differing properties of a geological material in the vertical direction compared to horizontal direction.
Water table	The top of the saturated zone in an unconfined aquifer.
Well	A hole drilled into a groundwater resource (aquifer), oil or gas resource reservoir) and constructed with a casing and screen or similar. In Australia also commonly referred to as a 'bore'.
Well field	A group of boreholes in a particular area having a common use, such as for groundwater, oil or gas extraction.

11 References

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Appendix A

Shallow monitoring bore water level results

APPENDIX A: SHALLOW MONITORING BORE WATER LEVEL RESULTS

Bore Name	SWL (mAHd)																															
	9/06/2012	13/12/2012	8/04/2013	25/05/2013	8/08/2013	6/12/2013	5/05/2014	19/08/2014	5/12/2014	11/03/2015	17/05/2015	27/07/2015	13/11/2015	2/03/2016	13/05/2016	29/08/2016	15/11/2016	15/06/2017	12/11/2017	1/06/2018	17/11/2018	24/05/2019	12/11/2019	22/11/2020	24/05/2021	30/10/2021	9/08/2022	29/11/2022	23/05/2023	21/11/2023		
M339W	200.43	200.46	200.43	200.45	200.46	200.55	200.49		200.56	200.53	200.42	200.40	200.56	200.47	200.48	200.43	200.50	200.51	200.50	200.52	200.80	200.62	200.66	200.75	200.68	200.82	200.78	200.87	200.77	200.44		
M225W	206.30	206.64	206.74	206.80	207.46	207.15	207.11		207.27	207.35	207.26	207.23	207.40	207.22	207.25	207.25	207.32	207.54	207.69	207.75	207.90		207.78	207.43	207.20	207.14	207.01	207.03	206.99	206.99		
M340W	207.62	208.97	208.12	208.22	208.26	208.51	208.60		208.70	208.77	208.75	208.81	208.92	208.87	208.90	208.76	205.95	203.03	dry													
M230W	208.50	208.71	208.72	208.84	208.87	209.06	209.07		209.20	209.20	209.11	209.06	209.15	208.88	208.92	208.86	208.99	208.63	208.59	208.21	207.70	208.94	205.95	203.17	202.60	and replaced with M300W						
M300W																										200.10	204.50	204.44	202.64	201.06		
M250W	233.29	233.25	233.24	233.23	233.25	233.31	233.26		233.33	233.29	233.25	233.22	233.25	233.24	233.26	233.33	233.24	233.28	233.27	233.29	233.32	233.34	233.34			233.55	233.39	233.39	233.39	233.38		
ANO21F															237.06		242.34		238.47	239.06	239.52		240.52	241.52	241.83	242.11	242.44	242.70	242.54	242.75		
M224W	211.68	211.37	211.45	211.71	211.42	211.11	210.89	210.65	210.49	210.56	210.42	210.28	209.98	210.02	209.97		209.85	210.35	210.36	210.08	209.68	209.57	208.36	208.96	207.84	208.76	208.80	209.22	209.91	209.63		
M222W	202.41	202.97	203.21		203.82	204.01	204.30	204.65	204.95	205.21	205.44	205.54	205.99	205.93	205.97	206.01	206.01	206.15	206.30	206.30	206.28	206.22	206.22	206.22	205.98	206.00	205.94	206.02	206.11	206.26		
ANO20F														238.37	238.37	238.48	238.44			237.18	238.61	238.39	238.36	238.36	237.99	237.62	237.37	236.86	236.61	236.23	no access	

Appendix B

Water quality results

SHALLOW MONITORING BORES

DEEP MONITORING BORES

[illegible]