APPENDIX H

Groundwater Impact Assessment

Australasian Groundwater and
Environmental Consultants Pty Ltd

Report on

Martins Creek Quarry Groundwater Impact Assessment

Prepared for
Buttai Gravel Pty Ltd

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Document details and history

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Report on

Martins Creek Quarry
Groundwater Impact Assessment

1 Introduction

The Martins Creek Quarry (MCQ) is licensed by Buttai Gravel Pty Ltd, which is part of the Daracon Group (Daracon). MCQ is an existing hard rock quarry situated within the Dungog Local Government Area (LGA), approximately 7 kilometres (km) north of Paterson and 28 km north of Maitland, New South Wales (NSW) (Figure 1.1).

In 2016, Daracon submitted a development application for the Martins Creek Quarry Extension Project. This application sought approval for the consolidation of the existing development approvals and the expansion of the quarry into new areas to extract approximately 1.5 million tonnes of material per annum over a 30 year period (the Original Project). The development application is being assessed as a State Significant Development (SSD 6612), requiring approval under Part 4 of the Environmental Planning and Assessment Act 1979 (EP&A Act).

The Environmental Impact Statement (EIS) for the Original Project was publicly exhibited in late 2016 (Monteath & Powys, 2016). Following detailed analysis of the EIS submissions, Daracon committed to key design changes and additional mitigation and management measures to minimise the Project's environmental and social amenity impacts. This included reductions in the proposed extraction limits, quarry operating hours and truck movements.

Following community engagement and feedback during 2018 and 2019, and the change to quarry operations in September 2019, Daracon has undertaken further quarry planning and design activities to optimise the use of the existing resource and minimise environmental and community impacts. As a result, the Revised Project now includes a number of additional amendments including further reductions in road transportation volumes, peak hourly truck movements, operational hours, as well as a 13.5 hectare (ha) reduction in the Project disturbance footprint by avoiding approximately 15.3 ha of native vegetation in the former East Pit (Lot 21 DP 773220).

Australasian Groundwater and Environmental Consultants Pty Ltd (AGE) has prepared this Groundwater Impact Assessment (GIA) to support the Amended Development Application and Response to Submissions (ADA & RTS) for the Revised Project. The scope of the GIA has been designed to assess the specific hydrogeological conditions of the Revised Project, and to address the requirements of the New South Wales Aquifer Interference Policy (2012) (AIP). The GIA also provides responses to the Agency submissions on the EIS for the Original Project. A summary of Agency submissions are shown in Table 1.1, along with a reference to the sections of this report relevant to each submission.

Table 1.1 Agency submissions

Organisation / Name	Submission	Section in report where addressed
DPI	The proponent should investigate purchase of an additional 2 shares in the New England Fold Belt Coast Groundwater Source.	Section 7.3 discusses water licensing. There is no need for further purchases at this time, based on the estimate of groundwater take (Section 6.2).
	The proponent should develop a Water Management Plan in consultation with DPI Water. The Plan should include: • Prescriptive Trigger Action Response Plans (TARPs) for impacts on surrounding surface and groundwater users. These should include make good provisions. • A groundwater monitoring plan for the monitoring and management of groundwater associated with the quarrying activities, as outlined in section 8.6 of the EIS and section 7.6.6 of Appendix 6. Groundwater monitoring sites should include water level loggers for continuous monitoring. This is important to obtain information for the first 4 years to inform if quarterly downloads of water level information, as proposed, are appropriate.	The current groundwater monitoring is undertaken regularly under the site Environmental Management Plan (EMP), and reporting is conducted annually, in accordance with the bore interception licence. Monitoring currently employs level loggers (pressure transducers). Results are presented in Section 5.3. Also refer below regarding management (Section 8.1).
Hunter New England Health	The type of operations undertaken on this site has an inherent risk to any ground water reserves in and around the site. There needs to be further assessment, management and monitoring of any ground water associated with this proposal.	Recommendations for management and mitigation are provided in Section 8.1, where it is recommended that a comprehensive Water Management Plan (WMP) should be developed in consultation with DPI Water, including a full outline of the surface water and groundwater monitoring program, and development of Trigger Action Response Plans (TARPs).

Organisation / Name	Submission	Section in report where addressed
	Any approval needs to ensure that the EIS has a comprehensive Water Management Plan addressing all aspects of assessment, management and continuous monitoring of potable, surface and ground water associated with this proposal.	See above regarding the WMP (Section 8.1).
Planning & Environment	The Department requests the following additional information is provided as part of the RTS: - justification as to how the limited groundwater monitoring data (three events at four locations) is sufficient to fully and adequately characterise existing groundwater conditions, provision of a more comprehensive sampling regime.	Since the EIS completion in 2016, additional data have been collected, including continual monitoring using level loggers, and data from additional groundwater sites (MW05, MW06, and MW07), which were installed in May 2018 to expand the monitoring network. The network is presented in Section 5.1, and the data are presented in Section 5.3.

1.1 Project description

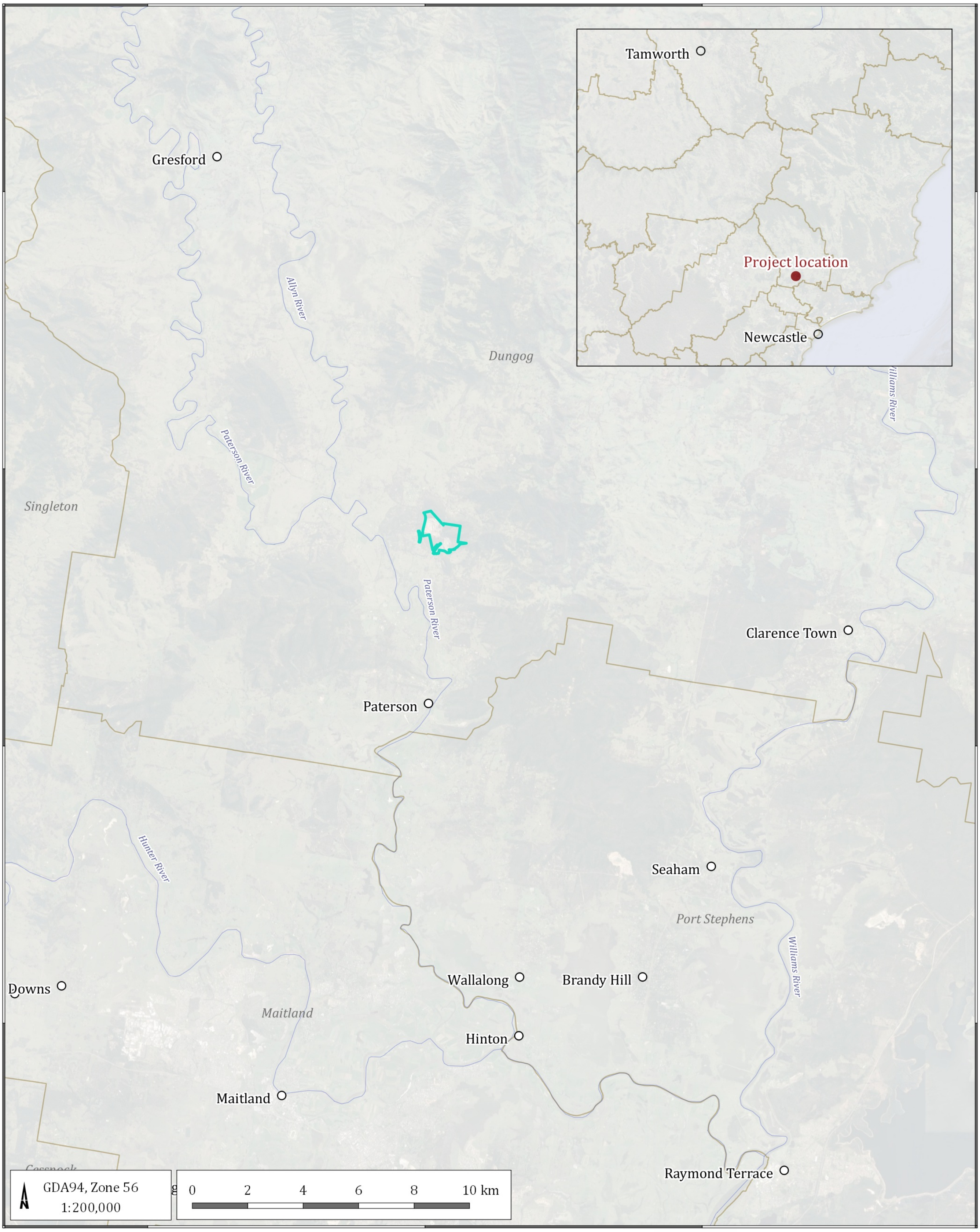
MCQ is located off Station Street, Martins Creek, in the Dungog LGA (Figure 1.1). The site is bounded by the North Coast Rail line to the west, Vogeles Road to the south, and by densely vegetated land to the north and east. The site slopes in a south west direction from a central ridgeline at the top of the quarry.

MCQ was established in 1914 by the NSW Government Railways for the purpose of supplying railway ballast and other quarry materials to both the NSW railway network and Hunter Valley/Newcastle construction projects.

In December 2012, Daracon secured a long term lease of the quarry and have been extracting a latite tuff material (also referred to locally as andesite or ignimbrite) to produce high quality aggregates, roadbase, ballast, gabion and other specified materials used in road, railway, concrete and civil construction. An established quarry and processing area exists at the site, with previous and current extraction exposing two pit sites. One of the pits lies to the east of Station Street and one to the north west of Station Street.

The site boundary and extent of the Original Project Disturbance Area and the Revised Project Disturbance Area are shown on Figure 1.2. Daracon have undertaken further detailed resource quantification and quarry plan design work to optimise future operations and minimise environmental and community impacts. As a result, the proposed additional disturbance area for the Project has reduced from 82.8 ha to 66 ha. Approximately 13.5 ha of undisturbed native vegetation in the former East Pit (Lot 21 DP 773220) is no longer proposed to be disturbed as part of the application.

The MCQ Revised Project involves the extraction of up to 1.1 million tonnes per annum (Mtpa) of product over 25 years. The proposed hours of operation are 7.00 am to 6.00 pm Monday to Saturday, with the exception of road haulage of quarry product, which will only occur Monday to Friday.



LEGEND

- Populated place
- Watercourse
- Project Area
- Local government area

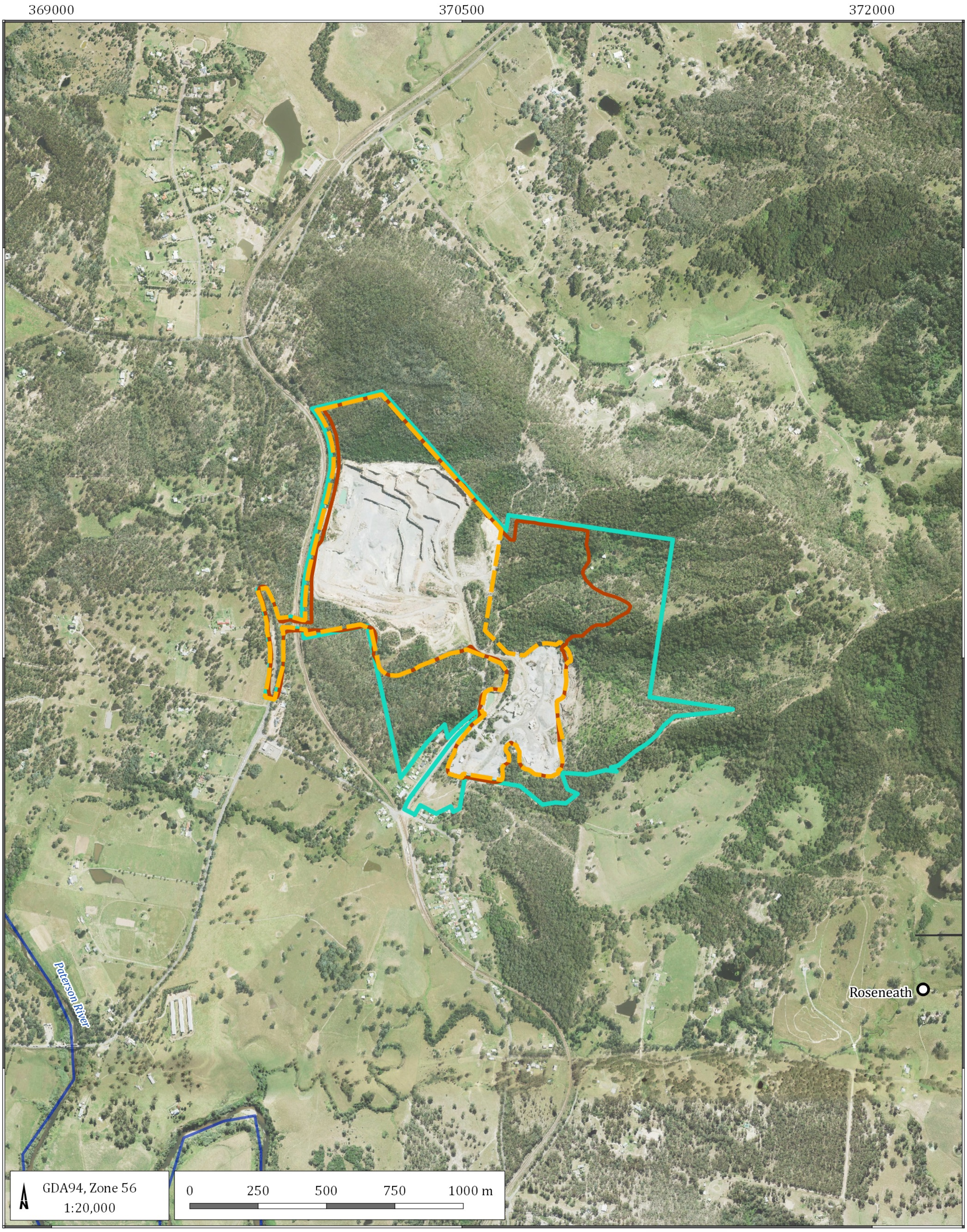
Martins Creek Quarry (G1908K)

Site location

AGE

DATE 04/03/2021

FIGURE No: **1.1**



LEGEND

- Populated place
- Drainage
- Project Area
- Original Project Disturbance Area
- Revised Project Disturbance Area

Martins Creek Quarry (G1908K)

Original and Revised Project Disturbance Area

AGE

DATE 04/03/2021

FIGURE No: **1.2**

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2 Existing environment

2.1 Climate

The climate at MCQ is temperate, with warm wet summers and dry winters. Rainfall data was obtained from the Bureau of Meteorology (BoM) weather station 061250 located at Paterson (approximately 7 km south of MCQ). The weather station has 51 years of rainfall data dating from 1967. A summary of average monthly and annual rainfall is presented in Table 2.1

The average annual rainfall is 932 mm with February and March being the wettest months, whilst August is the driest. The hottest month is January with average temperatures reaching 30°C, whilst July is the coldest with an average temperature around 17°C.

Table 2.1 Rainfall and temperature

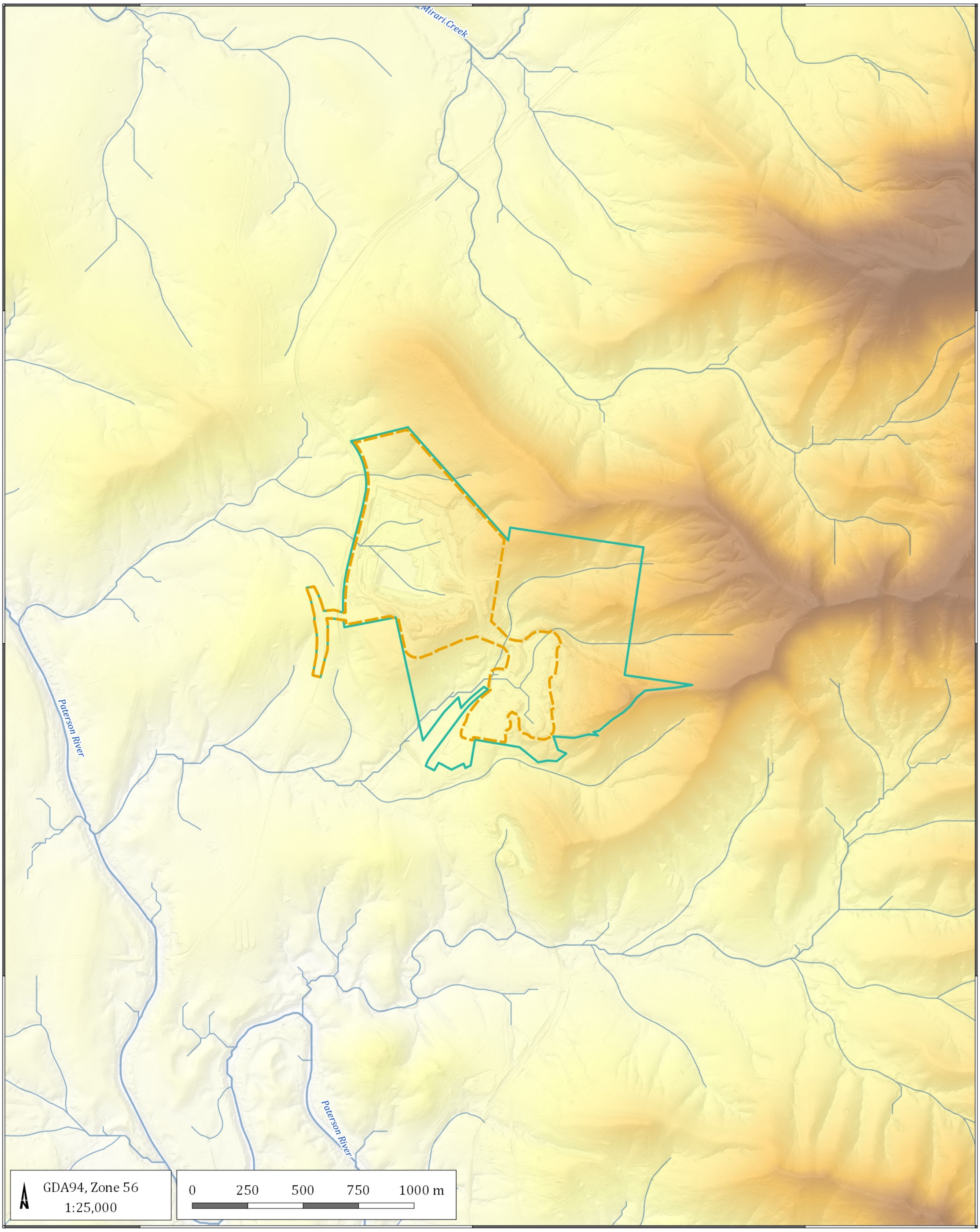
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Annual
Average rainfall (mm)	108	117	117	88	70	78	39	37	49	65	83	82	932
Average temperature (°C)	30	29	27	24	21	18	17	19	23	25	27	29	24

2.2 Terrain and drainage

MCQ lies within the Paterson River catchment downstream of the confluence with the Allyn River (Figure 2.1). The Paterson River and Allyn River have total catchment areas of approximately 277 km^2 and 367 km^2 respectively. The site is located on the south west facing slopes of a ridge with an elevation of up to 150 mAHD. The elevation of the alluvial flats associated with the Paterson River is around 9 mAHD; whereas the riverbed is close to 0 mAHD.

Runoff from the undisturbed catchment upslope of the existing processing area is drained by an unnamed second order ephemeral stream to the north of the East Pit and an unnamed third order ephemeral stream to the east of the East Pit. The streams converge to the north of the existing processing area with the combined stream flowing to the north of the processing area, via a culvert under the main haul road, off-site at the south west corner of the MCQ site and into the Paterson River approximately 1.5 km west of MCQ.

A first order and a second order ephemeral stream drain runoff from the catchment north of the West Pit which flows into the Paterson River approximately 1.5 km west of MCQ.



LEGEND

- Drainage
- Project Area
- Revised Project Disturbance Area

Elevation (mAHD)

- 0
- 50
- 100
- 200
- 250
- 400

Martins Creek Quarry (G1908K)

Terrain and drainage

AGE

DATE 04/03/2021

FIGURE No: **2.1**

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3 Geology

Regionally, MCQ is located within a mixed assemblage of Carboniferous aged volcaniclastic and sedimentary sequences as shown on Figure 3.1. A conceptual cross section of the site geology is shown on Figure 3.2**.** The MCQ stratigraphy is summarised in Table 3.1.

MCQ extracts rock from the Martins Creek Ignimbrite Member, which forms part of the Isismurra Formation (Figure 3.2). The target hard rock material is referred to locally as andesite but is actually a latite tuff (VGT Environmental Compliance Solutions Pty Ltd, 2021). This material is typically referred to as ignimbrite in this report for consistency with the historical stratigraphic nomenclature of the Martins Creek Ignimbrite Member. The site is underlain by the sedimentary sequences of the Wallaringa Formation, a bedded lithic sandstone and conglomerate. The contact zone between the two formations forms a thin zone of metamorphosed sediments (a meta-sandstone), and is readily distinguished by its red-brown colouration. This is informally considered as part of the Wallaringa Formation (Table 3.1).

The blue-grey latite tuff of the Martins Creek Ignimbrite is exposed on the quarry faces and floor. The base of this unit dips to the west at around 5 degrees to 8 degrees, which mirrors the general dip of the existing topography (Figure 3.2). The underlying Wallaringa Formation also has some exposures in parts of the quarry floor.

Table 3.1 MCQ stratigraphy

Map symbol	Age	Geological Formation	Member or unit name	Lithology	Base of unit (mAHD)	Thickness (m)
Qa	Quarter-nary	-	Alluvium			
Cgim	Carboniferous (Namurian to Visean)	Mowbray Formation	-			
Cgimb			Breckin Ignimbrite Member			
Cgin		Newton Formation	-			
Cginv			Vacy Ignimbrite Member			
Curim		Isismurra Formation	Martins Creek Ignimbrite Member	Ignimbrite/ latite tuff	8 - 125	~4- 50
*		Wallaringa Formation	Meta-sandstone	Meta-sandstone	12 - 129	2 - 4
Cugw			-	Sandstone and conglomerate	unknown	unknown

Notes: **informal unit is not shown on map (Figure 3.1), but is visible in cross section (Figure 3.2)*

LEGEND

- Watercourse
- Section line (SW - NE)
- Project Area
- Revised Disturbance Area

Monitoring bore

- Ignimbrite
- Meta-sandstone
- Wallaringa Sst (with gravel pack in ignimbrite and meta-sst)

Surface geology

- Quaternary alluvium (Qa)
- Breckin Ignimbrite Member (Cgimb)
- Martins Creek Ignimbrite Member (Curim)
- Mowbray Formation (Cgim)
- Newtown Formation (Cgin)
- Vacy Ignimbrite Member (Cginv)
- Wallaringa Formation (Cugw)

Martins Creek Quarry (G1908K)

Surface geology

AGE

DATE 04/03/2021

FIGURE No: **3.1**

Source: 1 second SRTM Derived DEM-S - © Commonwealth of Australia (Geoscience Australia) 2011.; GEODATA TOPO 250K Series 3 - © Commonwealth of Australia (Geoscience Australia) 2006.;
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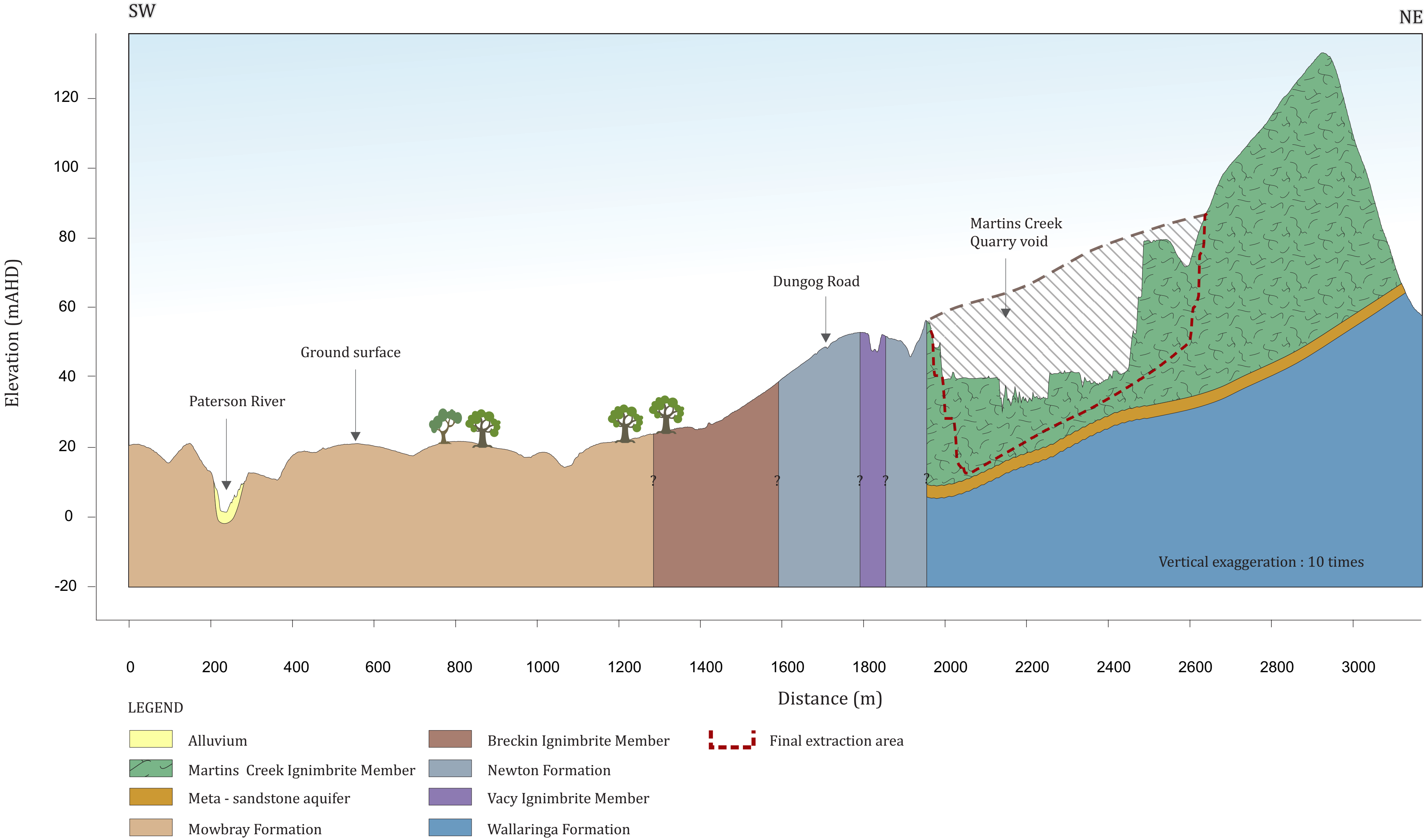


Geological cross section SW-NE

Figure 3.2

Martins Creek Quarry (G1908B)

4 Methods

4.1 Introduction

The potential impacts due to the proposed MCQ expansion are: interception of groundwater, drawdown within the aquifer system, and potential for impacts upon groundwater users (e.g. changes to water quality). The methods adopted relied on analysis of data collected during quarry operations, and linear analytical modelling. Analytical modelling was considered the most appropriate method to assess groundwater inflow volumes due to the type, frequency, and distribution of the data available. Groundwater seepage rates into the quarry and the associated future drawdown were estimated using:

- analytical methods informed by hydraulic conductivity and hydraulic gradients at the site;
- water level records within bores surrounding and monitored by MCQ.

These methods are outlined below, in addition to the approach used to quantitatively characterise the groundwater system and develop the conceptual hydrogeological model. The conceptualisation (refer to Section 5) is the critical basis for the predictions of potential seepage and drawdown.

4.2 Methods for groundwater system characterisation

4.2.1 *Estimations of permeability*

Permeability testing to obtain the hydraulic conductivity of the fractured rocks screened by the bores was carried out using falling and rising head tests. These tests involve monitoring water level responses and recovery during the introduction and removal of a solid "slug", which displaces water in the bore's water column. The data were analysed using Aquifer Test 2011.1 software (Schlumberger Water Services) using the standard method from Hvorslev (1951), which are applicable for unconfined or semi-confined aquifers.

4.2.2 *Characterisation of recharge*

The estimated percentage of rainfall contributing to groundwater recharge across the site was made using the chloride mass balance method. This method compares the concentration of chloride found in rainwater with the concentration found in groundwater to estimate the potential rate of groundwater recharge sourced from rainfall. Recharge [mm/yr] is calculated according to:

$$R = P \times \frac{Cl_P^-}{Cl_{gw}^-}$$

Where R is annual recharge [mm/year]; Cl_P is weighted average chloride concentration in rainfall [mg/L]; and Cl_{gw} is average chloride concentration in groundwater [mg/L] (Mensah *et al.*, 2014). Chloride concentration in precipitation was derived from published chloride accession/deposition data for the MCQ site (CSIRO, 2014). The value used for rainfall chloride concentration was derived from the mean deposition rate (40 to 45 kg/ha/year), and the average rainfall (932 mm/yr). The average chloride concentration in groundwater was derived from site groundwater geochemistry.

4.2.3 *Inference of groundwater flow paths and seepage behaviour*

Understanding the movement of groundwater within the fractured rocks at the site (Section 5) is the basis of the impact assessment (Section 6). As such, analysis of the groundwater level elevations were undertaken to assess how that groundwater is controlled by the geological framework, and how it interacts with surface features. The groundwater levels from all bores were assessed spatially (e.g. in a contour map) and temporally (e.g. hydrographs). The groundwater levels were also used in a comparative assessment to understand the relationship between deep and shallow groundwater across the site. Change over time and at different locations was compared to the history of the site and development of the quarry.

All the available data points were used in the development of the contour map, which represents the latest data (July 2020). In addition, information of the pit floor elevation (based on the most recent LiDAR data, which are from 2012) were used to inform the groundwater level contour map. With the exception of pit lakes / voids designed to receive surface runoff, site observations indicate that the pit floor is usually dry, except directly after rainfall events. Therefore, the regional water table elevation is below the base of the pit. The interpolation of groundwater levels in this assessment included the elevation of the pit floor as a potential maximum water level.

In addition, a scaled cross section is included as part of this assessment, using the latest groundwater level information (July 2020), and incorporating the Revised Project Disturbance Area, with the 2018 land surface from site survey data. The actual bore depths and construction details (e.g. screen interval) and their recently monitored water levels are shown as accurate values (elevations in mAHD), and in scaled context of the site geology. The existing site geology was also updated in this cross section to better reflect the geological logs (Appendix A).

4.2.4 *Identification of groundwater resources and users*

Public database searches were performed to identify groundwater users (i.e. registered bores and groundwater dependent ecosystems – GDEs), and characterise groundwater productivity (i.e. according to the AIP). The definition of GDEs according to the national GDE Atlas, is moderated with on site ecology data from the results of the Biodiversity Survey (Conacher Consulting, 2017). The on site observations are considered more accurate than the GDE Atlas, as the latter provides an indication of potential groundwater dependence through application of a standardised method[1]. The Atlas was generated by catchment scale mapping that integrated local expert knowledge and the best available spatial data. Notwithstanding this, there can be discrepancies between mapped areas and true on-site ecological characteristics, especially in remote areas.

4.3 Pit inflow estimation method

The impact of open pit quarrying creates a discontinuity of any groundwater system when the excavation intersects water bearing units. In this instance, the primary water bearing unit is the metamorphosed contact between the ignimbrite and the sandstone country rock, referred to as the meta-sandstone.

The water take associated with this void can be quantified in several ways, one of which is via analytical solutions. The method employed in this approach is outlined below. The conceptualised groundwater model is presented in Section 5.8.

Analytical methods use mathematical relationships to simulate idealised conditions and are based on a range of simplifying assumptions representing the groundwater system. Darcy's equation for steady state groundwater flow was used to estimate the inflow of groundwater to the quarry as follows:

$$Q = K \times i \times A \qquad [1]$$

Where, $\boldsymbol{Q}$ is seepage from the quarry face (m^3/day), $\boldsymbol{K}$ is the bulk rock median hydraulic conductivity (m/day), $\boldsymbol{i}$ is the steady state hydraulic gradient, and $\boldsymbol{A}$ is the cross sectional area of the aquifer (m^2), i.e. the seepage face.

Once a daily $\boldsymbol{Q}$ [m3/day] was estimated, an annual seepage rate [ML/yr] was calculated using an assumed number of days when seepage would be active (i.e. following rainfall events).

[1] http://www.bom.gov.au/water/groundwater/gde/reports.shtml

When estimating the groundwater inflow using this analytical solution it was assumed that:

- groundwater inflow occurs to the quarry only through the upgradient pit walls (northeast side);
- groundwater flow is perpendicular to the quarry wall seepage faces;
- the length of the seepage faces (walls) for each year are measured from the quarry extension plans;
- the saturated height of the predicted seepage faces ranges from 14.5 m and 37 m, which are based on specific heights of each quarry pit wall from the break of slope to the deepest point of the pit, as documented in the Revised Project plan. This is highly conservative based on the conceptual model;
- the duration of seepage ranges between 47 and 135 days per year, which is informed by on-site knowledge of seepage behaviour, and analysis of observed groundwater level responses to rainfall events (Section 5.3);
- the hydraulic gradient between bores MW04 to MW01 (0.032), and bores MW05 to MW07 (0.069) are representative of the minimum and maximum of hydraulic gradients relevant to the future seepage;
- the median hydraulic conductivity of the formations measured in all bores (1.5×10^{-1} m/day, Section 5.2) is a proxy for the bulk rock permeability at the site; and
- hydraulic gradient is linear.

The discharge volumes calculated with the analytical model are conservative due to the high value for saturated thickness of the quarry walls (up to 37 m), and the value used for hydraulic conductivity 1.5×10^{-1} m/day. As two of the inputs for the modelling (hydraulic gradient, and number of seepage days per year) vary between an upper and a lower assumed value, the model results show a range of four potential seepage volumes. Therefore, four scenarios of the analytical modelling are presented in Section 6.2, representing all combinations of these two variable parameters.

4.4 Drawdown prediction method

Potential drawdown impacts from the Revised Project were estimated based on a qualitative assessment of the current and historical observations of drawdown in monitoring bores, and a comparison of estimated seepage rates to recharge calculations. Predictions are outlined in Section 6.3.

5 Hydrogeological conceptual model

There are limited groundwater resources in the vicinity of MCQ owing to the low porosity of the andesitic ignimbrite and the underlying sandstone, which dominate the near-surface geology (Figure 3.1; Figure 3.2). A thin permeable zone, termed the meta-sandstone, is present at the base of the andesitic ignimbrite, along the contact with the underlying Wallaringa Formation sandstone. The contact zone contains a thin zone where the Wallaringa Formation is altered to form the meta-sandstone (Figure 3.2). This unit allows water to enter and move between the overlying and underlying formations.

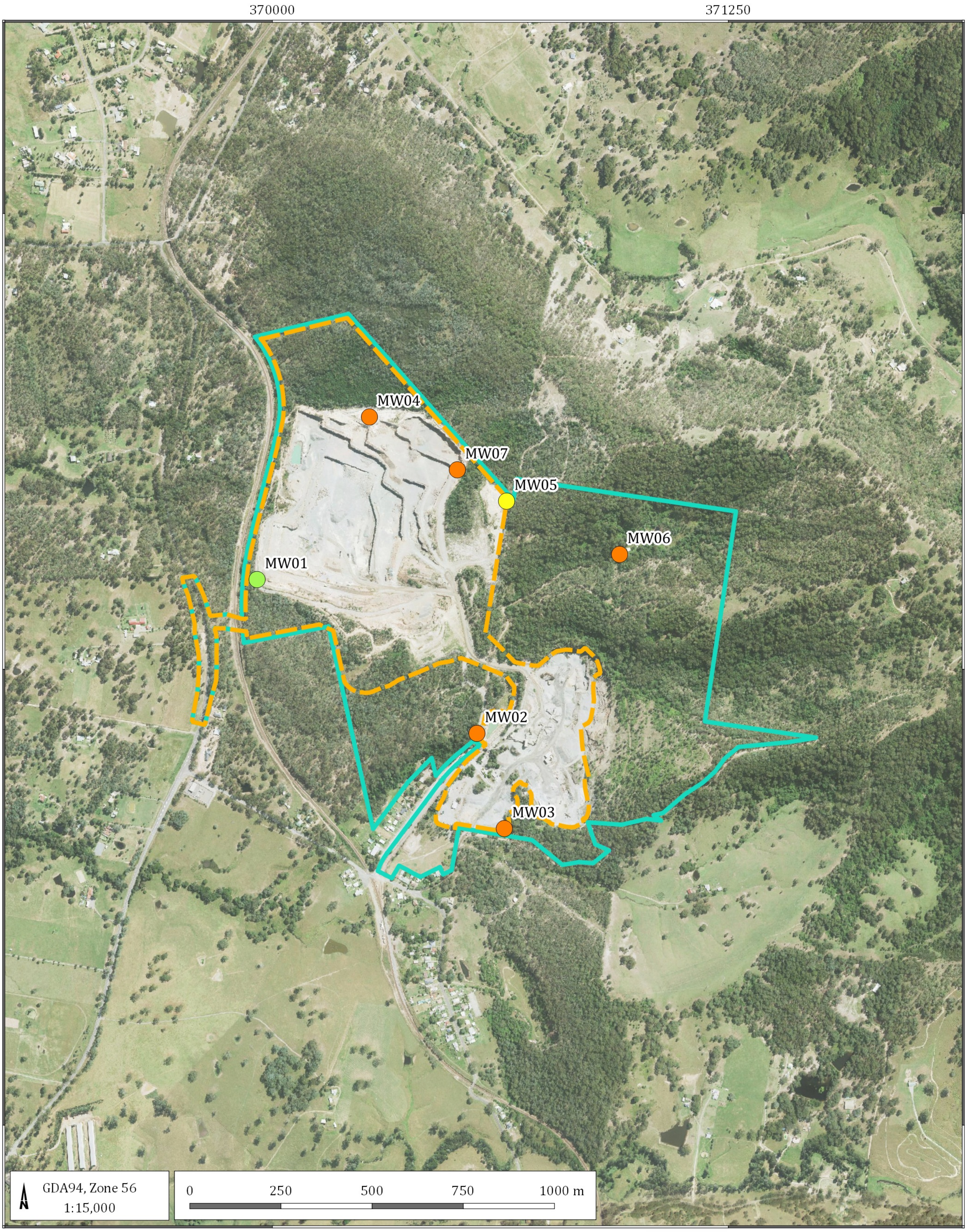
5.1 Groundwater monitoring network

The groundwater monitoring network at MCQ comprises seven monitoring bores (Figure 5.1). MW01, MW02, MW03 and MW04 were installed in 2016; and three additional monitoring bores, MW05, MW6 and MW07, were installed under the observation of an AGE Hydrogeologist in May 2018. The additional monitoring bore locations were determined following a review of the site geology and extraction plan, with an objective of increasing the spatial coverage of the monitoring network on the upgradient side of the current and proposed quarry operations. The expansion of the existing monitoring network ensured a comprehensive spatial coverage of the groundwater system at MCQ. The expanded monitoring network at MCQ is sufficient to detect impacts to groundwater that may occur as a result of the Revised Project.

Construction details for the monitoring bores are summarised in Table 5.1. Groundwater sampling and hydraulic testing was conducted following the monitoring bore installation in 2018 (refer to Section 5.2). The drill hole details and monitoring bore construction details for MW05, MW06 and MW07 are detailed in the drilling completion report (AGE, 2018a) and included in Appendix A.

Each monitoring bore within the network is fitted with a groundwater level pressure transducer (level logger) to record groundwater level fluctuations. Pressure transducers were installed in MW01, MW02, MW03 and MW04 in August 2016. MW05, MW06 and MW07 were fitted with pressure transducers in July 2018. Groundwater levels recorded by the level loggers are downloaded twice a year. Manual groundwater level measurements, field water quality parameters, and groundwater samples for laboratory analysis are collected annually.

The existing groundwater monitoring network at MCQ currently provides an appropriate level of understanding of the groundwater conditions at the site and prediction of any potential impacts associated with the MCQ Revised Project. However, some of the monitoring sites will be affected at different stages of the Revised Project (MW07 will be removed between project years 3 and 6, MW04 removed between project years 16 and 20, and MW05 may be disturbed between project years 21 and 25). Timely replacement of these monitoring sites prior to removal is required to provide an appropriate monitoring network. In addition, as the future quarrying will extend below the local water table (refer to Section 5.3), additional monitoring downgradient of MW01 is recommended, to detect and quantify potential drawdown. This should be considered in the initial development of the WMP (Section 8.1).



LEGEND

Monitoring bore

- Ignimbrite
- Meta-sandstone
- Wallaringa Sst (with gravel pack in ignimbrite and meta-sst)
- Project Area
- Revised Project Disturbance Area

Martins Creek Quarry (G1908K)

Monitoring bore network

AGE

DATE 04/03/2021

FIGURE No: **5.1**

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Table 5.1 Monitoring bore construction details

Monitoring bore	Easting	Northing	Ground elevation (mAHD)	Total depth (mBGL)	Screen interval (mBGL)	Screened geology
MW01	369958	6397746	52.9	24.1	21.1 – 24.1	quarry ignimbrite*
MW02	370561	6397324	47.3	14.4	11.4 – 14.4	meta-sandstone*
MW03	370636	6397063	56.0	24	21 - 24	meta-sandstone*
MW04	370266	6398192	77.0	48.1	39 - 42	meta-sandstone*
MW05	370642	6397961	123.5	45	42 - 45	Wallaringa Fm Sandstone (with gravel pack in the ignimbrite and meta-sandstone)
MW06	370952	6397815	86.6	21	8 - 14	meta-sandstone
MW07	370507	6398047	84.9	18	14.5 - 17.5	meta-sandstone

Note: ** the screened unit of these bores is inferred from local geological knowledge (bore logs not available)*

5.2 Hydraulic properties

Falling head tests were conducted following the installation of monitoring bores, in order to determine the hydraulic conductivity of the screened formations. The analyses indicate that hydraulic conductivity (K) varies by four orders of magnitude across the groundwater monitoring network (Table 5.2; Figure 5.2), which is typical for the rock types found on site. This variation is attributed to the nature of the secondary porosity that characterises the fractured rock system, and the degree of alteration and thus permeability of the aquifer intercepted by the monitoring bores. Median hydraulic conductivity values are generally associated with the meta-sandstone, which is anticipated given the altered nature of the rock at the contact between the ignimbrite and the underlying sandstone, and the dual porosity of the meta-sandstone. The highest estimate of hydraulic conductivity comes from bore MW01, which is the only bore known or considered to be screened in the ignimbrite. It is very close to operations, and immediately downgradient (west) of the quarry pit (Figure 5.1). The higher permeability at this location demonstrates the ability of the ignimbrite to transmit groundwater. However, it could also partially be attributed to quarry blasting creating additional fracturing, as long as blasting was conducted prior to the bore being installed and tested in 2015/2016. Given the length of the legacy quarrying on site (Section 1), this is considered possible. The shallowest bore, MW06, upgradient of operations, provides the median K value, 1.5 x 10^{-1} m/d (Figure 5.2).

Table 5.2 Falling head tests

Monitoring bore	Target geology	Hydraulic conductivity (m/d)	Source of value
MW01	quarry ignimbrite	1.17	(JM Environmental, 2016)
MW02	meta-sandstone	2.49 x 10^{-1}	(JM Environmental, 2016)
MW03	meta-sandstone	3.94 x 10^{-1}	(JM Environmental, 2016)
MW04	meta-sandstone	4.13 x 10^{-2}	(JM Environmental, 2016)
MW05	Wallaringa Fm Sandstone (with gravel pack in the ignimbrite and meta-sandstone)	7.40 x 10^{-3}	(AGE, 2018a)
MW06	meta-sandstone	1.50 x 10^{-1}	(AGE, 2018a)
MW07	meta-sandstone	4.50 x 10^{-2}	(AGE, 2018a)

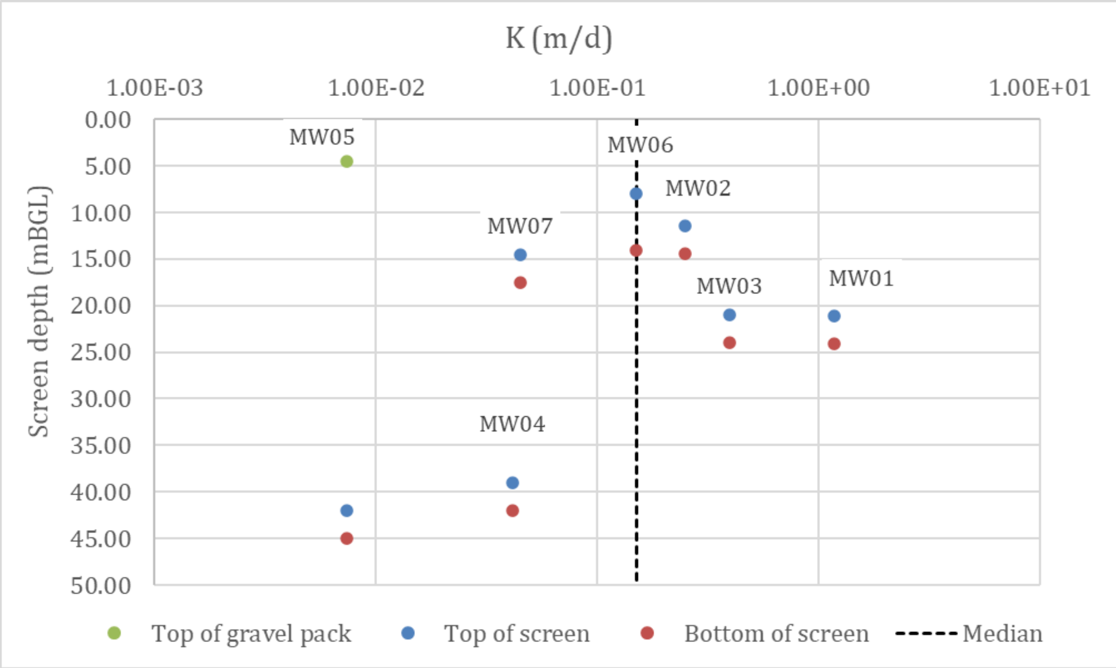


Figure 5.2 Hydraulic conductivity with screen depth

5.3 Groundwater levels and flow

Groundwater flow is constrained to the network of fractures within the Martins Creek Ignimbrite Member, and the thin alteration zone (the meta-sandstone), which is present at the base of the ignimbrite at the contact with the underlying Wallaringa Formation sandstone. Rainfall recharge to the aquifer typically occurs by rainfall moving down vertical fractures in the ignimbrite, and reaching the meta-sandstone. A previous estimate of groundwater recharge using chloride mass balance was 1% of rainfall, i.e. 9 mm/yr (JM Environmental, 2016). However, this study found that between 3% and 5% of rainfall is likely to become groundwater recharge (due to the lower values of chloride observed at MW07; Section 5.4). These recharge rates (3% to 5%) equate to 11.1 ML/yr to 16.8 ML/yr for the quarry area, assuming an upgradient catchment area of 36 ha (JM Environmental, 2016). The water table usually sits in the ignimbrite. The main aquifer zone of the meta-sandstone is limited laterally to where the ignimbrite exists, and this unit dips to the south west (Figure 3.2).

On-site knowledge of MCQ staff and observations made during the site investigation in May 2018 for bore installation indicate that there is limited groundwater inflow into the quarry. Inflow typically occurs for short periods following rainfall. Both groundwater inflow/seepage and runoff accumulate in the lowest lying quarry voids immediately after rain events (Figure 5.3). The image below (Figure 5.3) was taken on 18 May 2020, with 94 mm of rain in the preceding 60 days. Loss of water from these voids is via evaporation and seepage to groundwater, but also to operational losses, as water is reticulated across the site for various uses (e.g. dust suppression).

During dry times the rate of evaporation from the rock exposed in the pit walls and some floor areas commonly exceeds the seepage rate. This indicates that the overlying ignimbrite is mostly unsaturated in the zones directly adjacent to the current pit, especially in the upper benches (Figure 5.3). The absence of permanent groundwater seepage into pit sumps indicates that the water table is generally below the current floor of the quarry, other than in the short periods following rainfall events.

Manual groundwater level measurements (Table 5.3; Table 5.4), are recorded annually, with the highest groundwater elevations observed in MW05, MW06 and MW07, upgradient of MCQ. As expected, groundwater levels are a subdued reflection of topography (Figure 5.5), with groundwater elevations highest on the eastern side of MCQ (i.e. upgradient) and lower in the southwest direction. Depths to groundwater range with topography, currently between 3.27 mbgl (MW06; near a stream) to 37.68 mbgl (MW05; in the high elevation area) (Table 5.4).

Figure 5.3 Accumulated water after rain events (18 May 2020)

The groundwater level hydrographs from manual and logger readings for each monitoring bore are presented in Figure 5.4 and show groundwater levels at MW01, MW02 and MW03 have remained relatively stable since 2015, with no significant indication of drawdown from MCQ operations in those bores. The long-term change in groundwater levels at MW04 indicate approximately 10 metres of decline since 2015 (about 2 m/yr; Table 5.3). This is likely due in part to quarry drawdown, but may also be linked to the change in rainfall patterns over the same period (i.e. declining rainfall trends from 2015 to 2019; Figure 5.4). The manual groundwater levels at MW05 also show a decline (approximately 2.2 m/yr), although there are peaks recorded between these measurements by the level logger, which are due to recharge events (discussed below). Due to the low hydraulic conductivity at MW05, this declining trend may be an effect caused by the water level in the bore being slow to equilibrate after bore installation in 2018. Alternatively, the rate of decline is like that of MW04, and drawdown from the quarry could be a contributing factor. Further monitoring will inform this inference in the future. In contrast, the groundwater levels at MW06 appear unaffected by drawdown or rainfall recharge (Figure 5.4).

In the last 12 months, depths to groundwater levels in bores MW01, MW02 and MW03 have become shallower (Table 5.4; Figure 5.4). These bores are all downgradient of quarry pits, and therefore the increases in water levels could indicate that some water from the pit voids is infiltrating back into the ground. However, the upgradient site of MW07 also has increasing groundwater levels over the same period, and thus this trend could be due to the very recent rainfall levels.

Groundwater levels in most bores respond to rainfall events, denoting recharge processes in the catchment (Figure 5.4). The most significant of these responses is shown in the bore MW05, which triggers a significant change in groundwater pressure (about 10 m or more) for any rainfall event exceeding about 20 mm/day. Bore MW05 is the deepest bore on site, and is screened in the Wallaringa Formation (although the gravel pack in the bore annulus is also installed across the ignimbrite and the meta-sandstone). However, this bore is also located in the most upgradient location (Figure 5.1), representative of recharge zones. As such, the cause of the large magnitude recharge response is consistent with the bore location. In addition, the higher pressure of semi-confined conditions at depth, and the lower permeability expected in the sandstone of the Wallaringa Formation (Section 5.2) also contribute to the cause of the oscillating recharge pattern. The rates of recession after these peaks (bore MW05, and the smaller changes in other bores) are variable depending on the magnitude of the rainfall events, but vary between about 10 to 15 days. This temporary change in pressure indicates how the groundwater levels dictate transient periods of seepage into the current quarry after rainfall: when the water levels are higher, they temporarily rise up to saturate the current pit wall and cause seepage.

Table 5.3 Groundwater level elevations (manual readings 2015 – 2020)

Groundwater elevation (mAHD)	MW1	MW2	MW3	MW4	MW5	MW6	MW7
18-03-15	36.10	41.92	44.63	63.19			
11-08-16	36.75	42.30	42.70	60.42			
16-08-16	36.82	41.73	43.73	59.93			
23-07-18	36.98				90.08		
24-07-18		42.37				83.62	
25-07-18			44.46	55.26			75.24
16-08-18	36.59	42.06	44.35	53.88			
26-03-19	35.11	41.95	44.02	54.62	87.50	83.50	74.82
12-07-19	34.65	41.91	43.80	53.36	85.76	83.38	73.81
18-05-20	35.37	42.86	44.87	52.71	85.04	83.14	74.13
09-07-20	35.86	42.91	44.94	53.44	85.81	83.29	76.06
Change in level (linear average) [m/yr]	-0.25	0.14	0.17	-2.01	NA	-0.21	0.09

Table 5.4 Depth to groundwater levels (manual readings 2015 – 2020)

Depth to water (mBGL)	MW1	MW2	MW3	MW4	MW5	MW6	MW7
18-03-15	16.80	5.38	11.37	13.81			
11-08-16	16.15	5.00	13.30	16.58			
16-08-16	16.08	5.57	12.27	17.07			
23-07-18	15.92				33.41		
24-07-18		4.93				2.94	
25-07-18			11.54	21.74			
16-08-18	16.31	5.24	11.65	23.12			
26-03-19	17.79	5.35	11.98	22.38	35.99	3.06	10.11
12-07-19	18.25	5.39	12.20	23.64	37.73	3.18	11.12
18-05-20	17.53	4.44	11.13	24.29	38.45	3.42	10.80
09-07-20	17.04	4.39	11.06	23.56	37.68	3.27	8.87

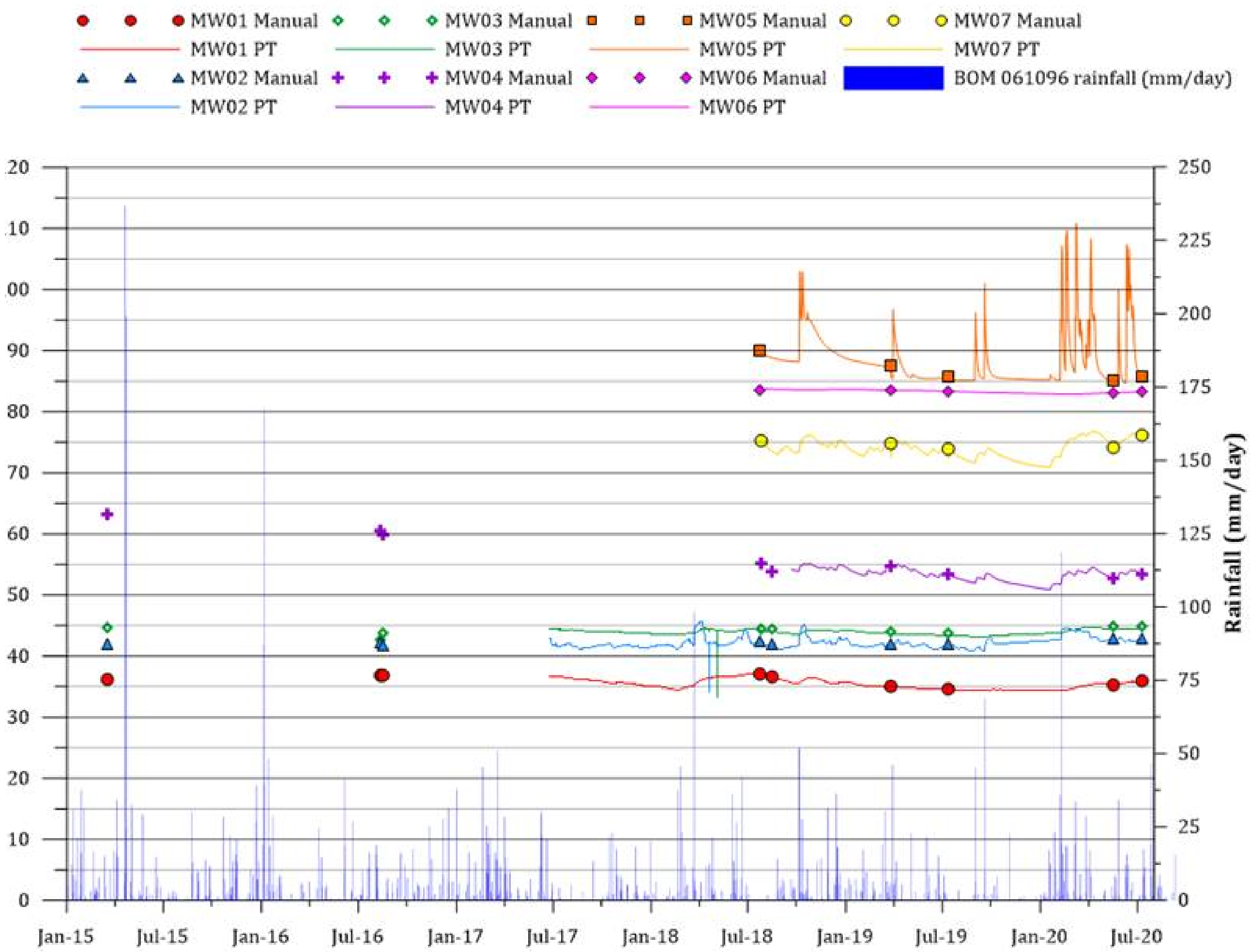
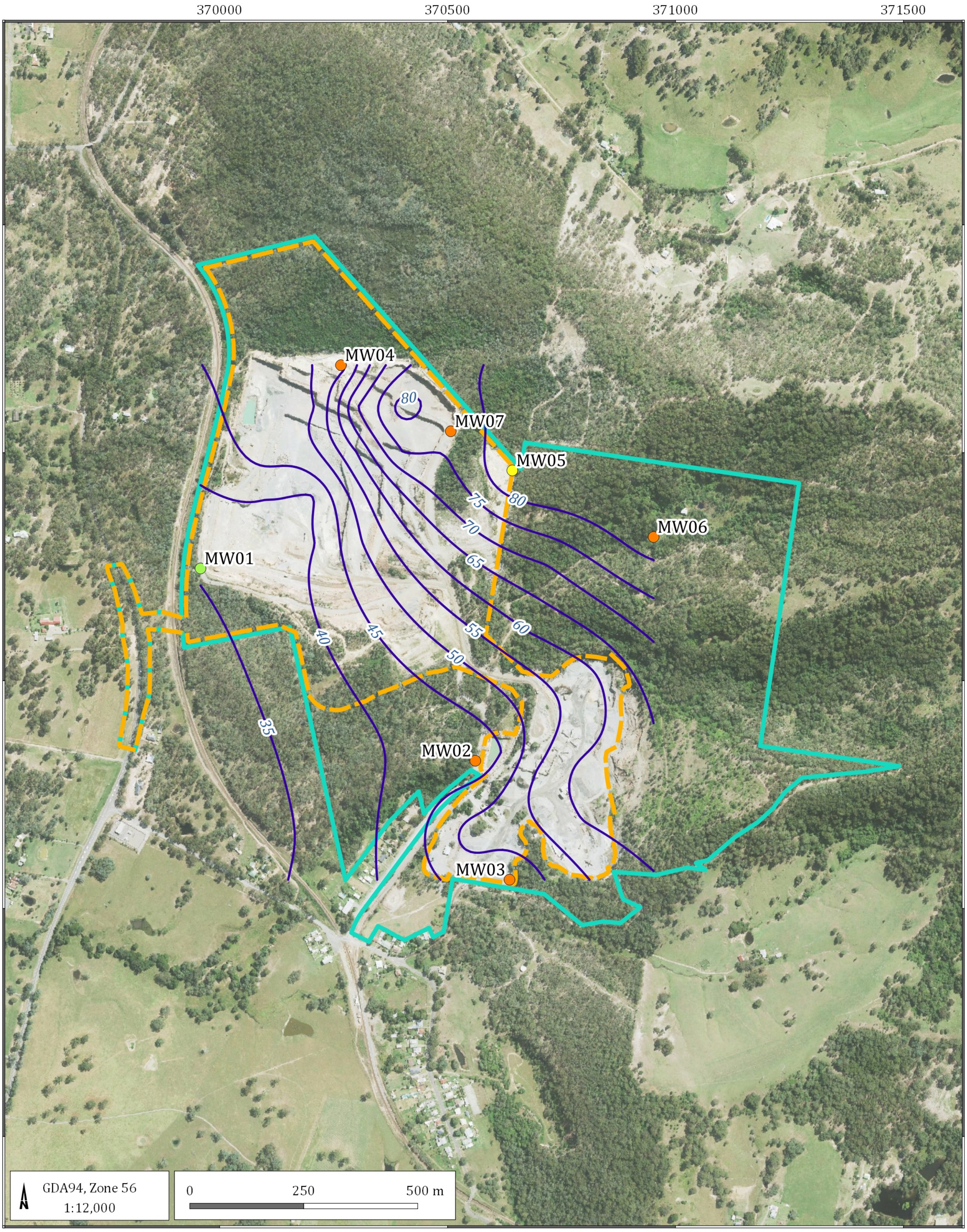


Figure 5.4 Groundwater hydrographs



LEGEND

- Project Area
- Revised Project Disturbance Area
- Groundwater level contours (mAHD)

Monitoring bore

- Ignimbrite
- Meta-sandstone
- Wallaringa Sst (with gravel pack in ignimbrite and meta-sst)

Martins Creek Quarry (G1908K)

Groundwater contours (May 2020)

AGE

DATE 04/03/2021

FIGURE No: **5.5**

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5.4 Groundwater quality

Groundwater quality samples have been collected once or twice a year since 2015 (except 2017); results from July 2020 are shown in Table 5.5 and Table 5.6, with recent dissolved metal concentrations (2018 data) provided in Table 5.7. The groundwater electrical conductivity (EC) changes over time are shown in Figure 5.6, and those for pH in Figure 5.7. The historical proportions of major ions in solution are shown in a Piper diagram (Figure 5.8), where more recent samples are plotted using larger symbols. The groundwater is generally fresh to brackish, with EC currently ranging from 849 µS/cm (MW01) to 3,702 µS/cm (MW06) (Table 5.5). Field pH is circum-neutral, currently ranging from 6.93 (MW03) to 7.36 (MW04) (Table 5.5).

Dissolved metals analysis shows that most samples have concentrations below the limit of detection, with the exception of Al, As, B, Ba, Br, Mn, Mo, Ni, Sr, Zn (Table 5.7). Where concentrations of dissolved metals are detected, they are usually low, and most are below the guideline value designed to protect 95% of freshwater species (ANZECC/ARMCANZ, 2000; Table 5.7). Exceptions to this are: aluminium, boron, copper and zinc, which are marginally higher than the freshwater values in some locations. This is expected in groundwater of brackish quality, as interaction with minerals in the host rock and contribute metals to solution.

Historically, pH is similar across the sites, varying from 6.5 to 8 (Figure 5.7); whereas EC is consistent within a single bore, but variable across the site (Figure 5.6). This is typical of many groundwater regimes, as groundwater flows slowly compared to surface water, and the extent of geochemical evolution at any given monitoring point can be very variable (e.g. immature or advanced). This effect is more pronounced in fractured systems, where connectivity between sites is limited by discrete fracture networks. As such, the variation in water quality between the sites is likely to relate to the residence time of groundwater. The highest EC values are recorded at MW06, and MW03, and the lowest at MW01.

MW06 is upgradient of quarry workings and its levels appear unaffected by drawdown or recharge (Section 5.3). It is located adjacent to a stream, indicating that is could be at the end of a local flow system, where groundwater baseflow reaches the surface. This position in the local or regional flow system is consistent with the higher EC value. EC at MW06 is consistently below 5,000 µS/cm, which is below the stock drinking water guideline level (ANZECC/ARMCANZ, 2000).

Bore MW03 is downgradient of the east pit, and may be receiving infiltration from temporary storage of pit water (Section 5.3). The increase in EC at MW03 could be an indication of this process; however, this is yet to be confirmed via a comparison with pit water quality. The current EC levels at MW03 are similar to those observed in 2015.

Bore MW1 is located downgradient of the west quarry pit, and recent water levels show that it may be receiving infiltration of water from pit voids (Section 5.3). As most of the water in voids is catchment runoff, the infiltration of this water could be the cause of the lower EC at bore MW01. However, bore MW01 also has the highest hydraulic conductivity value (Section 5.2), and this implies efficient recharge to the water table, which typically relates to fresh groundwater. The groundwater samples at MW01 are also the most dominated by sodium and bicarbonate (Figure 5.8), which is typical of freshly recharged groundwater. Therefore, the local hydraulic conditions of the ignimbrite could also be the cause of the consistently low EC records at MW01 (Figure 5.6).

As mentioned above, the water from MW01 is sodium-bicarbonate type, as is that from MW07 (although water from MW07 has variable abundance of sulfate). MW07 sit in a topographically elevated area, indicative of a recharge zone, thus the similarity to water from MW01 is expected. The rest of the sites have groundwater that is sodium-chloride type (Figure 5.8); although samples at MW02 and MW05 also have significant bicarbonate (between 30% and 50% of anions).

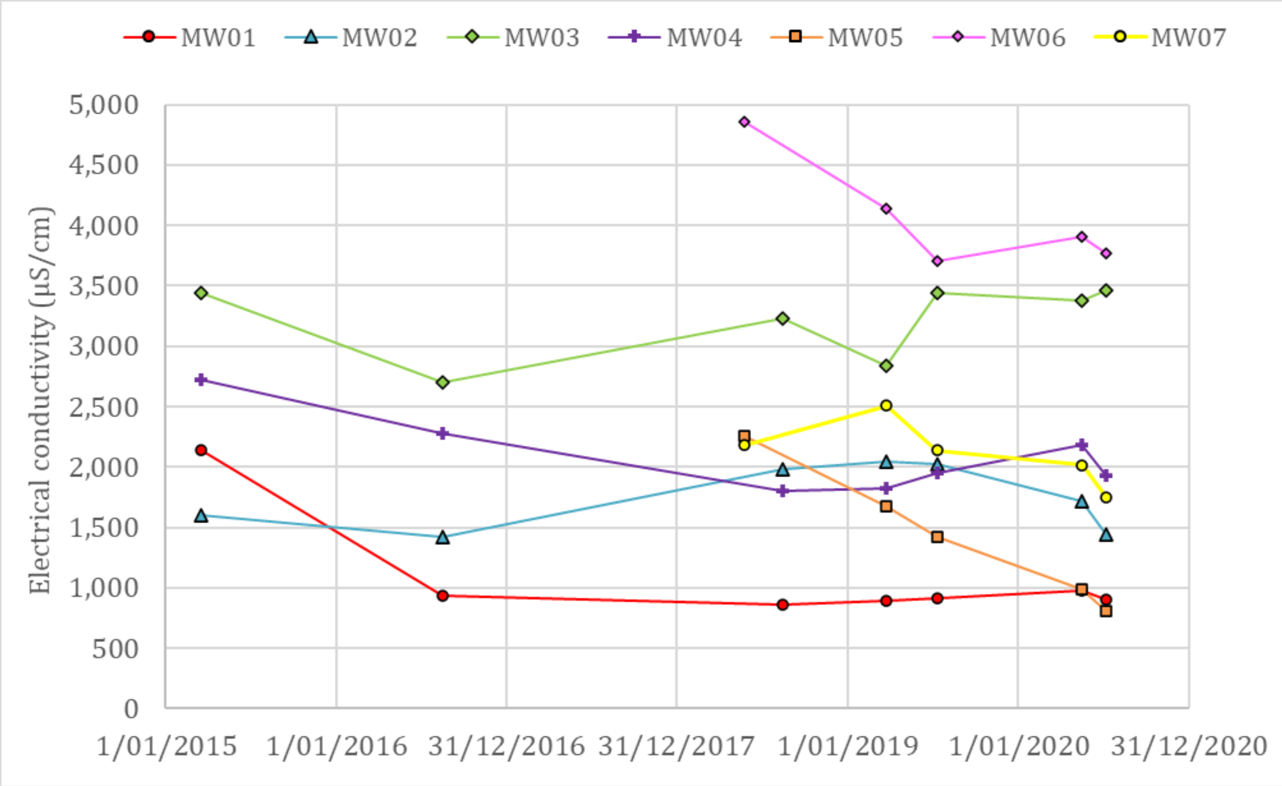


Figure 5.6 Electrical conductivity over time

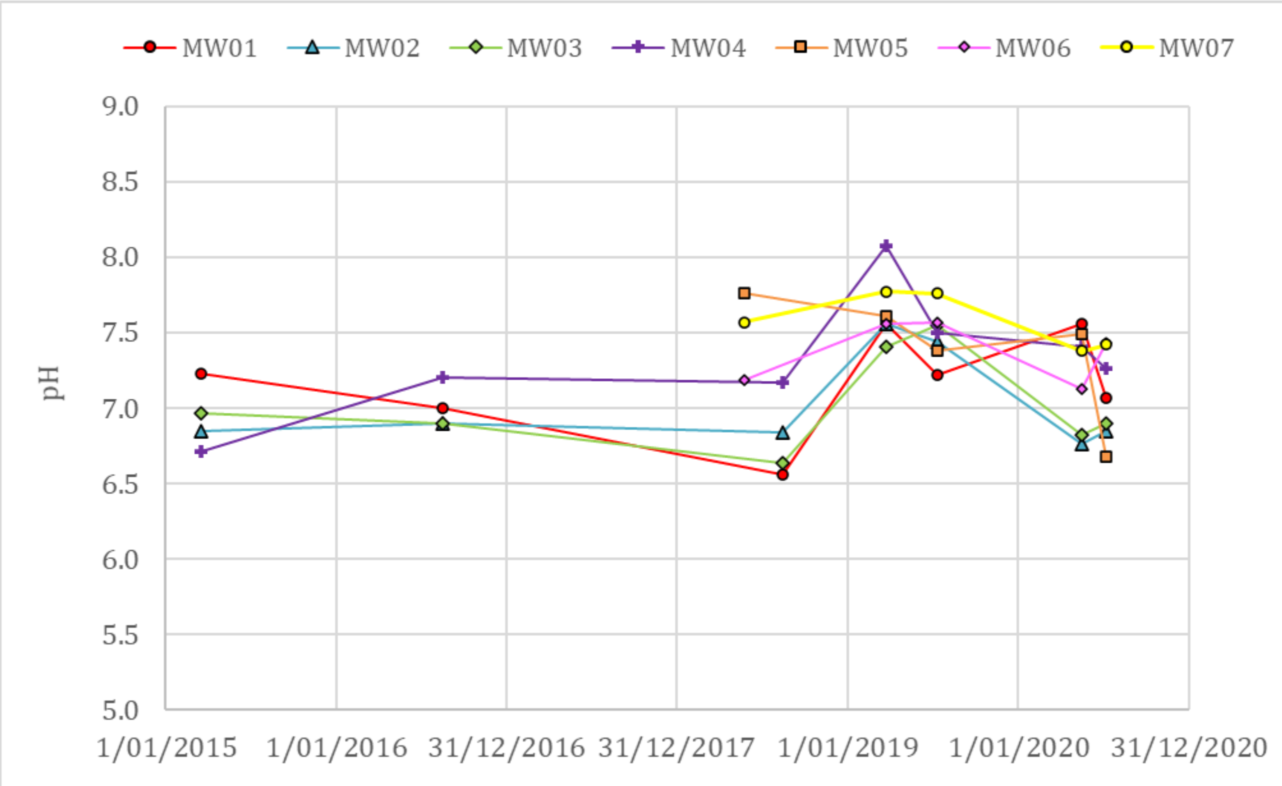


Figure 5.7 Groundwater pH over time

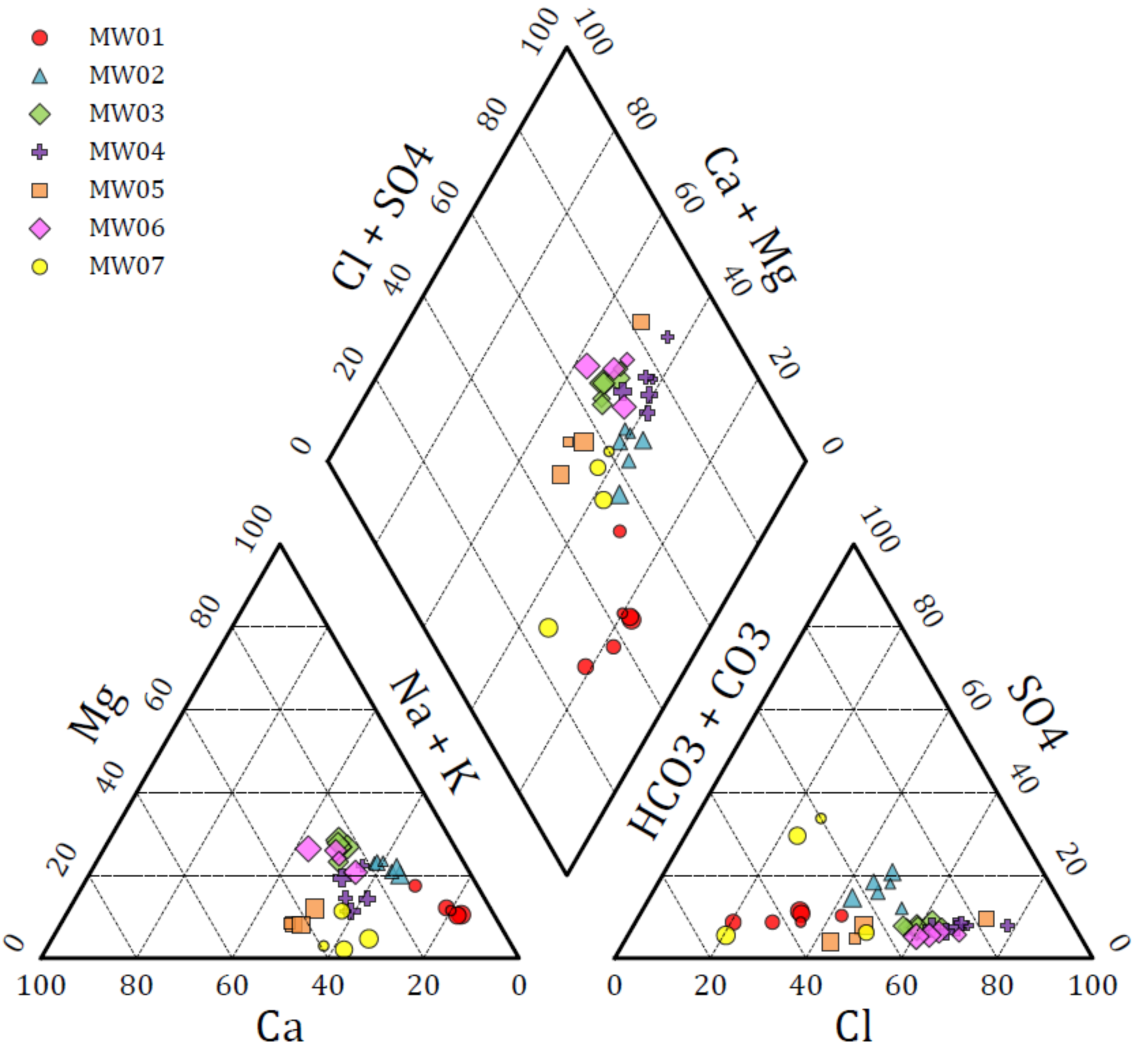


Figure 5.8 Major ion composition – Piper diagram

Table 5.5 Groundwater quality results (July 2020) - pH, EC, TDS

Parameter	MW01	MW02	MW03	MW04	MW05	MW06	MW07
pH	6.88	6.76	6.78	6.72	6.59	7.16	7.3
EC (µS/cm)	893	1401	3375	1828	782	3676	1746
TDS (mg/L)	618	990	2573	1319	537	2818	1253

Table 5.6 Groundwater quality results (July 2020) - major ions

Parameter	MW01	MW02	MW03	MW04	MW05	MW06	MW07
Ca (mg/L)	13	44	169	117	66	292	124
Mg (mg/L)	12	36	123	50	13	150	12
K (mg/L)	<1	2	2	5	6	12	4
Na (mg/L)	181	222	398	262	106	465	325
Cl (mg/L)	104	214	730	380	130	740	130
SO4 (mg/L)	49	101	124	61	29	88	48
HCO3 (mg/L)	250	310	580	260	170	600	670
F (mg/L)	3.2	1.5	2.2	0.4	1	1.6	0.2

Table 5.7 Groundwater quality results (2018)- dissolved metals and minor ions

Parameter	Guide-line*	Limit of detection	MW01	MW02	MW03	MW04	MW05	MW06	MW07
Al (mg/L)	0.055	0.01	**0.06**	<0.01	0.02	<0.01	<0.01	<0.01	<0.01
As (mg/L)	0.013	0.001	0.001	<0.001	0.002	<0.001	0.001	0.002	0.004
Be (mg/L)	ID	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Ba (mg/L)	NL	0.001	0.003	0.013	0.02	0.007	0.036	0.059	0.028
Cd (mg/L)	0.0002	0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Cr (mg/L)	0.001	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Co (mg/L)	ID	0.001	0.001	0.001	<0.001	<0.001	<0.001	0.002	<0.001
Cu (mg/L)	0.0014	0.001	**0.09**	<0.001	<0.001	**0.002**	<0.001	**0.002**	<0.001
Pb (mg/L)	0.0034	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Mn (mg/L)	1.9	0.001	0.139	0.488	0.293	0.042	0.06	0.264	0.117
Mo (mg/L)	ID	0.001	0.002	0.003	0.01	<0.001	0.003	0.003	0.005
Ni (mg/L)	0.011	0.001	0.004	<0.001	0.002	<0.001	0.002	0.006	0.005
Se (mg/L)	0.011	0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Sr (mg/L)	NL	0.001	0.039	0.335	0.763	0.145	0.429	1.34	0.324
V (mg/L)	ID	0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Zn (mg/L)	0.008	0.005	**2.56**	**0.491**	**0.02**	**0.037**	**0.011**	**0.017**	<0.005
B (mg/L)	0.37	0.05	0.19	0.2	**0.53**	0.19	**0.87**	**0.6**	**0.57**
Fe (mg/L)	ID	0.05	<0.05	<0.05	0.66	<0.05	<0.05	<0.05	<0.05
Br (mg/L)	NL	0.1	1.1	1.2	1.1	0.6	0.8	1.9	0.6

Notes: ** Guideline levels are trigger values for protection of 95% of species in freshwater (Table 3.4.1 of ANZECC/ARMCANZ, 2000)*

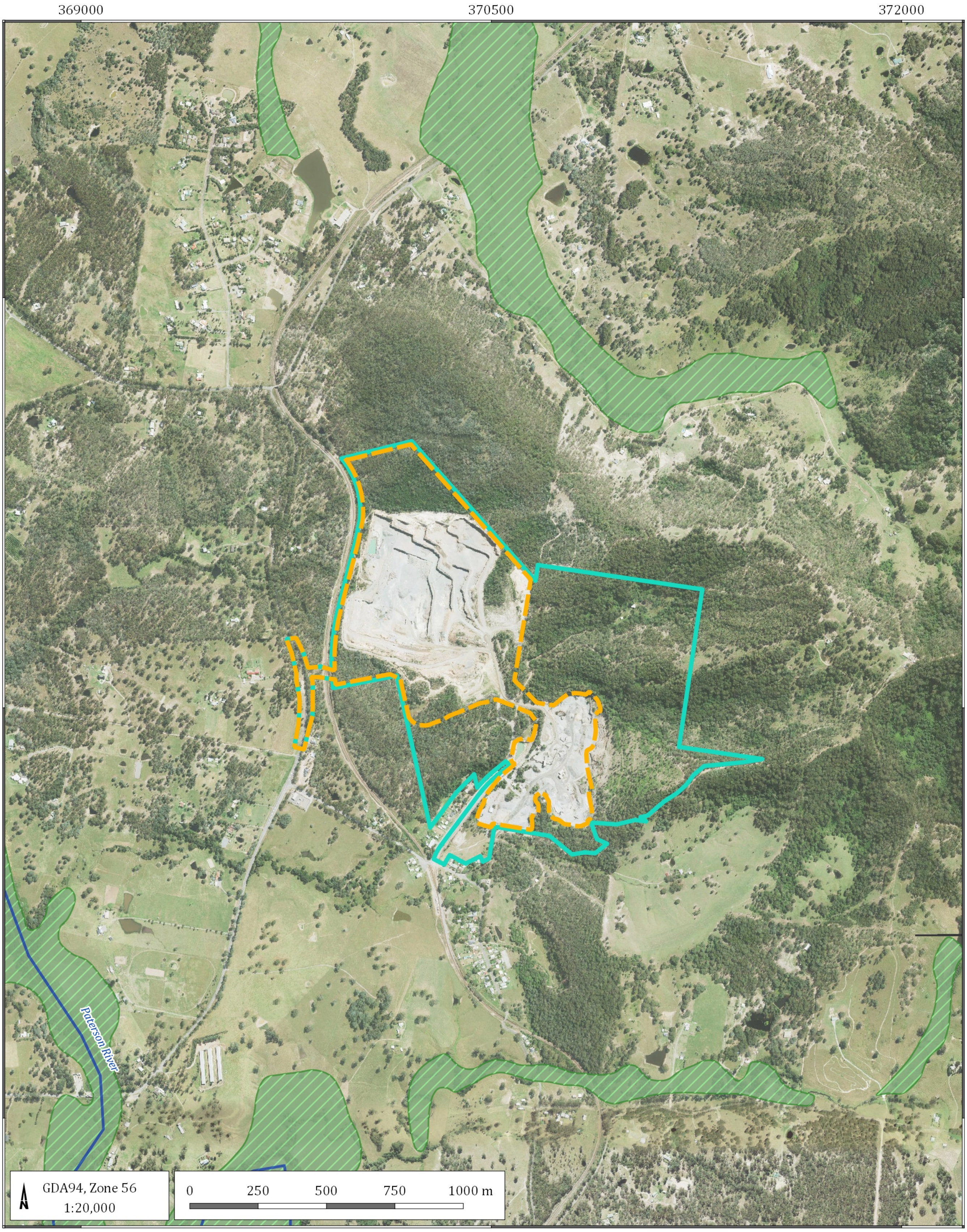
NL – not listed in guidelines

ID – insufficient data for toxicology assessment (ANZECC/ARMCANZ, 2000)

Bold values are greater than guideline values

5.5 Groundwater productivity

In accordance with the definitions contained within the NSW Aquifer Interference Policy (AIP) groundwater productivity at MCQ has been mapped as 'less productive' (Figure 5.9). The nearest 'highly productive' groundwater sources near MCQ are within the alluvial sediments on the flats (Figure 3.2) associated with the Paterson River (over 1.2 km from MCQ) and Mirari Creek (Figure 5.9).



LEGEND

- Drainage
- Project Area
- Revised Project Disturbance Area
- High groundwater productivity zone

Martins Creek Quarry (G1908K)

Groundwater productivity

AGE

DATE 04/03/2021

FIGURE No: **5.9**

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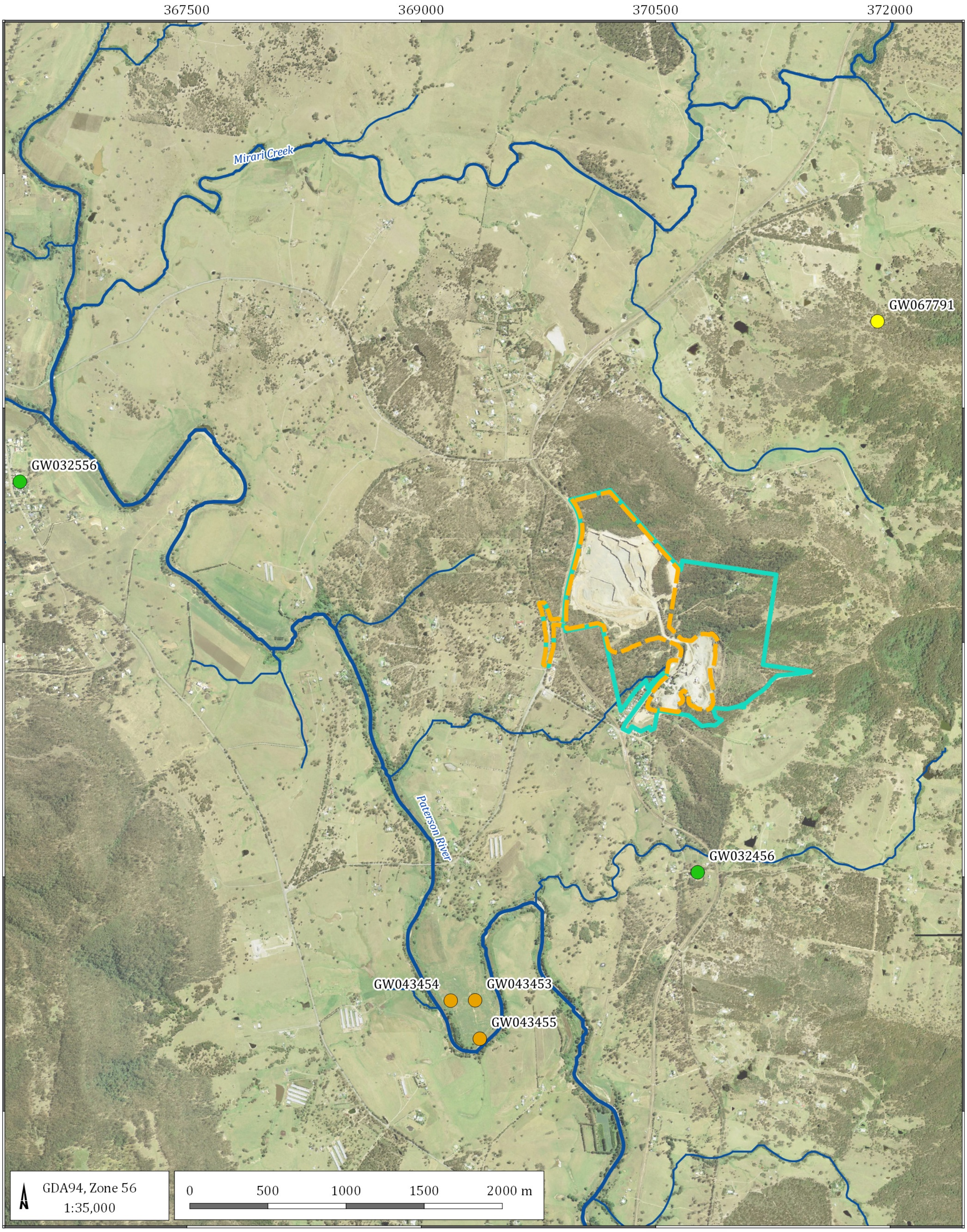
5.6 Landholder bores

A search of the NSW Groundwater database identified six registered bores within a five kilometre radius of the MCQ boundary. Details are summarised in Table 5.8 and locations are shown in Figure 5.10. Two of the registered bores are currently active, with an authorised purpose of water supply. Both are located outside of the mapped extent of the Martins Creek Ignimbrite Member, and as such do not source water from the meta-sandstone aquifer that is present at MCQ beneath the ignimbrite. The closest active bore is more than 1,000 m from the east pit of the quarry, and is not directly downgradient of the groundwater around MCQ, as the bore is located to the south (Figure 5.10).

Table 5.8 Landholder bores details

Station	Easting	Northing	Install date	Depth	Purpose	Status
GW032456	370768	6396028	1/03/1969	18.3	Water supply	active
GW067791	371919	6399554	11/04/1989	26.9	Stock and domestic	lapsed
GW043453	369344	6395209	1/05/1973	17.1	Test bore	cancelled
GW043454	369188	6395207	-	13.4	Test bore	cancelled
GW043455	369374	6394963	1/10/1973	18.3	Test bore	cancelled
GW032556	366431	6398528	1/05/1968	36.6	Water supply	active



LEGEND

- Project Area
- Revised Project Disturbance Area
- Drainage

Landholder bores status

- Active
- Lapsed
- Cancelled

Martins Creek Quarry (G1908K)

Landholder bores

DATE 04/03/2021

FIGURE No: **5.10**

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5.7 Groundwater dependent ecosystems

A review of the Bureau of Meteorology Groundwater Dependent Ecosystems Atlas (GDE Atlas) including aquatic and terrestrial GDEs surrounding MCQ was completed. The local potential GDEs according to the national GDE Atlas are shown in Figure 5.11. The GDE Atlas was developed as a national dataset of Australian GDEs to inform groundwater planning and management. The GDE Atlas has no mapped aquatic GDEs in the area (Figure 5.11). There are several potential terrestrial GDE zones mapped in the Atlas near MCQ (Figure 5.11). The ecosystem type and their potential for dependence on groundwater according to the GDE Atlas are shown on Figure 5.11. The potential terrestrial GDEs in the downgradient areas are all of low or moderate potential (Figure 5.11).

In addition, vegetation data obtained in an on-site Biodiversity Offset Land Survey (Conacher Consulting, 2017) are mapped in Figure 5.12. The on-site observations are considered more accurate than the GDE Atlas, as the latter provides an indication of potential groundwater dependence, mainly through use of regional mapping, some of it remotely conducted. As such, there can be discrepancies between mapped areas in the Atlas and true on-site ecological characteristics. The main vegetation community downgradient of groundwater at MCQ is: HU619 – Slaty Red Gum grassy woodland on hinterland foothills of the southern North Coast (Figure 5.12; Conacher Consulting, 2017). These communities generally coincide with areas of low or moderate potential for groundwater dependence (compare Figure 5.11 and Figure 5.12).

HU739 is a warm temperate rainforest community (Conacher, 2017). The small area of HU739 mapped near MCQ is in a gully, upgradient of the eastern pit (Figure 5.12). The analogous site with groundwater monitoring for this would be bore MW06 (Figure 5.1). The groundwater levels at MW06 appear unaffected by drawdown or rainfall recharge (Figure 5.4), thus there is no impact expected at the HU739 location. In addition, the current condition of this community indicates little to no impacts associated with existing quarry operations. This HU739 community coincides with an area of low potential for groundwater dependence (Figure 5.11).

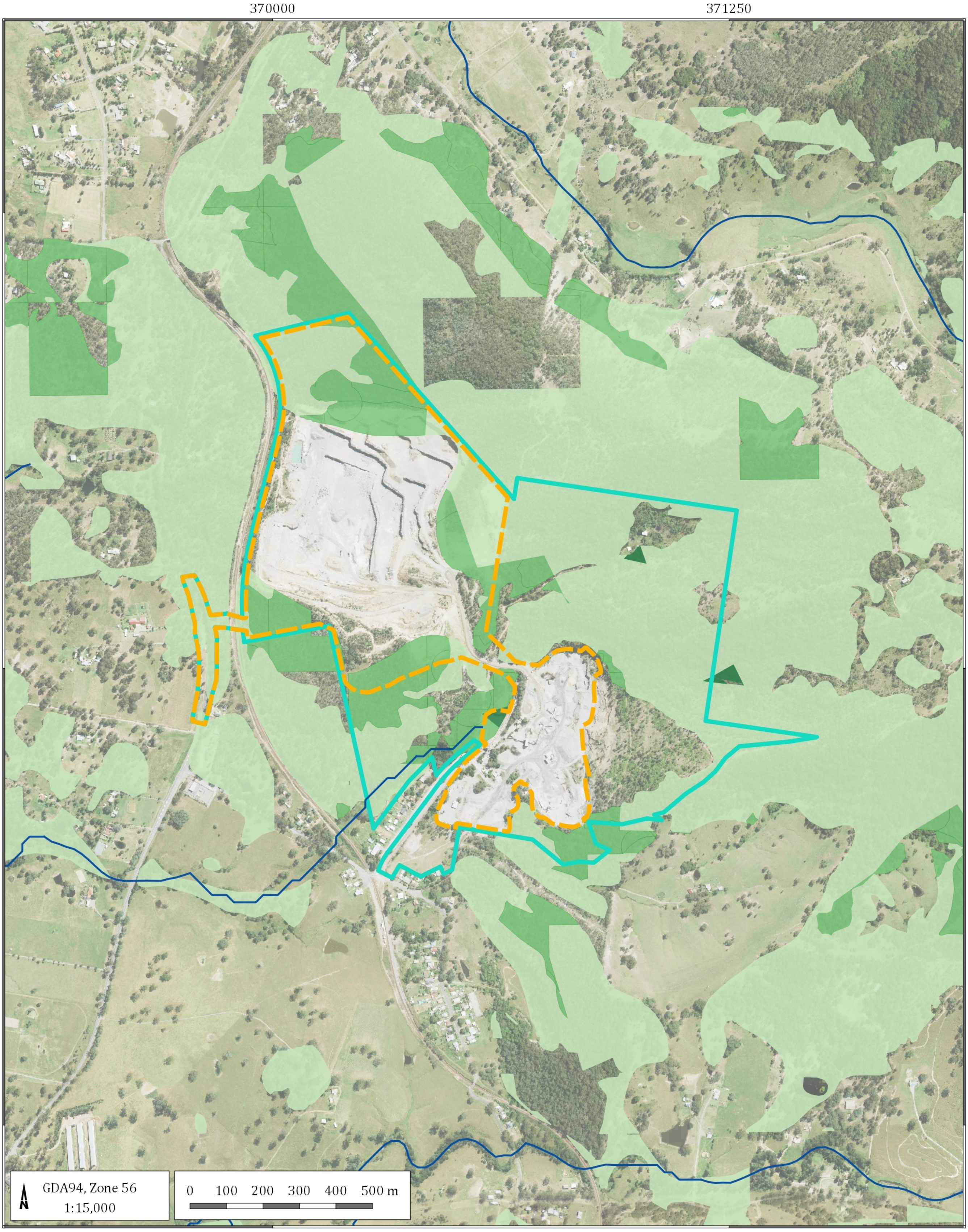
HU755 is a dry rainforest community (Conacher, 2017). The main area of this community is located immediately upgradient (north) of the current pit wall in the western pit (Figure 5.12). This HU755 community coincides with areas of low and medium potential for groundwater dependence (Figure 5.11). However, observations outlined below indicate that groundwater dependence is not prevalent in the community. The analogous site with groundwater monitoring for this area is bore MW04 (Figure 5.1), where water levels are typically 20 m below surface. The current health of the community observed indicates that reductions in the water table associated with existing quarry operations have not had an adverse impact on the community.

It is not clear if any communities are terrestrial GDEs, as there is no direct evidence regarding tree root access to groundwater at the site. All bores except MW02 and MW06 have groundwater levels that are typically deeper than 10 m below surface (Table 5.9; bores shown in Figure 5.11). While opportunistic groundwater use by vegetation may be occurring in low-lying areas, the presence of these communities in areas where the water table is well over 10m bgl indicates these communities are not dependent on groundwater.

There are no high priority GDEs identified in water sharing plans in close proximity to MCQ.

Table 5.9 Average depth to water over historical record

Bore	MW1	MW2	MW3	MW4	MW5	MW6	MW7
Average depth to water	16.9	5.1	11.8	20.7	36.7	3.2	10.2



LEGEND

- Drainage
- Project Area
- Revised Project Disturbance Area

Potential terrestrial GDEs

- High potential GDE - from regional studies
- Moderate potential GDE - from regional studies
- Low potential GDE - from regional studies

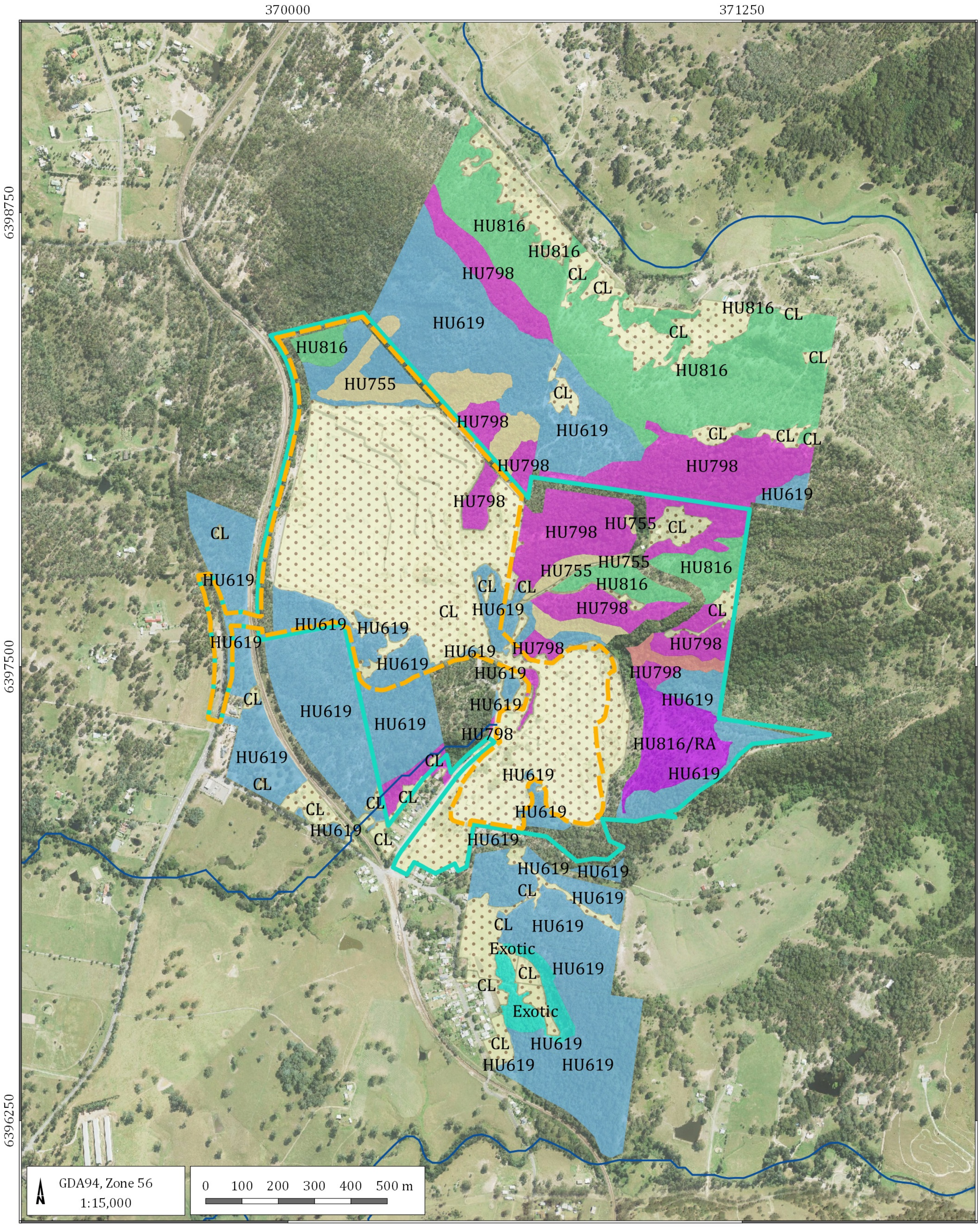
Martins Creek Quarry (G1908K)

Groundwater dependent ecosystems

AGE

DATE 04/03/2021

FIGURE No: **5.11**



LEGEND

Vegetation types

- Cleared Land (CL)
- Exotic, Regrowth
- HU 619 Slaty Red Gum grassy woodland
- HU 739 Sandpaper Fig - Whalebone Tree warm temperate rainforest
- HU 755 Whalebone Tree - Red Kamala dry subtropioal rainforest
- HU 798 White Mahogany - Spotted Gum - Grey Myrtle open forest
- HU 816 Spotted Gum - Narrow-leaved Ironbark open forest
- HU 816 Spotted Gum - Narrow-leaved Ironbark (Regenerating Area)

- Drainage
- Project Area
- Revised Project Disturbance Area

Martins Creek Quarry (G1908K)

Vegetation types (Conacher Consulting, 2017)

AGE

DATE 04/03/2021

FIGURE No: **5.12**

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5.8 Conceptual groundwater summary

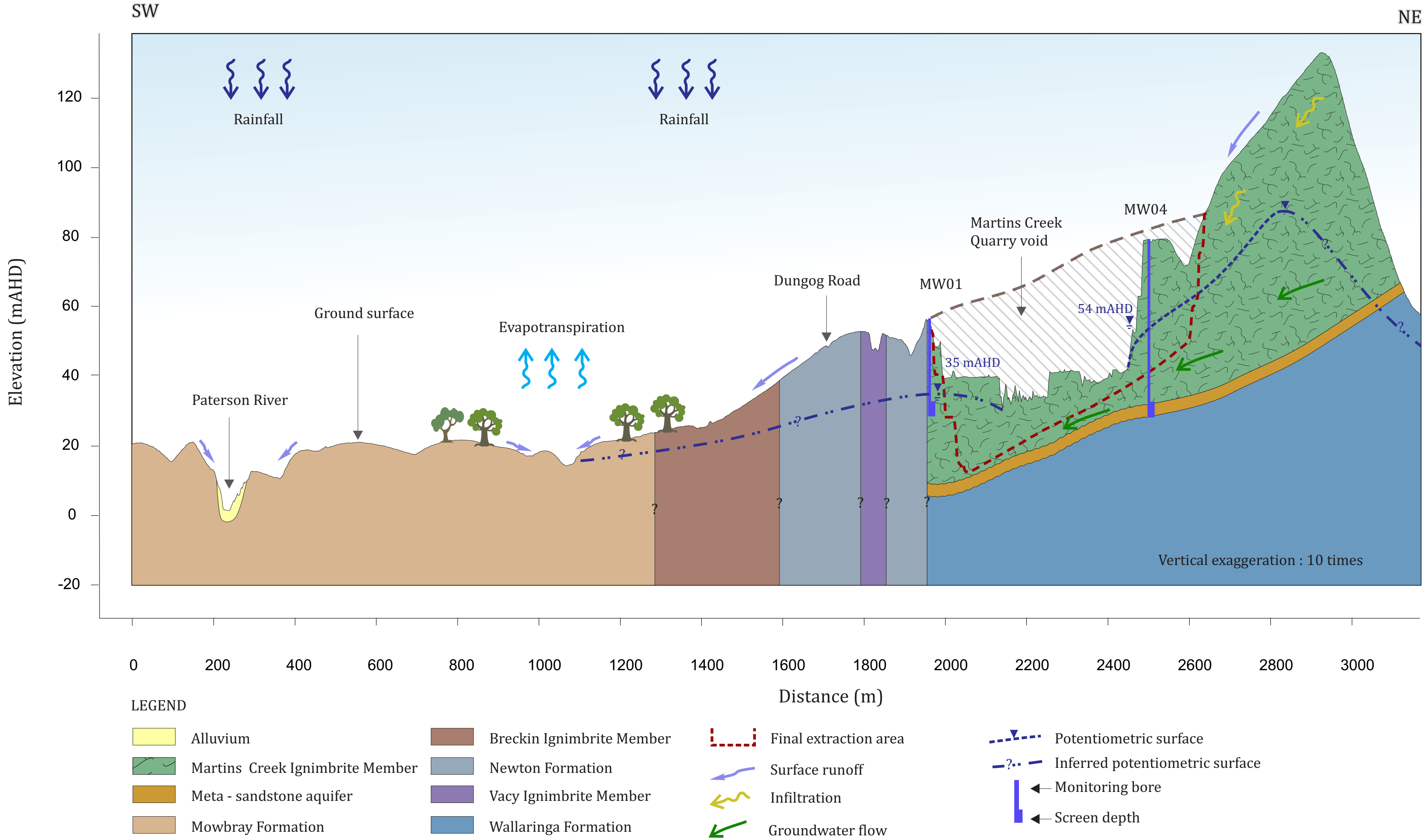
The conceptual groundwater model summarises the main hydrogeological features and processes over MCQ and surrounds, including recharge, discharge, groundwater flow, quality, and users. The conceptual groundwater model is presented graphically in Figure 5.13, showing a section that runs through the west pit from MW04 to MW01. The local groundwater system at MCQ is hosted in fractured rock aquifers (ignimbrite and meta-sandstone) that are thin (penetrated saturated thickness <20 m), with variable permeability, and moderate lateral extent (<5 km across). The aquifer system is associated with the ignimbrite, and the metamorphosed meta-sandstone at the contact between the ignimbrite and the underlying sedimentary rocks. The alteration zone forms the meta-sandstone and provides a thin (about 2 m to 4 m) permeable zone for groundwater transmission. This aquifer dips to the south west following the base contours of the ignimbrite. Groundwater is also hosted in the ignimbrite, which appears to have viable permeability. There are no alluvial groundwater systems within the MCQ boundary; the closest alluvium is associated with the Paterson River (over 1.2 km from MCQ).

Rainfall recharge is limited (i.e. 3% to 5% of rainfall) and typically occurs by rainfall moving down vertical fractures in the andesitic ignimbrite. Where the ignimbrite has been quarried, these sub-vertical fractures are exposed in the current quarry face, temporarily allowing any water present within the ignimbrite to flow into the quarry after rainfall events. According to data from MW05, seepage may last for about 10 days or more after rainfall, and is only triggered by events of at least 20 mm/day. The current potentiometric groundwater surface (Figure 5.5) is a general reflection of topography, with groundwater flowing to the south and south west, towards the Paterson River. While the quarry is likely to have localised impacts on the immediately adjacent groundwater, the terrain appears to be the driving factor in the water table of the wider area (Figure 5.13). As such, the quarry pits are currently intermittent "through-flow" features, because they receive seepage from upgradient faces, and then allow infiltration to downgradient areas for transient periods post-rainfall. Once the quarry excavation advances to the final years (refer to Figure 5.13), the quarry voids may act more as local groundwater sinks, as the Revised Project elevation of the pit floor (will be 13 mAHD) could sit below the future water table level. Whether the voids remain as sinks after the water level in the voids reaches an equilibrium point depends mainly on the balance of rainfall and evaporation.

Temporal trends in groundwater levels at MW04 show evidence of drawdown from quarrying, with a rate of about 2 m/yr. Other bores show little drawdown, or oscillating trends that are not unambiguously interpreted.

Alluvial deposits are present along the Paterson River, about 1.2 km to the west and south of MCQ (Figure 3.1). The Paterson River is over 20 m lower in elevation than the current pit floor of MCQ and over 100 m lower in elevation than the ridgeline to the north of MCQ (Figure 5.13). The river bed sits at about 0 mAHD; in comparison the final pit void will reach 13 mAHD at its deepest point (Figure 5.13). The Paterson River receives surface runoff from the surrounding catchment, as discussed in Section 2.2. These vertical distances are significant considering the slow rate of groundwater flow. The groundwater systems of the Paterson River alluvium and the Martins Creek Ignimbrite Member are also separated by physical barriers such as the interceding geological formations (also mainly fractured ignimbrites; Figure 5.13).

Groundwater quality across MCQ is variable, ranging from fresh to brackish (Section 5.4). Groundwater quality variability is likely a result of several factors, including residence time of the groundwater, and the varying degree of water-rock interaction that occurs along the flow path.



Conceptual groundwater model (SW-NE section)

Figure 5.13

Martins Creek Quarry (G1908B)

6 Impact assessment

This section summarises the assessment of the potential impacts and is structured as follows:

- Section 6.1 outlines the proposed quarry activities;
- Section 6.2 describes the estimated groundwater seepage rates; and
- Section 6.3 discusses the potential for groundwater drawdown around the quarry.

6.1 Proposed activities

The MCQ Revised Project involves the extraction of up to 1.1 Mtpa of product over 25 years. The extension area is generally upgradient of the existing quarry. Any groundwater that is captured within the disturbed areas of the MCQ and is not evaporated, would continue to be collected in quarry sumps (refer Figure 5.3). Water would continue to be reused from these dams for dust suppression (haul road, process plant) or treated and discharged via one of three Licence Discharge Points (LDP) in accordance with Environmental Protection Licence (EPL) 1378.

As discussed in Section 5.3, it is expected that small amounts of water within the sumps may eventually infiltrate to the downgradient aquifer (e.g. rising water levels and less saline water observed in MW01). However, infiltration via this means is considered to be volumetrically low, and accumulated water in the voids is mostly runoff, with a smaller component of groundwater.

6.2 Pit inflow estimates and discussion

The seepage rates estimated using the analytical method indicate the potential inflow over the quarrying operation, rather than the inflow at any time.

The methods used for the pit inflow or seepage assessment are provided in Section 4.3. As described, assumed values for all inputs (based on data analysis provided in Section 5) were used to calculate a range of potential seepage rates for each phase of the Revised Project. The inputs used are provided in Table 6.1. A range in daily seepage (Q [m3/day]) was estimated using these assumptions. Subsequently, an annual seepage rate [ML/yr] was calculated using a portion of the year when seepage would be active (i.e. following rainfall events; Table 6.1). This was performed for the complete Revised Project; the results are shown in Table 6.2 and Figure 6.1. The four scenarios presented represent the seepage estimated under different conditions, where the hydraulic gradients around the pit may change, or the climate conditions may alter (Table 6.2). The highest and lowest estimates are considered much less likely, and the two moderate scenarios (which define the box in the box-and-whisker plots of Figure 6.1) are much more likely. These moderate estimated seepage rates (assuming a dry year with a high gradient, and a wet year with a low gradient) range from 5.7 ML/yr to 22.4 ML/yr per year across the years of the Revised Project plan for the west pit, and from 6.2 ML/yr to 8.2 ML/yr for the east pit (from year 25) (Figure 6.1; Table 6.2).

The total potential seepage to the west pit for each year, representing the estimates of total groundwater take for that pit, are presented as a time series in Figure 6.2. The maximum rate of inflow expected is from year 21 of the Revised Project (Figure 6.2). Three of the four prediction scenarios (Figure 6.2) estimate seepage for the west pit to be constantly below the licenced allocation of 33 ML/yr held by MCQ under Groundwater Interception Licence 20BL173933. Note that seepage for the east pit is relevant from year 25 (Table 6.2). In the highest seepage prediction scenario (wet year, high gradient), which is considered unlikely to persist over the project, the estimated seepage for the west pit exceeds the licence allocation in project year 21 (Figure 6.2). Such a wet year would also likely result in increased recharge of groundwater, which may drive a lower gradient. Thus, this scenario of wet year and high gradient combined is considered unlikely.

Table 6.1 Seepage analysis inputs

Parameter/input Value	Value and units	
lengths of upgradient pit walls (varies with each part of plan)	ranges from 489 m to 1,120 m	
saturated height of the seepage faces is 10 m	ranges from 14.5 m to 37 m	
duration of seepage	47 days/yr	135 days/yr
hydraulic gradient	0.032	0.068
bulk hydraulic conductivity	1.5 x 10^{-1} m/day	

Table 6.2 Seepage estimates for four scenarios

Year of Revised Project	Up to 6	7 to 10	11 to 15	16 to 20	21 to 24	25	25 (east)
Q (ML/yr) dry year, low gradient	2.6	4.2	3.7	3.3	7.1	7.8	2.9
Q (ML/yr) dry year, high gradient	5.7	9.0	7.9	7.2	15.4	16.8	6.2
Q (ML/yr) wet year, low gradient	7.5	12.0	10.5	9.6	20.4	22.4	8.2
Q (ML/yr) wet year, high gradient	16.3	25.9	22.7	20.7	44.2	48.4	17.8

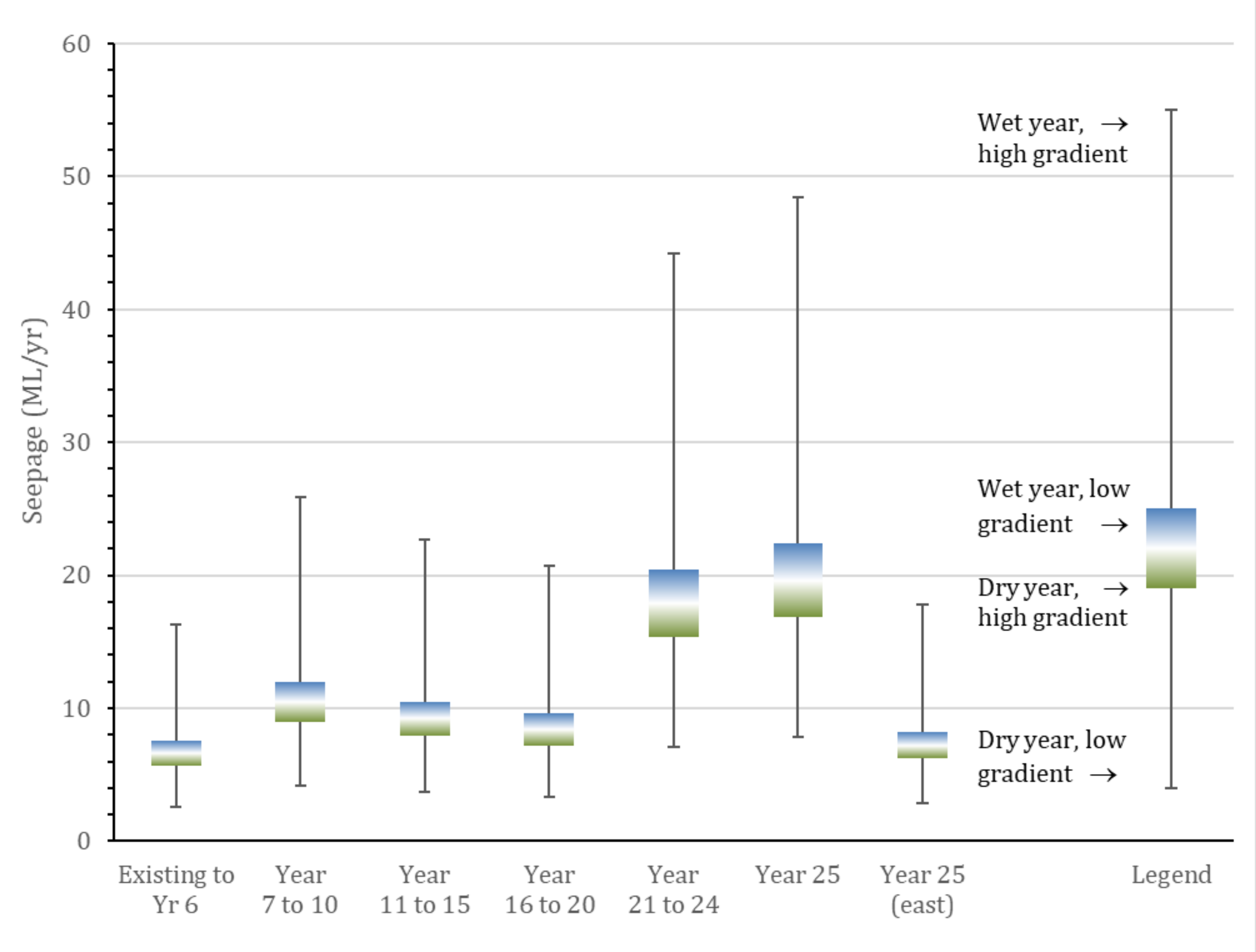


Figure 6.1 Ranges of seepage estimates for project years

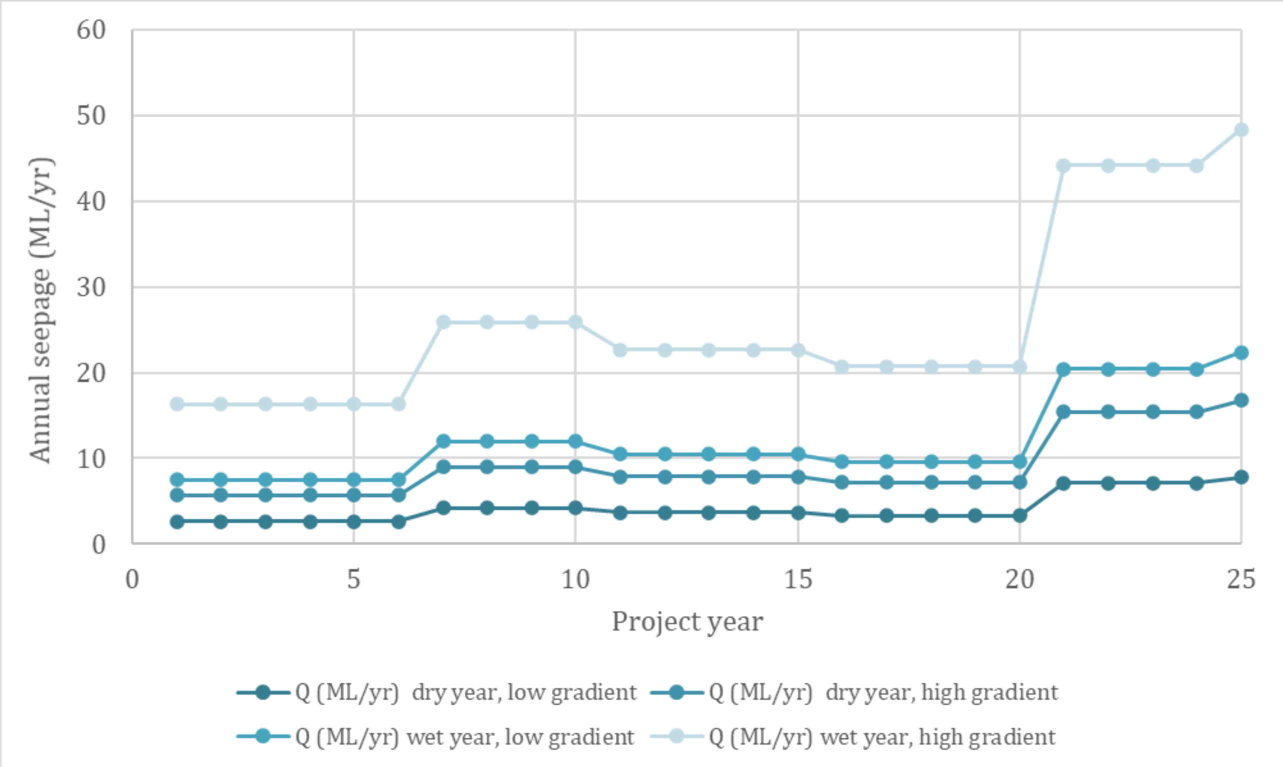


Figure 6.2 Annual estimated seepage for west pit

6.3 Drawdown

The proposed quarry extension area is on the upgradient side of the existing quarry operation. The MCQ Revised Project will quarry the existing resource (Martins Creek Ignimbrite) while the underlying unit (meta-sandstone) will not be quarried. Currently, only partial and transient saturation of the new quarry walls occurs, as most of the current void is above the local water table (Figure 5.13). However, this may change as the progressive excavation will reach 13 mAHD, and the water table at MW01 is currently about 35 mAHD. This is likely to result in groundwater inflow to the pits (Section 6.2). Pit inflows have the potential to cause groundwater drawdown. The historical groundwater levels are presented on Figure 5.4. The results show that long-term change in groundwater levels at MW04 indicate approximately 10 metres of decline since 2015 (about 2 m/yr; Table 5.3). MW04 is adjacent to the pit, and near the upgradient walls, where seepage is intermittently occurring. In contrast, there is no clear evidence of groundwater drawdown from the existing quarrying operations since the commencement of recorded water levels (i.e. March 2015) at any other bores. For example, the groundwater levels at MW06 (about 250 m from the pit) appear unaffected by drawdown.

The reason why drawdown is currently not observed at high rates around the pit is that pit inflow is slow (due to the moderate hydraulic conductivity of the rock, the moderate hydraulic gradients, and the intermittent nature of pit wall saturation). This slow inflow (e.g. 10 ML/yr to 20 ML/yr; Figure 6.2) results in a pit seepage rate that is commensurate with recharge estimates (11.1 ML/yr to 16.8 ML/yr; Section 5.3). When rainfall recharge to the surrounding water table can largely compensate for groundwater discharge to the pit, there is a much reduced likelihood of drawdown occurring.

In addition, potential drawdown in areas downgradient of the pits is ameliorated by infiltration of water (mostly runoff) that accumulates in the pits after rainfall (Section 5.3). This is evident in the lack of drawdown at bores MW01, MW02 and MW03. This process of water leaving the pit is cyclical, with groundwater entering the pit at other times. The balance of these processes is expected to continue throughout the revised Project, even though future quarrying will extend below the local water table. This is because the accumulation of rainfall runoff in the pits is expected to elevate the water level in the pits above the water table for transient periods. The infiltration of runoff to the water table downgradient of the pits will limit the extent of drawdown.

Based on these observations, it is estimated that drawdown impact from the Revised Project will be similar to the current drawdown. That is, local drawdown effects only, with a magnitude of about 2 m/yr, capped at the elevation of the deepest pit floor (about 13 mAHD). Based on MW06 data, the radius upgradient of the pits that may be affected by drawdown is estimated to be 250 m. The radius downgradient of the pits that may be affected by drawdown is conservatively estimated to be 500 m. This is based on the above observations, and the downgradient conditions, namely: topography, expected water table height, and subsurface geology (Figure 5.13). The difference in elevation between the Paterson River and MCQ means that there is negligible chance that MCQ may draw water from the alluvium.

6.4 Impact on groundwater users

Two active registered bores were identified within five kilometres of MCQ. Details are summarised in Table 5.8 and shown on Figure 5.10. Both of the registered bores are located outside of the mapped extent of the Martins Creek Ignimbrite Member (Figure 3.1). Neither of the two active bores are directly downgradient of MCQ, and drawdown impacts are expected only in the localised zone around the pits. Therefore, no impacts on these bores will occur due to the MCQ expansion.

6.5 Impact on groundwater dependent ecosystems

No high priority GDEs are located within the footprint of the Revised Project Extraction Area (refer Figure 5.11). The absence of aquifer depressurisation observed in MCQ monitoring bores (excepting MW04, which is adjacent the pit) indicates that low or moderate potential GDEs at MCQ will likely be unaffected. Further, current communities near MW04 (where the water table is declining) show no signs of declining health. This is strongly indicative that the communities located immediately up slope from MW04 are not groundwater dependent.

7 Aquifer Interference Policy – minimal impact considerations

7.1 The Aquifer Interference Policy

The AIP outlines requirements for obtaining water licences (WAL) and the assessment of aquifer interference activities. It establishes and objectively defines considerations in assessing the minimal impacts that may occur to key water dependent assets. The sections below compare the expected impacts against the requirements of the AIP and discuss compliance with the policy.

The MCQ Revised Project does not seek to gain additional groundwater WALs. The AIP has been used to objectively assess if the potential impact on the surrounding groundwater system is within the minimal impact considerations.

Licensing is discussed further in Section 7.3.

7.2 Minimal impact considerations

The minimal impact considerations are a series of thresholds that define minimal impacts from aquifer interference activities. There are two levels of minimal impact considerations specified in the AIP, being Level 1 and Level 2. If the predicted impacts are less than the threshold level specified by the Level 1, then these impacts are acceptable under the AIP. Where the predicted impacts are greater than the Level 1 minimal impact considerations, then additional studies are required to fully assess and manage these predicted impacts. If this assessment shows that the predicted impacts do not prevent the long-term viability of the relevant water-dependent asset, then the impacts will be considered acceptable.

Minimal impact considerations also take into account whether the aquifer is highly productive or less productive and whether the water source is alluvial or fractured rock. A highly productive aquifer is defined by the AIP as a groundwater source which has been declared in Regulations and datasets based on the following criteria:

- has a total dissolved solids (TDS) concentration less than 1,500 mg/L; and
- contains water supply works that can yield water at a rate greater than 5 L/s.

Highly productive groundwater sources are further grouped by geology into alluvial, coastal sands, porous rock, and fractured rock. Less productive groundwater sources include aquifers that cannot be defined as highly productive according to the yield and water quality criteria.

Based on these criteria, the groundwater source for MCQ has been defined as less productive.

Table 7.1 compares the potential impacts of the minimal impact considerations for less productive aquifers.

Table 7.1 Minimal impact considerations

Aquifer	Fractured rock
Category	Less productive
Level 1 Minimal Impact Consideration	**Assessment**
Water Table Less than or equal to a 10% cumulative variation in the water table, allowing for typical climatic 'post water sharing plan' variations, 40 metres from any: • High priority groundwater dependent ecosystem or • High priority cultural significant site Listed in the schedule of the relevant water sharing plan **OR** A maximum of a 2 metre water table decline cumulatively at any water supply work unless make good provisions apply	Groundwater fluctuations have been limited (Figure 5.4). The extended extraction area is upslope of the current pit and hence there would be no additional effect on the recharge zone for the aquifer. At the time of writing, there were no Culturally Significant Sites or high priority GDEs located within the proposed quarry extension area according to the North Coast Fold Belt Coast Groundwater Source Rules Summary Sheet. Nearby significant aquifers (i.e. the Paterson River alluvium) are over 1.2 km from MCQ. Additionally, the elevation of the ignimbrite and meta-sandstone aquifer is greater than that of the Paterson River alluvium. Therefore, the alluvium cannot be drained by drawdown at MCQ. There are no known water supply works located within the relevant aquifer at MCQ in areas where the Project is predicted to influence the water table.
Water Quality Any change in the groundwater quality should not lower the beneficial use category of the groundwater source beyond 40 metres from the activity. No increase of more than 1% per activity in the long-term average salinity in a highly connected surface water source at the nearest point to the activity	The MCQ Revised Project is not anticipated to affect the beneficial use category or salinity

7.3 Water licensing

NSW Water Sharing Plans (WSPs) establish rules for sharing water between the environmental needs of the river or aquifer and water users, and between different types of water use such as town supply, rural domestic supply, stock watering, industry and irrigation. The purposes of these plans are to protect the health of rivers and groundwater, while also providing water users with perpetual access licences, equitable conditions, and increased opportunities to trade water through separation of land and water rights.

Groundwater at MCQ is managed under the North Coast Fractured and Porous Rock WSP that was established in 2016. It is located within the New England Fold Belt Coast water source. MCQ is located within the Water Sharing Plan for the Paterson Regulated River Water Source, with the groundwater interception allocation for MCQ provided for under Section 115 of the NSW *Water Act 1912*. Under the Act, MCQ is licensed to extract no more than 33 megalitres (ML) in any 12-month period commencing 1 July. The groundwater interception licence details are summarised in Table 7.2. A search of the WaterNSW – NSW Water Register – indicates this licence has not been converted to a water access licence and is not subject to a water sharing plan.

Table 7.2 Water licence details

Licence number	Date issued	Date of expiry	Lot/DP number	Allocation (ML)
20BL173933	29 January 2016	28 January 2021	5//242210, 6//242210	33

As noted in Section 6.2, the analytical model results indicate that the more probable estimated groundwater inflow (water take) is based on two scenarios: dry year with a high gradient, or a wet year with a low gradient. These likely estimated seepage rates range from 5.7 ML/yr to 22.4 ML/yr per year across the Revised Project years (Figure 6.1; compare to a recent estimate of past/current seepage, which is 10.3 ML/yr; AGE, 2020). These estimates are independent of any infiltration to the water table of water that accumulates in the pits (e.g. after rainfall).

This is within the licenced allocation of 33 ML/yr held by MCQ. Therefore, there is no recommendation to purchase additional shares in the New England Fold Belt Coast Groundwater Source. Monitoring is recommended (refer to Section 8.1) to compare the seepage estimates to site observations over the Revised Project timeline. In this way, the most accurate of the four predictive scenarios can be identified. This may lead to a need to reassess the current allocation in future.

8 Discussion and conclusion

MCQ was established in 1914 by the NSW Government Railways for the purpose of supplying railway ballast and other quarry materials to both the NSW railway network and Hunter Valley/Newcastle construction projects.

In December 2012, Daracon secured a long term lease of the quarry and have been extracting quarry material to produce high quality aggregates, roadbase, ballast, gabion and other specified materials used in road, railway, concrete and civil construction. The MCQ Revised Project involves a progression of quarrying in an uphill direction. The base of the andesite marks the lower limit of extraction and there are no plans to quarry below this unit. The meta-sandstone aquifer is situated below the andesite and as such will not be quarried.

The current groundwater monitoring at MCQ, discussed in Section 5, comprises seven monitoring bores, located strategically around MCQ. Each of the monitoring bores is equipped with a level logger datalogger which records groundwater levels at 12 hr intervals and is downloaded quarterly. Annual water quality sampling has been conducted since 2015. Historical water levels in most bores have remained relatively constant since the commencement of record keeping in March 2015 (Figure 5.4). However, groundwater drawdown due to quarrying is evident at bore MW04 at a rate of about 2 m/yr. The current monitoring regime is sufficient and Daracon will continue with annual reporting to the Natural Resource Assessment Regulator and Department of Planning, Infrastructure and the Environment.

Analytical groundwater modelling results estimated the Revised Project groundwater inflow (water take) based on four scenarios. Of these four, the two moderate scenarios (dry year with a high gradient, or a wet year with a low gradient) are considered most likely. These more probable estimates of seepage rates range from 5.7 ML/yr to 22.4 ML/yr per year across the Revised Project plan for the west pit, and from 6.2 ML/yr to 8.2 ML/yr for the east pit (from year 25). Inflow is expected to increase from current levels, due to the quarry void extending below the local water table in the future. MCQ currently holds an allocation to extract 33 ML of groundwater per year (Table 7.2). Therefore, the purchase of any additional water allocation is not required. However, monitoring of pit inflows is recommended (refer to Section 8.1) to compare these seepage estimates to site observations over the Revised Project plan. This may lead to a need to reassess the current allocation in future.

Drawdown is likely to be constrained with 250 m of the pit in an upgradient direction and, conservatively, 500 m of the pit in a downgradient direction. Near the pit, drawdown may be similar to the rate observed in MW04 (2 m/yr). The drawdown is expected to be minimal due to the estimates of seepage being similar to water table recharge. It is recommended (refer to Section 8.1) that drawdown be monitored and compared to predictions. A review of the monitoring network may also aid in drawdown detection as the quarry excavation moves below the local water table.

Groundwater at MCQ resides in the latite / ignimbrite and the meta-sandstone. The nearest mapped extent of the Martins Creek Ignimbrite Member is approximately 1.2 km from the edge of the Paterson River, and the units are separated by a large change in elevation and structural barriers, such as other crystalline rock units and their sub-vertical contacts (Figure 5.13). Therefore, no impacts to the Paterson River alluvium are predicted as a result of the MCQ Revised Project.

There are six registered landholder bores within five kilometres of the proposed extension. Two of these are active and both are located outside of the mapped extent of the Martins Creek Ignimbrite Member and area of potential drawdown. Neither bore is directly downgradient of the quarry. As such, no impacts on these bores are expected from the MCQ Revised Project and the beneficial water quality use category will not be affected. If infiltration from the quarry pit water were to occur, a change in water quality would first be observed at MW01, MW02 and MW03. No concerning trends are currently observed.

An assessment of the MCQ Revised Project against the AIP minimal impact considerations for less productive aquifers was completed. The analysis indicated that none of the minimal impact criteria outlined in Table 7.1 would be exceeded.

In summary, the MCQ Revised Project is unlikely to have any significant impact on the groundwater system outside MCQ. The groundwater take associated with the extension is within the licensed volume, and the estimated impacts do not exceed the minimal impact considerations outlined in the AIP.

8.1 Proposed management measures

AGE recommend the following management measures.

- Review of the monitoring network (discussed below).
- The continuation of the current monitoring program. As previously mentioned, each monitoring bore is fitted with a level logger datalogger that records groundwater levels fluctuations. These dataloggers should be downloaded at least twice a year.
- Continuation of water quality sampling for major ion chemistry, TDS and dissolved metals should continue to be conducted annually, with proper purging of the stagnant water column. Water quality results should continue to be reported to the Natural Resource Assessment Regulator and Department of Planning, Infrastructure and the Environment annually.
- Development of a Water Management Plan (WMP), discussed below.
- Review of current predictions against ongoing monitoring, with adjustment to the WMP or water licencing as needed, also discussed below.

Daracon will continue to adhere to all conditions outlined within NSW Office of Water bore license certificate 20BL173933.

The existing groundwater monitoring network at MCQ and recommended monitoring framework currently provide an appropriate level of understanding of the groundwater conditions at the site and any potential impacts associated with the MCQ Revised Project. However, some of the monitoring sites will be affected at different stages of the Revised Project (MW07 will be removed between project years 3 and 6, MW04 removed between project years 16 and 20, and MW05 may be disturbed between project years 21 and 25). Timely replacement of these monitoring sites prior to removal is required to maintain an appropriate monitoring network. In addition, as the future quarrying will extend below the local water table, additional monitoring downgradient of MW01 is recommended, to detect and quantify potential drawdown.

It is recommended that a comprehensive Water Management Plan (WMP) be developed for the MCQ extension, in consultation with DPI Water. The WMP should include programs of all monitoring, both surface water and groundwater, that is carried out at MCQ. The development of the WMP would include a review of the current monitoring network (refer above) and practices, with regular review included in the procedures of the WMP.

The WMP should also include details of the site water balance, which estimates the groundwater pit inflows and the rainfall runoff that accumulates in the voids. Within the WMP there will be an explanation of the processes for ongoing review of monitoring data against the water balance and the impact predictions in this GIA. The WMP will also include development of Trigger Action Response Plans (TARPs). TARPs define the actions Daracon must take if monitoring data exceed trigger levels/limits or fall short of objectives. For example, if the groundwater take estimates in this GIA are less than the site observations of pit inflow over the Revised Project timeline, then there are implications for groundwater management. This may lead to a need to reassess the water licence allocation in future, although the current allocation appears adequate.

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Appendix A Martins Creek Quarry groundwater drilling completion report

Australasian Groundwater and
Environmental Consultants Pty Ltd

Report on

Martins Creek Quarry

Monitoring Bore Installation

Prepared for
Umwelt (Australia) Pty Ltd

Project No. G1908A August 2018
www.ageconsultants.com.au ABN 64 080 238 642

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Report on

Martins Creek Quarry
Monitoring Bore Installation

1 Introduction

Martins Creek Quarry (MCQ) is an existing hard rock quarry located at Station Street - Martins Creek, within the Dungog Shire Council Local Government Area (Dungog LGA). The quarry is a high quality, hard rock and durable andesitic ignimbrite and was originally developed by the NSW Government in 1914 to supply materials for the North Coast rail line and has continued to supply rail construction materials to present times. Buttai Gravel Pty Ltd took ownership of the quarry from December 2012. Daracon have operated Martins Creek Quarry since December 2012.

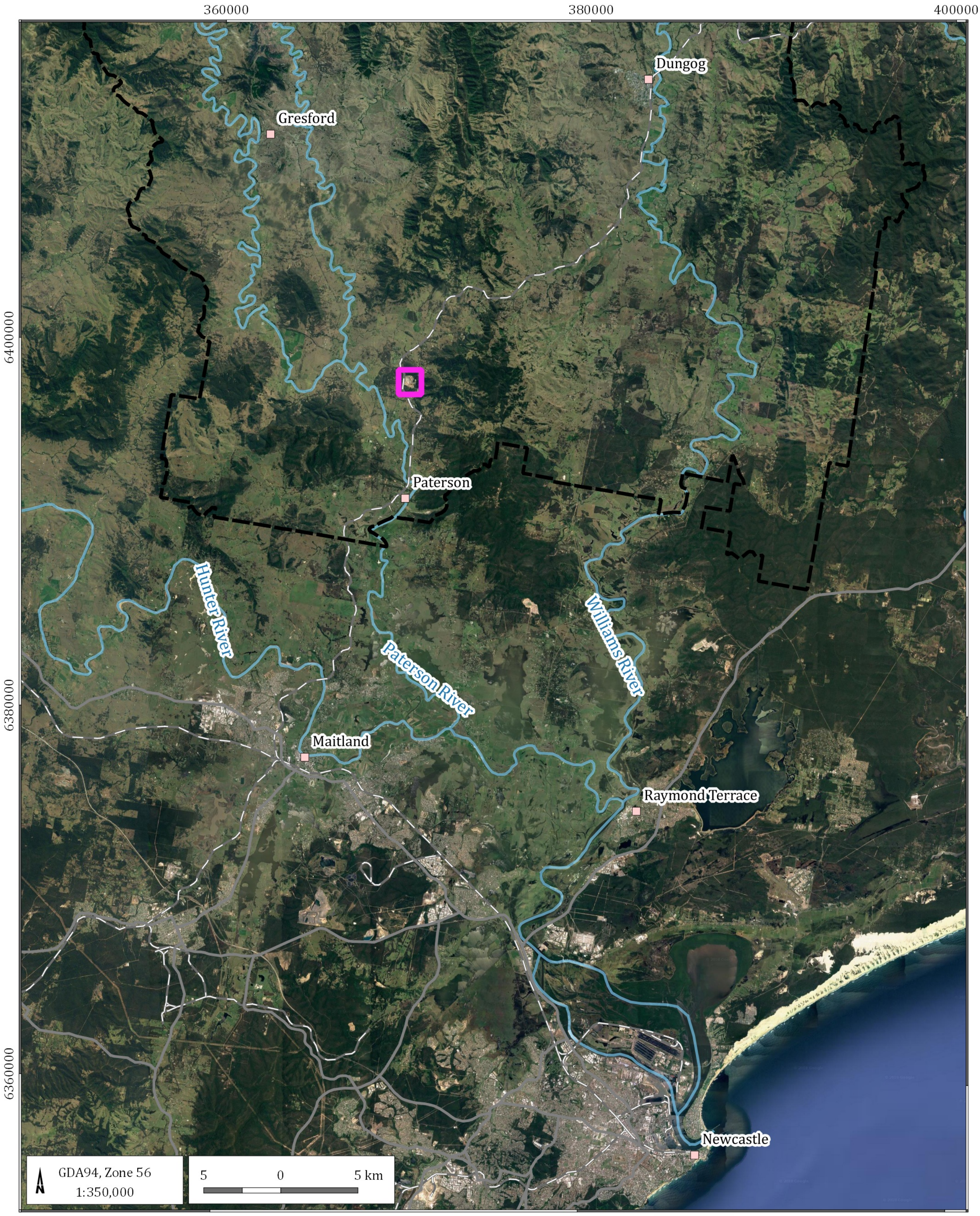
Australasian Groundwater and Environmental Consultants Pty Ltd (AGE) were engaged by Umwelt (Australia) Pty Ltd (Umwelt) to supervise the installation of three new monitoring bores. AGE hydrogeologist Thomas Walters provided direction to a drilling contractor installing of MW05, MW06 and MW07 from 21 to 24 May 2018 and undertook hydraulic testing and groundwater sampling on 28 May 2018. These are in addition to the four existing monitoring bores at the site. Details of existing monitoring bores including locations, water levels, quality and hydraulic conductivity are included in previous report *Martins Creek Quarry Groundwater Investigation* (AGE, 2018).

2 Project setting

2.1 Location and land use

MCQ is located off Station Street, Martins Creek, approx. 20 km north of Maitland and 7 km north of Paterson, NSW, in the Dungog LGA shown on Figure 2.1. The site is bounded by the North Coast Rail line to the west, Vogeles Road to the south, and by densely vegetated land to the north and east. The site slopes downward in a south west direction from a central ridgeline at the top of the quarry.

MCQ has been operating as an existing quarry and processing area with previous and current extraction exposing two pit sites. One pit lies to the east of Station Street and the other to the north west of Station Street.



LEGEND

- Martins Creek Quarry
- Dungog Local Goverment Area (LGA)
- Populated place
- Road major
- Rail
- Watercourse

Martins Creek Quarry (G1908A)

Martins Creek Quarry location

AGE

DATE 07/06/2018

FIGURE No: **2.1**

N:/Groundwater Jobs/G1908A.Martins Creek Quarry Bore Network/3_GIS/Workspaces/002_Martins Creek Quarry Bore Network/02_01_G1908A_Martins Creek Quarry location.qgs

2.2 Site geology

MCQ extracts stone from the Martins Creek Ignimbrite Member, which forms part of the Isismurra Formation. The site is underlain by the sedimentary sequences of the Wallaringa Formation (Wallaringa Fm), a bedded lithic sandstone and conglomerate. The contact zone between the two formations forms a thin zone of metamorphosed sediments.

The blue-grey andesitic ignimbrite is exposed on the quarry faces and floor. The base of the Martins Creek Ignimbrite dips to the west at around 5 degrees to 8 degrees, which seems to mimic the dip of the existing topography. The underlying Wallaringa Formation has some exposures in parts of the quarry floor. The contact of the meta-sediments is red/black/ brown, which is a reflection of the fine grained matrix of the rock.

During site fieldwork weathered faults, joints and weathering profile were identified within the pit walls. An interpreted weathered fault plane is shown on Figure 2.2 . These features were dry during the site visit.

Figure 2.2 Weathered fault plane adjacent MW07

2.3 Groundwater regime

There is limited groundwater resource in the vicinity of MCQ owing to the low-porosity of the andesitic ignimbrite. A thin aquifer is present at the base of the andesite at the contact with the underlying Wallaringa Fm sandstone. The contact zone forms a thin zone of alteration, which allows water to enter and move between the two formations. Rainfall recharge to the aquifer is limited and typically occurs by rainfall moving down vertical fractures and/ or along faults (if permeable) in the andesite. The thin aquifer dips to the south west following the base contours of the andesite. This would result in any upslope recharge reporting to the quarry floor after rainfall, where the metamorphosed sediments have been intercepted.

3 Monitoring bores

3.1 Locations

The three new monitoring bore locations and elevation details are summarised in Table 3.1. The new and existing MCQ monitoring bore locations are show in Figure 3.1. The final site locations differ slightly from the planned locations. The final locations were determined in the field based on site conditions (e.g drill rig access, ground slope). Final locations and ground elevations were surveyed by the site surveyor.

Table 3.1 Monitoring bore locations

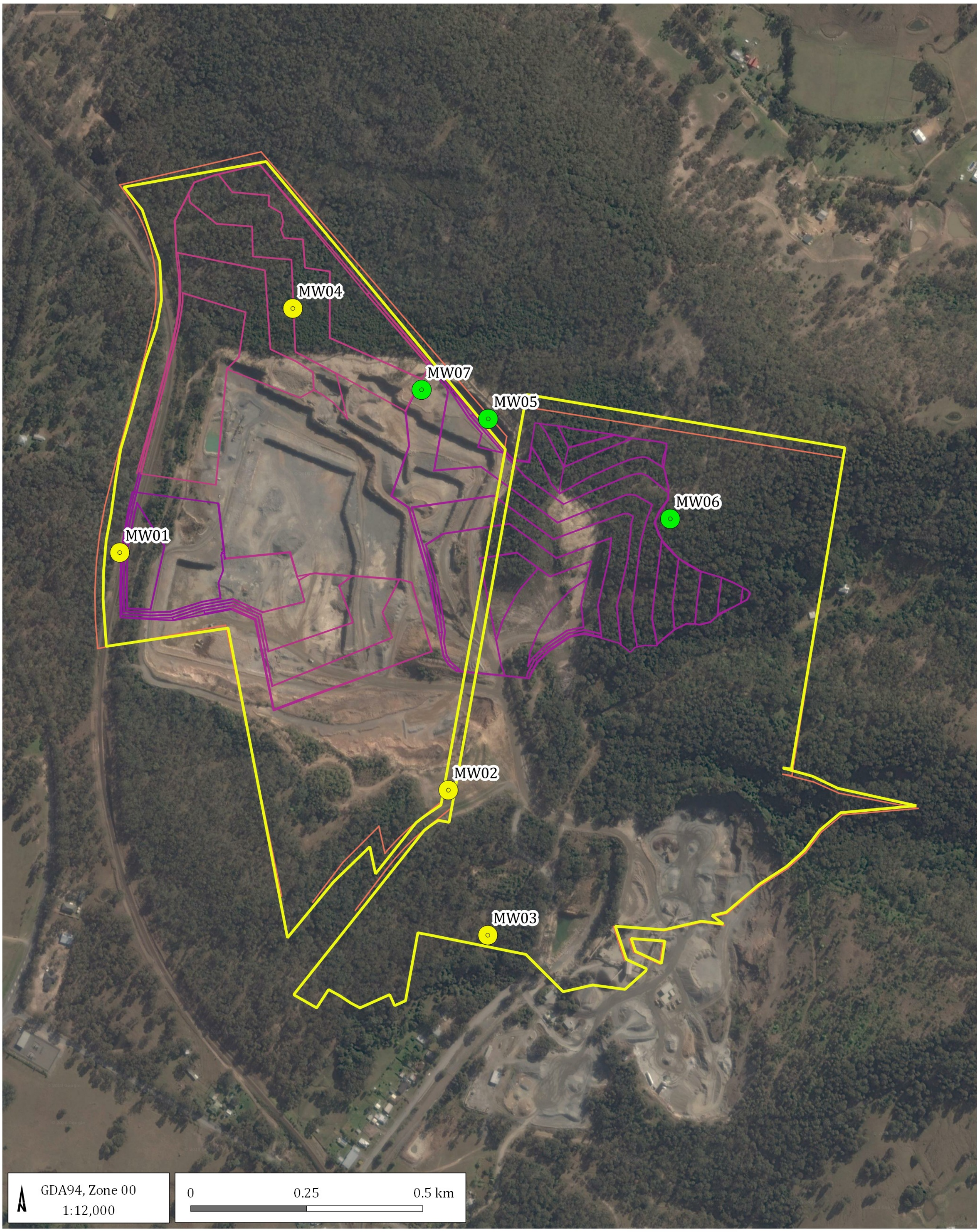
ID	Easting (GDA 94/ MGA 56)	Northing (GDA 94/ MGA 56)	Ground elevation (mAHD)	Top PVC (mAHD)	Stickup (m)
MW05	370642	6397961	123.49	124.22	0.73
MW06	370952	6397815	86.56	87.25	0.69
MW07	370507	6398047	84.39	85.04	0.65

3.2 Drill holes

The geology and water cuts encountered during drilling of MW05, MW06 and MW07 are summarised in Table 3.2. Drill cuttings were sampled at one metre intervals and logged by the onsite hydrogeologist. Water quality was not able to be determined during the drilling as water was being injected by the drill rig for dust suppression and to lift the drill cuttings from the hole. Detailed borelogs are in Appendix A.

Table 3.2 Geology and water cuts

<table>
<tr><th>ID</th><th>Depth (mBGL)</th><th>Geology</th><th>Water cut</th></tr>
<tr><td rowspan="6">MW05</td><td>0 - 1</td><td>Soil (BOW)</td><td rowspan="6">No water cut encountered</td></tr>
<tr><td>1 - 12</td><td>Ignimbrite (with weathered joints)</td></tr>
<tr><td>12 - 25.5</td><td>Ignimbrite</td></tr>
<tr><td>25.5 - 29</td><td>Metasediment</td></tr>
<tr><td>29 - 36</td><td>Sandstone/siltstone metasediment</td></tr>
<tr><td>36 - 45</td><td>Sandstone/siltstone country rock</td></tr>
<tr><td rowspan="3">MW06</td><td>0 - 6</td><td>Sand</td><td>-</td></tr>
<tr><td>6 - 14</td><td>Sandstone metasediment weathered (BOW)</td><td>9 - 10 mBGL - seep (<0.1 L/s)</td></tr>
<tr><td>14 - 21</td><td>Siltstone</td><td>-</td></tr>
<tr><td rowspan="5">MW07</td><td>0 - 0.5</td><td>Road fill</td><td rowspan="3">-</td></tr>
<tr><td>0.5 - 13</td><td>Ignimbrite (with weathered joints)</td></tr>
<tr><td>13 - 15.5</td><td>Ignimbrite chilled margin</td></tr>
<tr><td>15.5 - 16</td><td>Metasediment</td><td>15.5 mBGL - seep (<0.1 L/s)</td></tr>
<tr><td>16 - 18</td><td>Sandstone/siltstone metasediment</td><td>-</td></tr>
</table>



LEGEND

Monitoring bores

Existing

New

Martins Creek Quarry boundary

Martins Creek Quarry (G1908C)

Monitoring bore locations

DATE 06/08/2018

FIGURE No: **3.1**

4 Construction summary

Monitoring bore MW05, MW06 and MW07 construction details are summarised in Table 4.1 with full graphics logs available in Appendix A. The monitoring bore screen was placed over the main water bearing zone that represented the target aquifer. MW05 did not intercept any measurable water bearing zones during drilling and the screen was placed at the base of the hole.

All monitoring bores were constructed with Class 18 uPCV casing with an end cap was installed on bottom of the casing. The screened section has 1 mm machined slots. Clean graded gravel (2-5 mm) was placed next to and slightly above the screened interval. MW05 where the gravel pack was placed to 4.5 mBGL. This was to allow any intercepted seepages that were not detectable during drilling to flow into the casing. The bentonite seal was placed on top of the gravel pack to limit any inflow of water from above. Annual fill was sourced from the quarry and placed above the bentonite seal. A concrete plinth and headworks with lockable cap was installed at the surface for all monitoring bores.

Drilling, construction and development of the monitoring bores conformed to the *Minimum Construction Requirements for Water Bores in Australia* (2012).

Table 4.1 MW05, MW06 and MW07 construction details

ID	Target geology	Blank Casing (mBGL)	Screen (mBGL)	Bentonite Seal (mBGL)	Gravel pack (mBGL)
MW05	Ignimbrite	-0.84 - 42	42 - 45	2.5 - 4.5	4.5 - 45.1
MW06	Meta-sediment sandstone	-0.77 - 8	8 - 14	4.3 - 7	7 - 14
MW07	Meta-sediment sandstone	-0.71 - 14.6	14.6 - 17.6	12.1 - 14.5	14.5 - 17.6

5 Groundwater monitoring

5.1 Groundwater levels

The three new monitoring bore standing water levels (SWL) in metres below ground level (mBGL) are summarised in Table 5.1. The new and existing MCQ monitoring bore locations are show in Figure 3.1**.** Groundwater level pressure transducers have been installed in the three new monitoring bores in July 2018.

Table 5.1 Monitoring bore water levels

ID	Ground elevation (mAHD)	Top PVC (mAHD)	Stickup (m)	Date SWL	Initial SWL (mBGL)	Initial SWL (mAHD)
MW05	123.49	124.22	0.73	28/05/2018	43.95	79.54
MW06	86.56	87.25	0.69	28/05/2018	2.86	83.70
MW07	84.39	85.04	0.65	28/05/2018	11.48	72.91

5.2 Groundwater quality

Groundwater quality field samples collected from the new monitoring bores is moderately saline. Electrical conductivity (EC) ranges from 2,197 µS/cm (MW07) to 4,783 µS/cm (MW06). Field pH is generally neutral, ranging from 6.92 (MW05) to 7.32 (MW07). Dissolved and total metals have low concentrations with all concentrations below the 1 mg/L, with the exception of strontium in MW06 (1.34 mg/L). Laboratory certificates of analysis are presented in Appendix B. Sodium and chloride are dominant ions resulting in a sodium chloride water type.

Groundwater quality is summarised in Table 5.2 (field and lab quality results), Table 5.3 (major ions), Table 5.4 (dissolved metals), and Table 5.5 (total metals). Table 5.6 summarises the water type and a piper plot of groundwater chemistry is shown on Figure 5.1.

Table 5.2 Groundwater quality results (field and laboratory)

Parameter	MW05 - field	MW06 - field	MW07 - field
pH (field)	6.92	6.98	7.32
EC (µS/cm) (field)	2246	4783	2179
TDS (mg/L) (field)	1642	3709	1582
Temperature	19	20	20
pH (lab)	7.76	7.19	7.57
EC (µS/cm) (lab)	2260	4860	1700
TDS (mg/L) (lab)	1520	3400	1050

Table 5.3 Groundwater quality results (major ions)

Parameter	MW05	MW06	MW07
Ca (mg/L)	166	237	101
Mg (mg/L)	19	146	22
K (mg/L)	216	524	212
Na (mg/L)	3	2	1
Cl (mg/L)	613	1160	350
SO4 (mg/L)	109	155	60
HCO3 (mg/L)	211	743	447

Table 5.4 Groundwater quality results (dissolved metals)

Parameter	Limit of Reporting	MW05	MW06	MW07
Al (mg/L)	0.01	<0.01	<0.01	<0.01
As (mg/L)	0.001	0.001	0.002	0.004
Be (mg/L)	0.001	<0.001	<0.001	<0.001
Ba (mg/L)	0.001	0.036	0.059	0.028
Cd (mg/L)	0.0001	<0.0001	<0.0001	<0.0001
Cr (mg/L)	0.001	<0.001	<0.001	<0.001
Co (mg/L)	0.001	<0.001	0.002	<0.001
Cu (mg/L)	0.001	<0.001	0.002	<0.001

Parameter	Limit of Reporting	MW05	MW06	MW07
Pb (mg/L)	0.001	<0.001	<0.001	<0.001
Mn (mg/L)	0.001	0.06	0.264	0.117
Mo (mg/L)	0.001	0.003	0.003	0.005
Ni (mg/L)	0.001	0.002	0.006	0.005
Se (mg/L)	0.01	<0.01	<0.01	<0.01
Sr (mg/L)	0.001	0.429	1.34	0.324
V (mg/L)	0.01	<0.01	<0.01	<0.01
Zn (mg/L)	0.005	0.011	0.017	<0.005
B (mg/L)	0.05	0.87	0.6	0.57
Fe (mg/L)	0.05	<0.05	<0.05	<0.05
Br (mg/L)	0.1	0.8	1.9	0.6

Table 5.5 Groundwater quality results (total metals)

Parameter	Limit of Reporting	MW05	MW06	MW07
Al (mg/L)	0.01	1.03	63.3	59.6
As (mg/L)	0.001	0.002	0.008	0.011
Be (mg/L)	0.001	<0.001	0.002	0.002
Ba (mg/L)	0.001	0.041	0.206	0.639
Cd (mg/L)	0.0001	0.0002	0.0001	0.0002
Cr (mg/L)	0.001	0.003	0.124	0.142
Co (mg/L)	0.001	<0.001	0.03	0.028
Cu (mg/L)	0.001	0.001	0.042	0.045
Pb (mg/L)	0.001	<0.001	0.026	0.04
Mn (mg/L)	0.001	0.073	1.09	1.19
Mo (mg/L)	0.001	0.004	0.005	0.006
Ni (mg/L)	0.001	0.008	0.062	0.078
Se (mg/L)	0.01	<0.01	<0.01	<0.01
Sr (mg/L)	0.001	0.45	1.76	1.04
V (mg/L)	0.01	<0.01	0.09	0.08
Zn (mg/L)	0.005	0.019	0.167	0.177
B (mg/L)	0.05	0.91	0.77	0.69
Fe (mg/L)	0.05	0.79	53	51.3

Table 5.6 Water quality type

Parameter	MW05	MW06	MW07
Water Type	Na-Ca-Cl	Na-Mg-Ca-Cl-HCO3	Na-Ca-Cl-HCO3

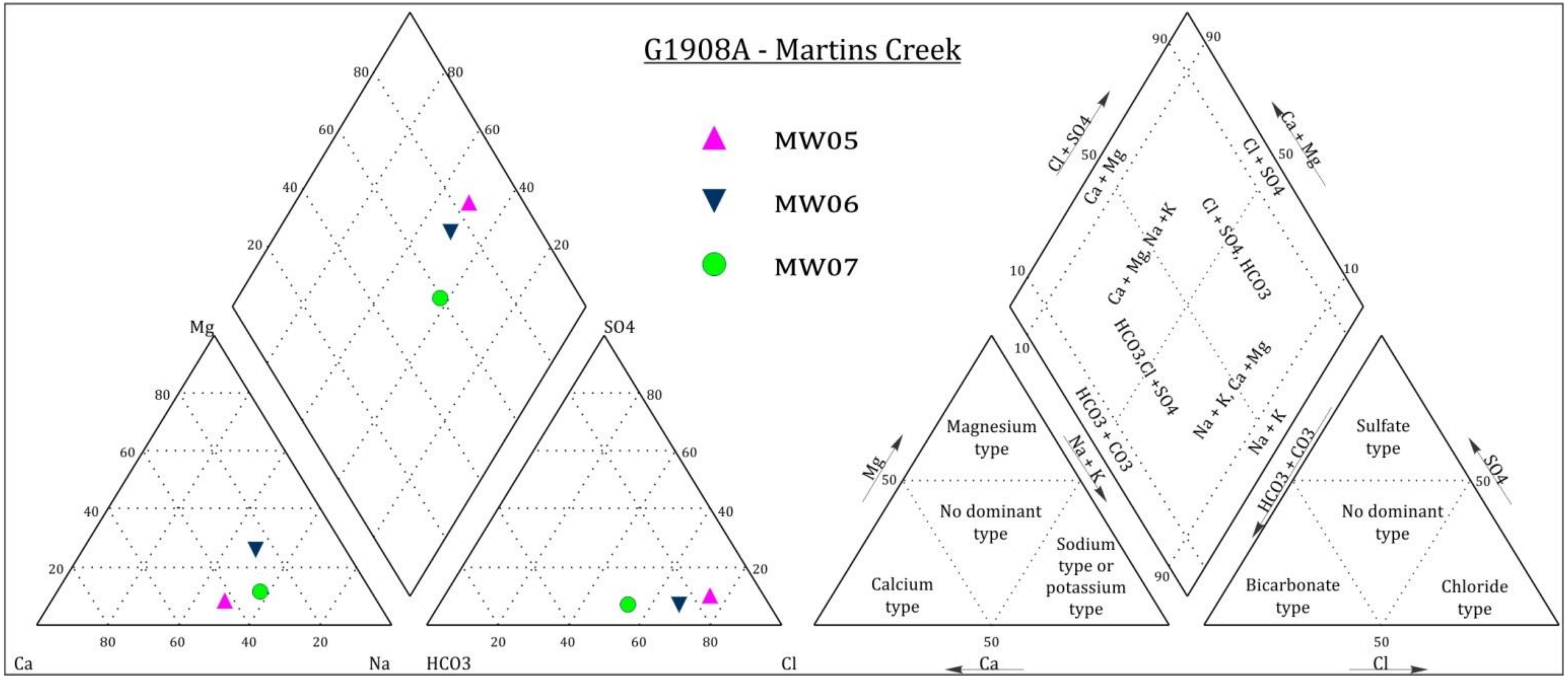


Figure 5.1 Groundwater chemistry piper plot

6 Hydraulic testing

Hydraulic testing was undertaken on MW05, MW06 and MW07 using a rising head slug-test with water extracted using a bailer. The tests were interpreted with AQTESOLV v4.0 software using the Hvorslev method.

The interpreted hydraulic test results are presented in Table 6.1 with hydraulic conductivity (K) varying by three orders of magnitude. Monitoring bore MW05 predominantly screens the ignimbrite and has the lowest hydraulic conductivity. MW06 is screened across the weathered meta-sandstone and has the highest hydraulic conductivity. This corresponds to previous testing conducted at MCQ (JM Environments, 2016). The data, time-displacement graphs and test results are presented in Appendix C.

Table 6.1 Hydraulic conductivity

ID	K (m/day)	Initial displacement (m)	Target geology
MW05	0.0074	0.49	Ignimbrite
MW06	0.15	0.36	Meta-sediment sandstone
MW07	0.045	0.52	Meta-sediment sandstone

7 Discussion

Monitoring bore MW05, MW06 and MW07 were installed north-west and within the existing quarry. Groundwater was measured in all three bores with drilling confirming a very thin and low permeability aquifer at the interface between the ignimbrite and underlying meta-sediments. Groundwater quality and type is consistent whilst hydraulic conductivity varies according to the screened rock. The monitoring bores will provide data up-gradient of the quarry and are suitable for future monitoring.

8 References

Australian Groundwater and Environmental Consultants. (2018). *Martins Creek Quarry Groundwater Investigation.*

JM Environments. (2016). *Water quality impact assessment.*

National Uniform Drillers Licensing Committee. (2012). *Minimum Construction Requirements for Water Bores in Australia, Third edition.*

Appendix A Drill hole logs and monitoring construction details

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4 Hudson St, Hamilton, NSW 2303
Level 2, 15 Mallon Street, Bowen Hills, Queensland 4006

BOREHOLE LOG

MW05

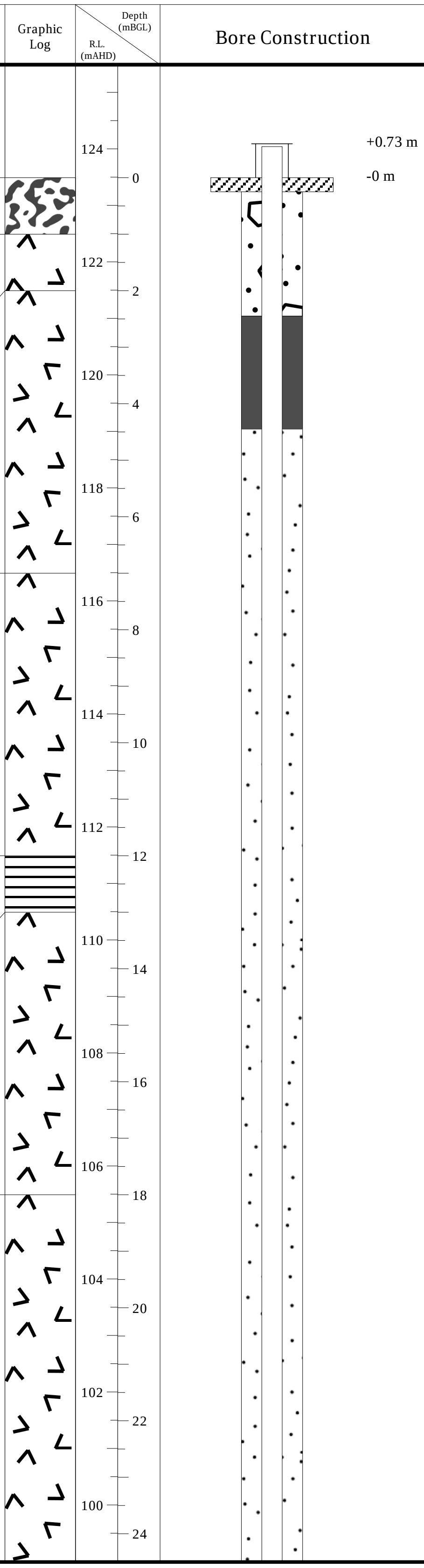
PROJECT No: **G1908A**
PROJECT NAME: **Martins Creek NSW**
DATE DRILLED: **22-May-18**
LOGGED BY: **T.Walters (AGE)**

DRILLING COMPANY: **BFG Daracon**
DRILLER: **C.Sheil (BFG Daracon)**
DRILLING METHOD: **Air / 125mm OD hammer**
DRILL RIG: **Boart Longyear Delta Base 102**

EASTING: **370642 mE**
NORTHING: **6397961 mN**
DATUM: **MGA94 (z56)**
RL: **123.49 mAHD**
EOH: **45 mBGL**

COMMENTS: **Location at northern strip area.**

Stratigraphic Cloumn	Soil or Rock Field Material Description	Depth (mBGL)	Bore Description
Soil (BOW)	SOIL; Light brown, soil, powdered from hammer, clasts, weathered yellow and brown with moderate strength.	0 – 1	
Ignimbrite (with weathered joints)	IGNIMBRITE; Light brown to red, very hard, weathered, ignimbrite, phenocrysts of feldspar, quartz and amphibole(?). True effective base of surficial weathering (BOW).	1 – 2	50mm ID uPVC class 18 threaded blank casing.
	IGNIMBRITE; Light grey, very hard, partially weathered (as above) ignimbrite, phenocrysts of pale white feldspar, white quartz, equant biotite and amphibole laths, in grey groundmass, with weathered red streaks, light to brown orange joints, spots and epidote/chlorite(?) alteration of feldspar cores and in part groundmass. Moderate to weak foliation of feldspar and elongate/equant phenocrysts, i.e. pyroclastic ignimbrite, rock is massive.	2 – 7	Bentonite seal - coated bentonite pellets.
	IGNIMBRITE; Light brown to red (weathered) 50%, and light grey (50%) [weathered proportion increasing with depth >85%], very hard, ignimbrite, phenocryst assemblages of feldspar, quartz and mafic, increasing groundmass with depth, red spot weathering. Chip sized had decreased from overlying ignimbrite, appears to occur in weathered ignimbrite portions. Interval was dry. Jointing was noted over this section of ignimbrite from the surface.	7 – 12	
Ignimbrite (the resource)	CLAY; Light brown to yellow, very soft, powdery to puggy balls. Soft layer encountered 12-13m. The clay and underlying ignimbrite appear to be weathered, both were dry.	12 – 13	Possible seep which is now dry as the ignimbrite is weathered to clay, this is likely fault controlled as observed in the pit wall below adjacent MW07.
	IGNIMBRITE; Light brown to red, very hard, ignimbrite weathered, red, brown and blackish weathered faces to chips, feldspars, quartz, elongate and equant phenocrysts are still visible.	13 – 18	
	IGNIMBRITE; Light cream and reddish, very hard chips, ignimbrite with phenocrysts. Noted - weathered ignimbrite appears to return as smaller chips, similar to 1-4mm angular clasts.	18 – 24+	



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4 Hudson St, Hamilton, NSW 2303
Level 2, 15 Mallon Street, Bowen Hills, Queensland 4006

BOREHOLE LOG

MW05

PROJECT No: **G1908A**
PROJECT NAME: **Martins Creek NSW**
DATE DRILLED: **22-May-18**
LOGGED BY: **T.Walters (AGE)**

DRILLING COMPANY: **BFG Daracon**
DRILLER: **C.Sheil (BFG Daracon)**
DRILLING METHOD: **Air / 125mm OD hammer**
DRILL RIG: **Boart Longyear Delta Base 102**

EASTING: **370642 mE**
NORTHING: **6397961 mN**
DATUM: **MGA94 (z56)**
RL: **123.49 mAHD**
EOH: **45 mBGL**

COMMENTS: **Location at northern strip area.**

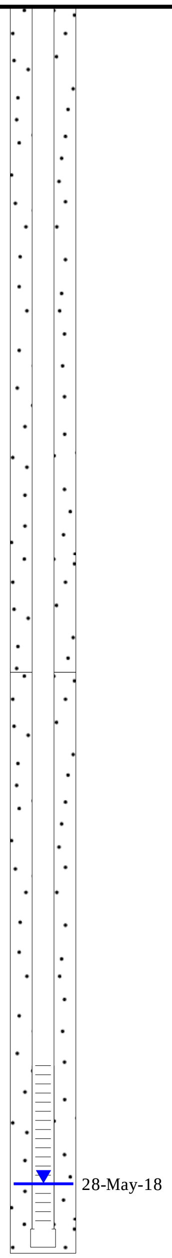
Stratigraphic Cloumn	Soil or Rock Field Material Description
Metasediment	IGNIMBRITE; Dark black with reddish mottles, very hard, ignimbrite, cream quartz phenocrysts (25%), feldspar (10%) red (pseudomorphed) phenocrysts, less mafic phenocrysts (amphibole 5%), <1mm sub-parallel red veins and with increasing depth red groundmass (50-60%). Red groundmass chilled margin, metamorphic contact feature. Ignimbrite is dry.
Metasediment	METASEDIMENT; Dark black, extremely fined grained/baked margin phenocryst(?), very hard, dark black, metasediment, Dark black and minor reddish hue, sandstone metasediment, very fine grained <1/4mm, well sorted, low strength. Baked sediments just below the contact.
Sandstone/siltstone metasediment	SANDSTONE METASEDIMENT; Dark black and minor reddish hue, sandstone metasediment, very fine grained <1/4mm, well sorted, low strength, powdered red return. Sandstone sediments contact metamorphosed.
Sandstone/siltstone metasediment	SILTSTONE METASEDIMENT; Dark brown to grey, low strength, siltstone, snapping sound, with very rare red plate like features, same red colour associated with the metasediments and base of ignimbrite. Siltstone sediments contact metamorphosed.
Sandstone/siltstone country rock	SILTSTONE; Dark grey and dark grey to brown, low strength (37-39m) moderate to hard (39-42m) apparent increasing sand component. Siltstone country rock.
Sandstone/siltstone country rock	SANDSTONE; Light grey, soft powder (42-43m), very hard to moderate strength (43-45m), <very fine grained, well sorted, possibly micaceous (44-45m), dry. Sandstone country rock.

Graphic Log

R.L. (mAHD): 98, 96, 94, 92, 90, 88, 86, 84, 82, 80, 78, 76, 74

Depth (mBGL): 26, 28, 30, 32, 34, 36, 38, 40, 42, 44, 46, 48, 50

Bore Construction



Bore Description

Backfill with 20-30mm ignimbrite gravel (resource).

Clean crushed quartz gravel graded sized 5mm.

50mm ID machine slotted threaded class 18 uPVC.
SWL 43.952 mBGL.

Push on cap.

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BOREHOLE LOG page:1 of 1

MW06

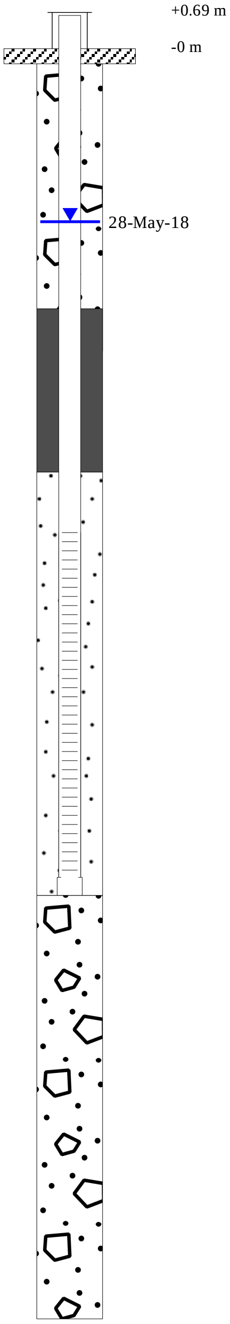
PROJECT No: **G1908A**	DRILLING COMPANY: **BFG Daracon**	EASTING: **370952 mE**
PROJECT NAME: **Martins Creek NSW**	DRILLER: **C.Sheil (BFG Daracon)**	NORTHING: **6397815 mN**
DATE DRILLED: **22-May-18**	DRILLING METHOD: **Air / 125mm OD hammer**	DATUM: **MGA94 (z56)**
LOGGED BY: **T.Walters (AGE)**	DRILL RIG: **Boart Longyear Delta Base 102**	RL: **86.56 mAHD**
		EOH: **21 mBGL**

COMMENTS: **Open grass area adjacent abandoned house.**

Stratigraphic Cloumn	Soil or Rock Field Material Description
Sand	SAND; Light cream coloured (reddish hue 4-5m), soft powdery, sand, <0.5mm (90%), with 2-4mm subrounded weathered clasts and clay peds (10% to 5%, respectively from 2-3m and 5-6m), moderately sorted.
Sandstone metasediment weathered (BOW)	SANDSTONE; Light grey, to cream and pinkish hue, low to moderate strength, sandstone, <0.5mm, black, grey and pink grains, well sorted, with pink quartz cement and veins (<0.1mm).
	SANDSTONE METASEDIMENT; Light grey (slightly darker 8-9m), moderate strength to hard (silty pieces), sandstone, <0.5mm to very fine grained, with siltstone, moist. Grey clay, wet and sloppy (9-10m), no water return from hole, water clogging sample return discharge.
	SANDSTONE; Light brown with reddish hue, moderate to hard strength, sandstone with siltstone clasts (10mm) [one clast identified), <0.5mm grey, brown, black and red grains, with <0.1mm veins.
	SANDSTONE; As above interval 11-13m. Sandstone (50%), siltstone (50%), moderate to hard (siltstone).
Siltstone	SILTSTONE METASEDIMENT; Dark grey, hard strength, siltstone (90%), with minor sandstone described above (10%), sandstone decreasing and disappearing with depth. Rock appears to be siliceous, apparent fissility and conchoidal fracture from the hammer bit. Dry.
	SILTSTONE; Dark grey, moderate strength, siltstone, in part clayey soft, red brown ironstone 2-3mm parallel laminations (18-19m). Low to moderate strength, return clay balls (17-18m). Siltstone country rock.

R.L. (mAHD): 87, 85, 83, 81, 79, 77, 75, 73, 71, 69, 67, 65, 63
Depth (mBGL): 0, 2, 4, 6, 8, 10, 12, 14, 16, 18, 20, 22, 24

Bore Construction



Bore Description

- 50mm ID uPVC class 18 threaded blank casing.
- SWL 2.86 mBGL.
- Back fill with drill cuttings.
- Bentonite seal - coated bentonite pellets.
- 50mm ID machine slotted threaded class 18 uPVC.
- WATER CUT: Seep @ 9-10m (<0.1 L/s).
- Clean crushed quartz gravel graded sized 5mm.
- Push on cap.
- Back fill with drill cuttings.

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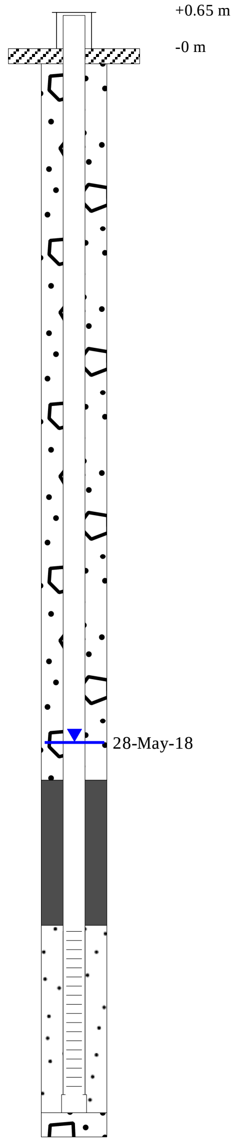
BOREHOLE LOG page:1 of 1

MW07

PROJECT No: **G1908A**	DRILLING COMPANY: **BFG Daracon**	EASTING: **370507 mE**
PROJECT NAME: **Martins Creek NSW**	DRILLER: **C.Sheil (BFG Daracon)**	NORTHING: **6398047 mN**
DATE DRILLED: **23-May-18**	DRILLING METHOD: **Air / 125mm OD hammer**	DATUM: **MGA94 (z56)**
LOGGED BY: **T.Walters (AGE)**	DRILL RIG: **Boart Longyear Delta Base 102**	RL: **84.39 mAHD**
COMMENTS: **Bench one access road.**		EOH: **18 mBGL**

Stratigraphic Cloumn	Soil or Rock Field Material Description
Road fill	FILL; Road fill material. Weathered ignimbrite, fresh and soil material.
Ignimbrite (with weathered joints)	IGNIMBRITE; Dark grey, very hard, ignimbrite, phenocrysts of feldspar (30%), quartz (12.5%), biotite (7.5%) and amphibole(?)[7.5%), and ash lithic (<0.02mm) and fiamme (<1mm long) [2.5%] with chlorite and epidote altered phenocrysts cores, patchy chlorite altered green, but dominantly grey groundmass (50%). Quartz vein fragment, veins visible in adjacent outcrop. Red weathered portions, weathered joints ((<0.1mm) [as seen in quarry face] at depth, and red weathered phenocrysts.
Chilled margin	IGNIMBRITE; Dark grey and red, very hard, ignimbrite, phenocrysts of feldspar, quartz, biotite and amphibole, with ash lithics and fiamme, all accentuated by vivid red (50%) groundmass [50% dark grey]. Weathering and or approaching quenched basal margin of ignimbrite.
	IGNIMBRITE; Dark grey and red, extremely hard, ignimbrite, phenocrysts feldspar (30%), quartz (10%), amphibole (10%), biotite (2.5%), fiamme and lithics (10%), with epidote altered cores and patchy chloritic alteration in groundmass, in grey and or vivid red groundmass (37.5%).
Metasediment	METASEDIMENT; Dark black, low to moderate strength, metasediment, no groundmass or grains evident, snapping sound when broken.
Sandstone/siltstone metasediment	SANDSTONE METASEDIMENT; Moderate, brown, red and grey, moderate strength, sandstone metasediment, very fine grained (almost siltstone) and fine grained chips (<0.25mm), both well sorted, distinctly different chip return, with <1mm red veins. Silt and sandy bands. Dry.
	SANDSTONE METASEDIMENT; Moderate grey and red, moderate strength, sandstone, very fine grained (almost siltstone), with darker red possibly banded and mottled altered portions. Dry.

Graphic Log | R.L. (mAHD) | Depth (mBGL) | Bore Construction



Bore Description

50mm ID uPVC class 18 threaded blank casing.

Backfill with 20-30mm ignimbrite gravel (resource).

SWL 11.48 mBGL.

Bentonite seal - coated bentonite pellets.

WATER CUT: Seep @ 15.5mBGL (<0.1 L/s). pH: 7.41, temp: 13.3 C, EC: 1223 µS/cm, TDS: 865 mg/L, ORP: 179 mV. Water dirty brown with slight black film. Made 115ml in 4 minutes.

Clean crushed quartz gravel graded sized 5mm.

50mm ID machine slotted threaded class 18 uPVC.
Push on cap.

Hole collapse, road base material.

Appendix B **Laboratory data**

CERTIFICATE OF ANALYSIS

Work Order	: **ES1814953**	Page	: 1 of 5
Client	: **AUSTRALASIAN GROUNDWATER AND ENVIRONMENTAL CONSULTANTS PTY LTD**	Laboratory	: Environmental Division Sydney
Contact	: MR THOMAS WALTERS	Contact	: Customer Services ES
Address	: 4 HUDSON STREET HAMILTON NSW 2303	Address	: 277-289 Woodpark Road Smithfield NSW Australia 2164
Telephone	: +61 02 4926 2811	Telephone	: +61-2-8784 8555
Project	: G1908A MARTINS CREEK QUARRY	Date Samples Received	: 28-May-2018 16:00
Order number	:	Date Analysis Commenced	: 28-May-2018
C-O-C number	: ----	Issue Date	: 04-Jun-2018 16:11
Sampler	: THOMAS WALTERS		
Site	: ----		
Quote number	: EN/222/17		
No. of samples received	: 3		
No. of samples analysed	: 3		

Accreditation No. 825
Accredited for compliance with
ISO/IEC 17025 - Testing

This report supersedes any previous report(s) with this reference. Results apply to the sample(s) as submitted. This document shall not be reproduced, except in full.

This Certificate of Analysis contains the following information:

- General Comments
- Analytical Results

Additional information pertinent to this report will be found in the following separate attachments: Quality Control Report, QA/QC Compliance Assessment to assist with Quality Review and Sample Receipt Notification.

Signatories

This document has been electronically signed by the authorized signatories below. Electronic signing is carried out in compliance with procedures specified in 21 CFR Part 11.

Signatories	*Position*	*Accreditation Category*
Ankit Joshi	Inorganic Chemist	Sydney Inorganics, Smithfield, NSW
Celine Conceicao	Senior Spectroscopist	Sydney Inorganics, Smithfield, NSW
Ivan Taylor	Analyst	Sydney Inorganics, Smithfield, NSW
Neil Martin	Team Leader - Chemistry	Chemistry, Newcastle West, NSW

General Comments

The analytical procedures used by the Environmental Division have been developed from established internationally recognized procedures such as those published by the USEPA, APHA, AS and NEPM. In house developed procedures are employed in the absence of documented standards or by client request.

Where moisture determination has been performed, results are reported on a dry weight basis.

Where a reported less than (<) result is higher than the LOR, this may be due to primary sample extract/digestate dilution and/or insufficient sample for analysis.

Where the LOR of a reported result differs from standard LOR, this may be due to high moisture content, insufficient sample (reduced weight employed) or matrix interference.

When sampling time information is not provided by the client, sampling dates are shown without a time component. In these instances, the time component has been assumed by the laboratory for processing purposes.

Where a result is required to meet compliance limits the associated uncertainty must be considered. Refer to the ALS Contact for details.

Key : CAS Number = CAS registry number from database maintained by Chemical Abstracts Services. The Chemical Abstracts Service is a division of the American Chemical Society.
LOR = Limit of reporting
^ = This result is computed from individual analyte detections at or above the level of reporting
ø = ALS is not NATA accredited for these tests.
~ = Indicates an estimated value.

- EG020: Bromine quantification may be unreliable due to its low solubility in acid, leading to variable volatility during measurement by ICPMS.
- Sodium Adsorption Ratio (where reported): Where results for Na, Ca or Mg are <LOR, a concentration at half the reported LOR is incorporated into the SAR calculation. This represents a conservative approach for Na relative to the assumption that <LOR = zero concentration and a conservative approach for Ca & Mg relative to the assumption that <LOR is equivalent to the LOR concentration.

Analytical Results

Sub-Matrix: WATER (Matrix: WATER)			Client sample ID	MW05	MW06	MW07	----	----
			Client sampling date / time	28-May-2018 08:34	28-May-2018 10:52	28-May-2018 13:38	----	----
Compound	CAS Number	LOR	Unit	ES1814953-001	ES1814953-002	ES1814953-003	--------	--------
				Result	Result	Result	----	----
EA005: pH								
pH Value	----	0.01	pH Unit	**7.76**	**7.19**	**7.57**	----	----
EA010P: Conductivity by PC Titrator								
Electrical Conductivity @ 25°C	----	1	µS/cm	**2260**	**4860**	**1700**	----	----
EA015: Total Dissolved Solids dried at 180 ± 5 °C								
Total Dissolved Solids @180°C	----	10	mg/L	**1520**	**3400**	**1050**	----	----
ED037P: Alkalinity by PC Titrator								
Hydroxide Alkalinity as CaCO3	DMO-210-001	1	mg/L	<1	<1	<1	----	----
Carbonate Alkalinity as CaCO3	3812-32-6	1	mg/L	<1	<1	<1	----	----
Bicarbonate Alkalinity as CaCO3	71-52-3	1	mg/L	**173**	**609**	**366**	----	----
Total Alkalinity as CaCO3	----	1	mg/L	**173**	**609**	**366**	----	----
ED040F: Dissolved Major Anions								
Silicon as SiO2	14464-46-1	0.1	mg/L	**20.8**	**29.4**	**27.5**	----	----
ED041G: Sulfate (Turbidimetric) as SO4 2- by DA								
Sulfate as SO4 - Turbidimetric	14808-79-8	1	mg/L	**109**	**155**	**60**	----	----
ED045G: Chloride by Discrete Analyser								
Chloride	16887-00-6	1	mg/L	**613**	**1160**	**350**	----	----
ED093F: Dissolved Major Cations								
Calcium	7440-70-2	1	mg/L	**166**	**237**	**101**	----	----
Magnesium	7439-95-4	1	mg/L	**19**	**146**	**22**	----	----
Sodium	7440-23-5	1	mg/L	**216**	**524**	**212**	----	----
Potassium	7440-09-7	1	mg/L	**3**	**2**	**1**	----	----
ED093F: SAR and Hardness Calculations								
Total Hardness as CaCO3	----	1	mg/L	**493**	**1190**	**343**	----	----
^ Sodium Adsorption Ratio	----	0.01	-	**4.23**	**6.60**	**4.98**	----	----
EG020F: Dissolved Metals by ICP-MS								
Aluminium	7429-90-5	0.01	mg/L	<0.01	<0.01	<0.01	----	----
Arsenic	7440-38-2	0.001	mg/L	**0.001**	**0.002**	**0.004**	----	----
Beryllium	7440-41-7	0.001	mg/L	<0.001	<0.001	<0.001	----	----
Barium	7440-39-3	0.001	mg/L	**0.036**	**0.059**	**0.028**	----	----
Cadmium	7440-43-9	0.0001	mg/L	<0.0001	<0.0001	<0.0001	----	----
Chromium	7440-47-3	0.001	mg/L	<0.001	<0.001	<0.001	----	----
Copper	7440-50-8	0.001	mg/L	<0.001	**0.002**	<0.001	----	----
Cobalt	7440-48-4	0.001	mg/L	<0.001	**0.002**	<0.001	----	----
Nickel	7440-02-0	0.001	mg/L	**0.002**	**0.006**	**0.005**	----	----

Analytical Results

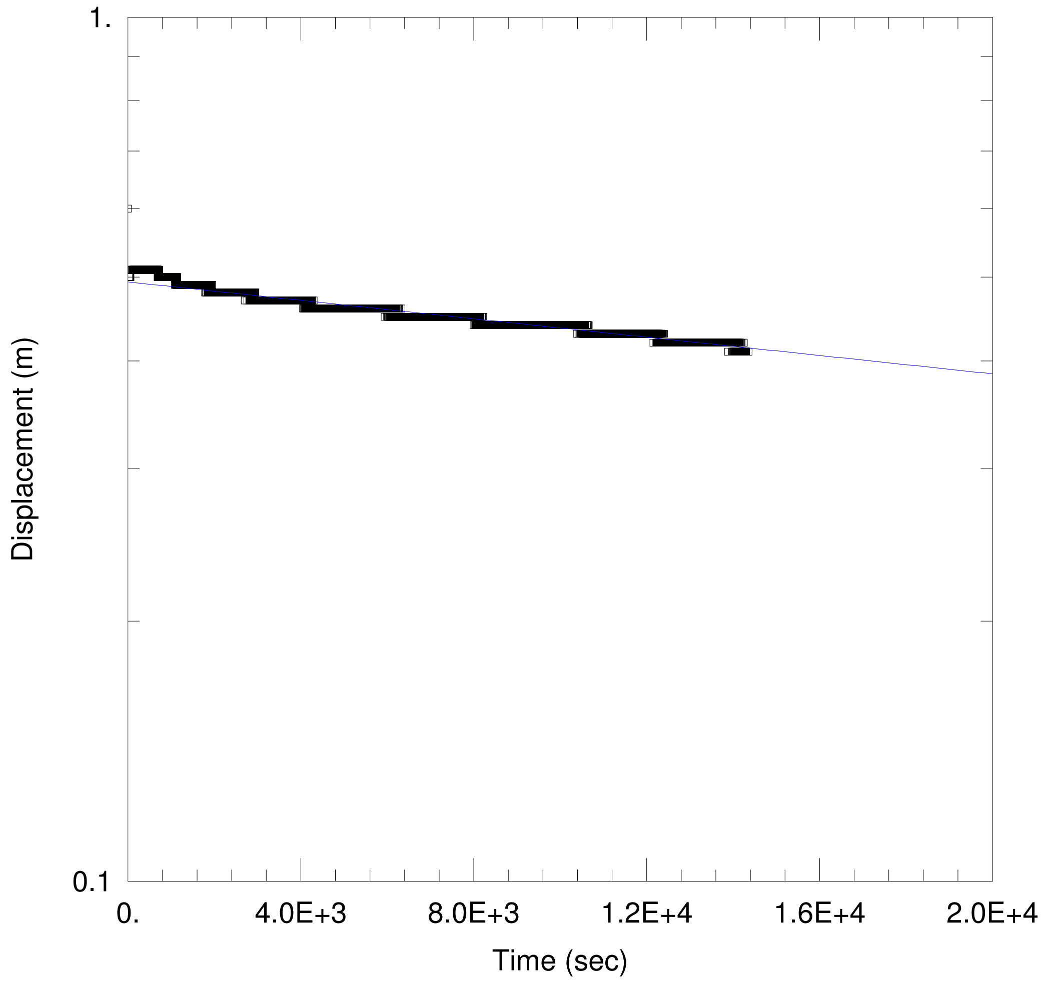
Sub-Matrix: WATER (Matrix: WATER)			Client sample ID	MW05	MW06	MW07	----	----
			Client sampling date / time	28-May-2018 08:34	28-May-2018 10:52	28-May-2018 13:38	----	----
Compound	CAS Number	LOR	Unit	ES1814953-001	ES1814953-002	ES1814953-003	--------	--------
				Result	Result	Result	----	----
EG020F: Dissolved Metals by ICP-MS - Continued								
Lead	7439-92-1	0.001	mg/L	<0.001	<0.001	<0.001	----	----
Zinc	7440-66-6	0.005	mg/L	**0.011**	**0.017**	<0.005	----	----
Manganese	7439-96-5	0.001	mg/L	**0.060**	**0.264**	**0.117**	----	----
Molybdenum	7439-98-7	0.001	mg/L	**0.003**	**0.003**	**0.005**	----	----
Selenium	7782-49-2	0.01	mg/L	<0.01	<0.01	<0.01	----	----
Strontium	7440-24-6	0.001	mg/L	**0.429**	**1.34**	**0.324**	----	----
Vanadium	7440-62-2	0.01	mg/L	<0.01	<0.01	<0.01	----	----
Boron	7440-42-8	0.05	mg/L	**0.87**	**0.60**	**0.57**	----	----
Iron	7439-89-6	0.05	mg/L	<0.05	<0.05	<0.05	----	----
Bromine	7726-95-6	0.1	mg/L	**0.8**	**1.9**	**0.6**	----	----
EG020T: Total Metals by ICP-MS								
Aluminium	7429-90-5	0.01	mg/L	**1.03**	**63.3**	**59.6**	----	----
Arsenic	7440-38-2	0.001	mg/L	**0.002**	**0.008**	**0.011**	----	----
Beryllium	7440-41-7	0.001	mg/L	<0.001	**0.002**	**0.002**	----	----
Barium	7440-39-3	0.001	mg/L	**0.041**	**0.206**	**0.639**	----	----
Cadmium	7440-43-9	0.0001	mg/L	**0.0002**	**0.0001**	**0.0002**	----	----
Chromium	7440-47-3	0.001	mg/L	**0.003**	**0.124**	**0.142**	----	----
Copper	7440-50-8	0.001	mg/L	**0.001**	**0.042**	**0.045**	----	----
Cobalt	7440-48-4	0.001	mg/L	<0.001	**0.030**	**0.028**	----	----
Nickel	7440-02-0	0.001	mg/L	**0.008**	**0.062**	**0.078**	----	----
Lead	7439-92-1	0.001	mg/L	<0.001	**0.026**	**0.040**	----	----
Zinc	7440-66-6	0.005	mg/L	**0.019**	**0.167**	**0.177**	----	----
Manganese	7439-96-5	0.001	mg/L	**0.073**	**1.09**	**1.19**	----	----
Molybdenum	7439-98-7	0.001	mg/L	**0.004**	**0.005**	**0.006**	----	----
Selenium	7782-49-2	0.01	mg/L	<0.01	<0.01	<0.01	----	----
Strontium	7440-24-6	0.001	mg/L	**0.450**	**1.76**	**1.04**	----	----
Vanadium	7440-62-2	0.01	mg/L	<0.01	**0.09**	**0.08**	----	----
Boron	7440-42-8	0.05	mg/L	**0.91**	**0.77**	**0.69**	----	----
Iron	7439-89-6	0.05	mg/L	**0.79**	**53.0**	**51.3**	----	----
EG035F: Dissolved Mercury by FIMS								
Mercury	7439-97-6	0.0001	mg/L	<0.0001	<0.0001	<0.0001	----	----
EG035T: Total Recoverable Mercury by FIMS								
Mercury	7439-97-6	0.0001	mg/L	<0.0001	<0.0001	<0.0001	----	----
EK040P: Fluoride by PC Titrator								

Analytical Results

Sub-Matrix: **WATER**
(Matrix: **WATER)**

			Client sample ID	MW05	MW06	MW07	----	----
			Client sampling date / time	28-May-2018 08:34	28-May-2018 10:52	28-May-2018 13:38	----	----
Compound	CAS Number	LOR	Unit	ES1814953-001	ES1814953-002	ES1814953-003	--------	--------
				Result	Result	Result	----	----
EK040P: Fluoride by PC Titrator - Continued								
Fluoride	16984-48-8	0.1	mg/L	1.0	1.1	1.7	----	----
EN055: Ionic Balance								
Total Anions	----	0.01	meq/L	23.0	48.1	18.4	----	----
Total Cations	----	0.01	meq/L	19.3	46.7	16.1	----	----
Ionic Balance	----	0.01	%	8.74	1.51	6.77	----	----

Appendix C **Hydraulic testing**



RISING HEAD TEST

Data Set: N:\...\MW05.aqt
Date: 06/04/18
Time: 11:34:04

PROJECT INFORMATION

Company: AGE Consultants
Client: Umwelt
Project: G1908A
Location: Martins Creek
Test Well: MW05
Test Date: 31/05/2018

AQUIFER DATA

Saturated Thickness: 0.1 m
Anisotropy Ratio (Kz/Kr): 1.

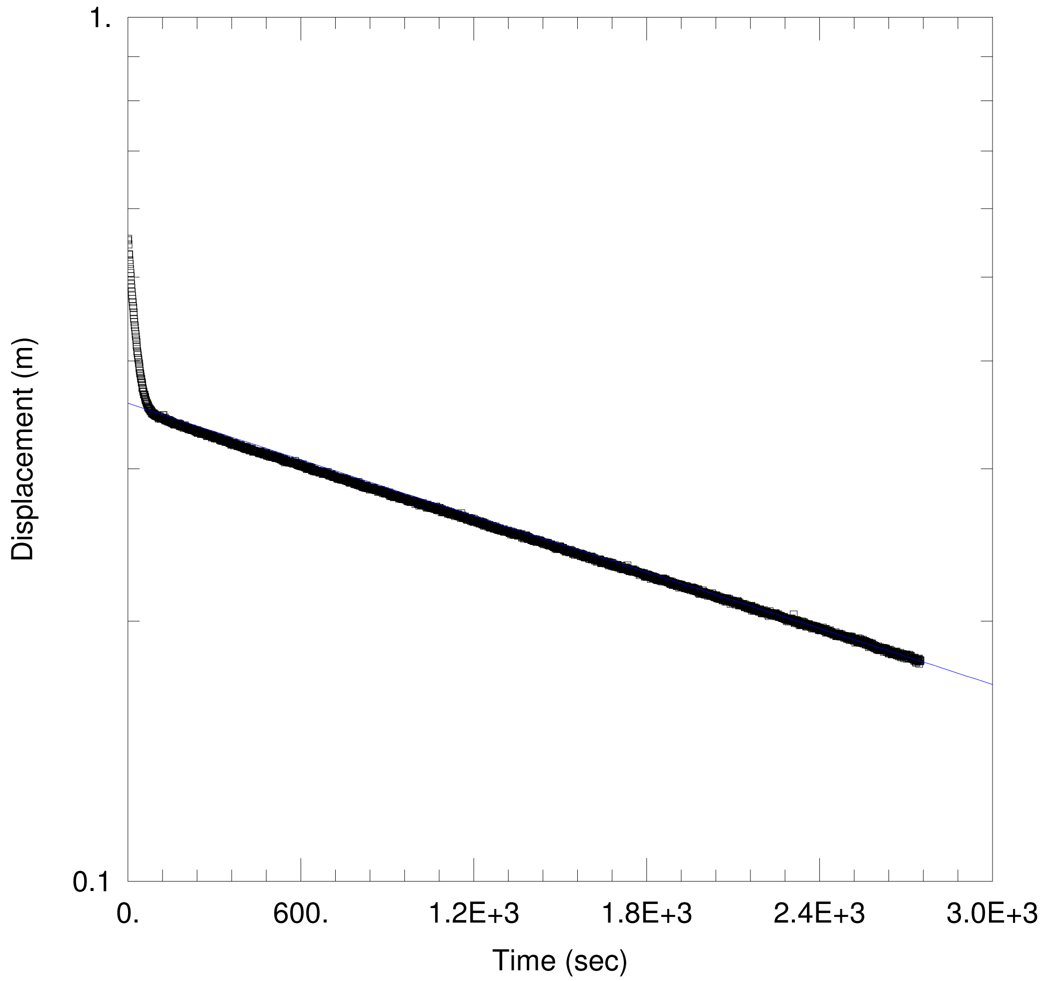
WELL DATA (MW05)

Initial Displacement: 1.088 m
Static Water Column Height: 1.088 m
Total Well Penetration Depth: 45. m
Screen Length: 3. m
Casing Radius: 0.025 m
Well Radius: 0.025 m

SOLUTION

Aquifer Model: Unconfined
Solution Method: Hvorslev

K = 0.007405 m/day
y0 = 0.4938 m



RISING HEAD TEST

Data Set: N:\...\MW06.aqt
Date: 06/04/18 Time: 11:34:23

PROJECT INFORMATION

Company: AGE Consultants
Client: Umwelt
Project: G1908A
Location: Martins Creek
Test Well: MW06
Test Date: 31/05/2018

AQUIFER DATA

Saturated Thickness: 0.1 m Anisotropy Ratio (Kz/Kr): 1.

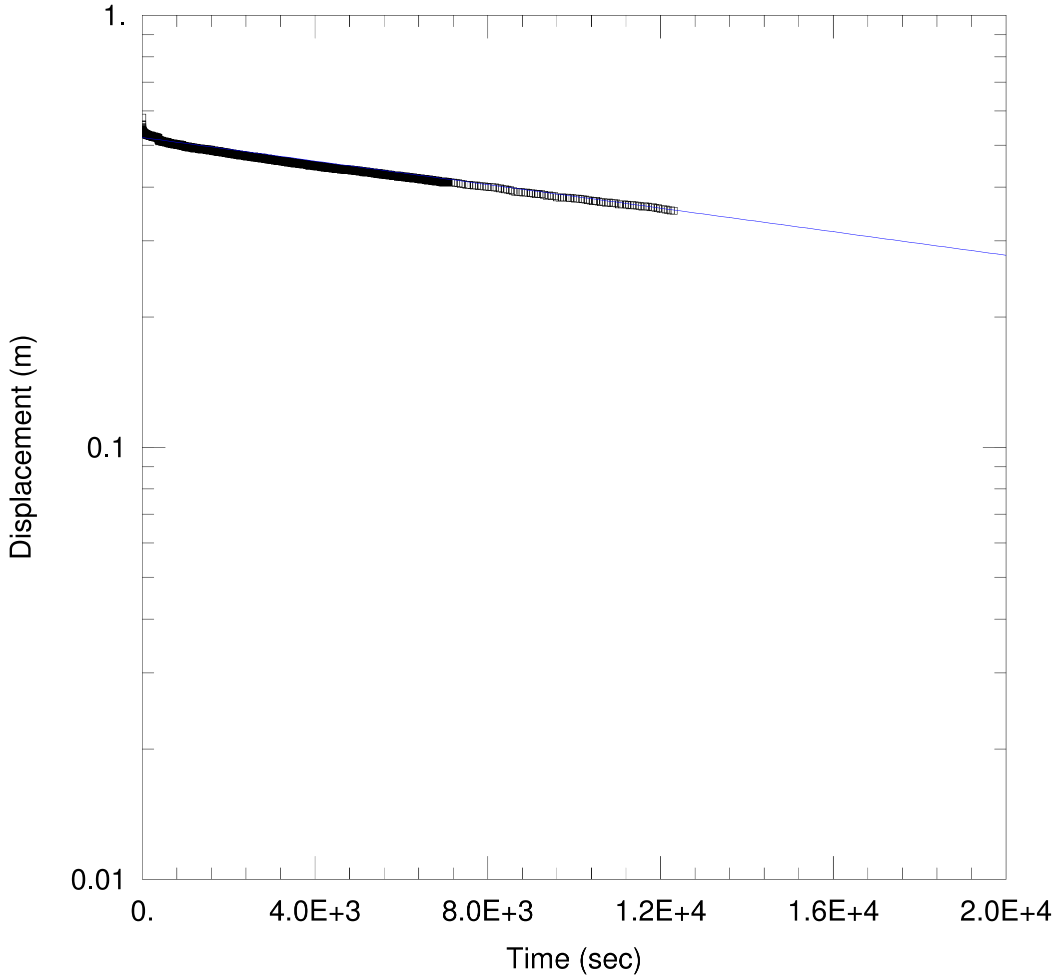
WELL DATA (MW06)

Initial Displacement: 2.87 m Static Water Column Height: 11.13 m
Total Well Penetration Depth: 22. m Screen Length: 14. m
Casing Radius: 0.025 m Well Radius: 0.025 m

SOLUTION

Aquifer Model: Unconfined Solution Method: Hvorslev

K = 0.1509 m/day y0 = 0.3572 m



WELL TEST ANALYSIS

Data Set: N:\...\MW07.aqt
Date: 06/05/18 Time: 14:08:13

PROJECT INFORMATION

Company: AGE Consultants
Client: Umwelt
Project: G1908A
Location: Martins Creek
Test Well: MW07
Test Date: 28/05/2018

AQUIFER DATA

Saturated Thickness: 0.1 m
Anisotropy Ratio (Kz/Kr): 1.

WELL DATA (MW07)

Initial Displacement: 11.37 m
Static Water Column Height: 6.2 m
Total Well Penetration Depth: 17.6 m
Screen Length: 3. m
Casing Radius: 0.025 m
Well Radius: 0.025 m

SOLUTION

Aquifer Model: Unconfined
Solution Method: Hvorslev

K = 0.04493 m/day
y0 = 0.5209 m