

Gunlake Quarry Extension Project

2

Environmental Impact Statement

Prepared for Gunlake Quarries Pty Limited | April 2016



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Groundwater Assessment

Gunlake Extension Project

Prepared for Gunlake Quarries Pty Limited | 24 March 2016





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Groundwater Assessment

Final

Report J14119RP1 | Prepared for Gunlake Quarries Pty Limited | 24 March 2016

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Date 24 March 2016

Date 24 March 2016

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1 Introduction

1.1 Overview

Gunlake Quarry is a hard rock quarry approximately 7 km north-west of Marulan, in the Goulburn Mulwaree local government area of New South Wales (NSW) (Figure 1.1). Gunlake Quarries Pty Ltd (Gunlake) commenced operations in 2009 under project approval 07-0074 granted in September 2008.

Gunlake is seeking development consent to increase the production rate to 2 million tonnes per annum (the extension project). The extension project is classified as a State significant development (SSD) in accordance with Schedule 1 of the *State Environmental Planning Policy* and will be assessed under Part 4, Division 4.1 of the *Environmental Planning and Assessment Act 1979* (EP&A Act).

This report details a groundwater assessment completed in support of a Environmental Impact Statement (EIS) for the extension project. The groundwater assessment considers the potential groundwater impacts of the extension project and provides mitigation and management measures to prevent or minimise environmental impacts.

1.2 Secretary's environmental assessment requirements

Secretary's environmental assessment requirements (SEARs) for the extension project were issued on 3 July 2015. Table 1.1 lists the SEARs of relevance to this groundwater assessment and outlines the section(s) where they are addressed within this report.

Table 1.1 SEARs relevant to this groundwater assessment

| Secretary's environmental assessment requirement | Where requirement is addressed |
|---|---|
| Detailed assessment of potential impacts on the quality and quantity of existing surface and ground water resources, including impacts on the regional water supply, having regard to the requirements of Department of Primary Industries (DPI). | Section 8 (with surface water impacts discussed in the Surface Water Assessment) ¹ |
| A detailed site water balance and an assessment of any volumetric water licensing requirements. | Section 8 (with the water balance discussed in the Surface Water Assessment) ¹ |
| Identification of any licensing requirements or other approvals under the Water Management Act 2000. | Section 3 |
| Demonstration that water for the construction and operation of the development can be obtained from an appropriately authorised and reliable supply in accordance with the operating rules of any relevant Water Sharing Plan (WSP). | Section 3 (with the water supply discussed in the Surface Water Assessment) ¹ |

Table 1.1 SEARs relevant to this groundwater assessment

| Secretary's environmental assessment requirement | Where requirement is addressed |
|---|---|
| An assessment of potential risks to surface water and groundwater from construction and operation, demonstrating clear consideration of the principle of achieving a neutral or beneficial effect on water quality in the Sydney Drinking Water Catchment, consistent with SEPP (Sydney Drinking Water Catchment) 2011. | Section 8 (with surface water risks discussed in the Surface Water Assessment) ¹ |
| The EIS must include a framework for the avoidance, mitigation, management and monitoring of water quality impacts during construction and operation. | Sections 8 and 9 |
| A description of the measures proposed to ensure the development can operate in accordance with the requirements of any relevant WSP or water source embargo, having regard to the requirements of DPI. | Section 8 |
| A detailed description of the proposed water management system (including sewage), water monitoring program and other measures to mitigate surface and groundwater impacts. | Section 9 (with surface water monitoring and the proposed management system discussed in the Surface Water Assessment) ¹ |

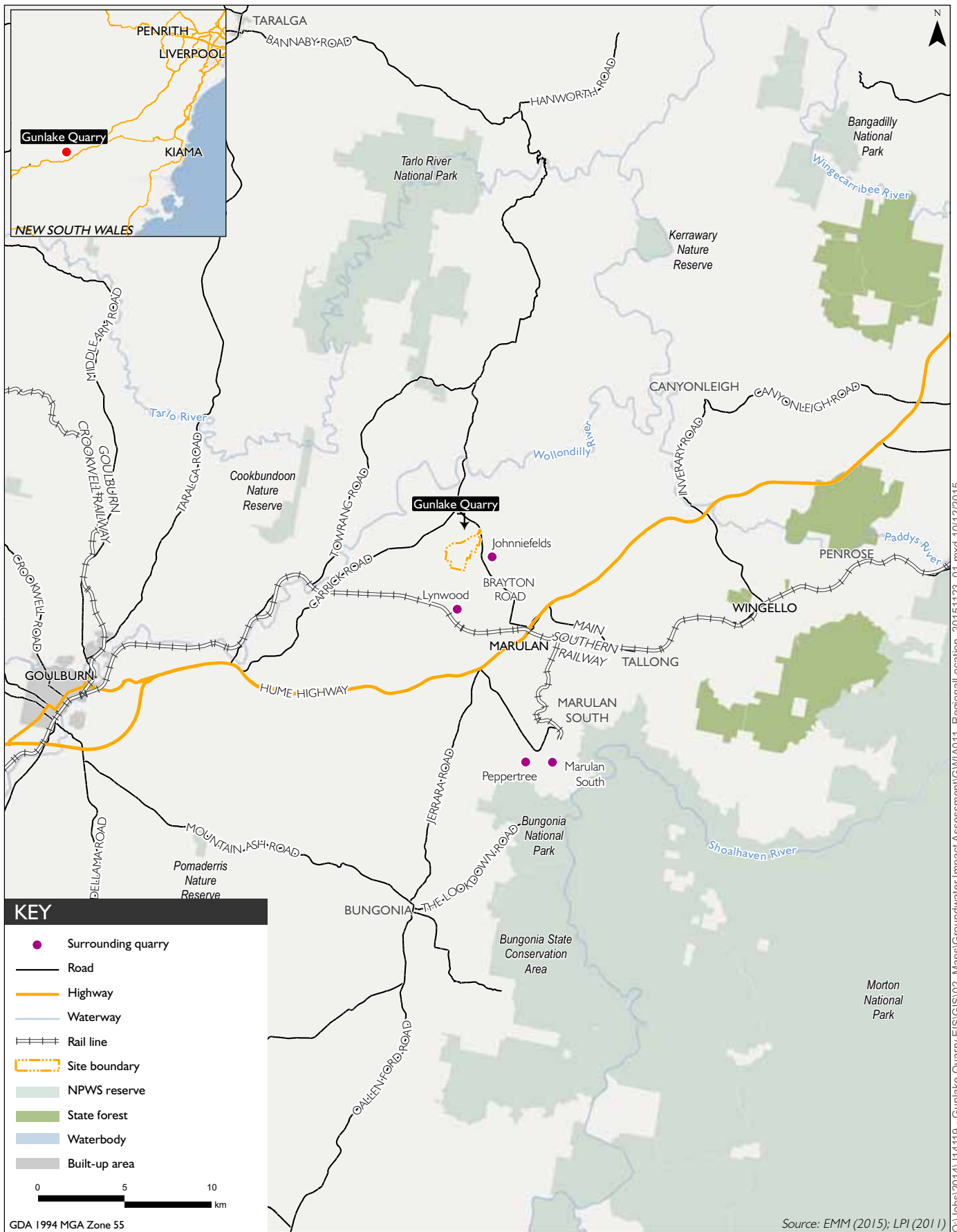
Notes: 1. *Gunlake Surface Water Assessment (RHDVH 2015).*

1.3 Assessment scope

EMM Consulting Pty Limited (EMM) was commissioned by Gunlake to prepare a groundwater assessment for the extension project. The assessment has been completed in accordance with leading practice and includes:

- a review of publically available literature relevant to the project:
 - *Gunlake Quarry Project, Environmental Assessment Volume II, Part 3 Groundwater Impact Assessment* (Larry Cook and Associates Pty Ltd 2008);
 - *Water Management Plan, Environmental Management System* (Olsen Consulting Group Pty Ltd 2009);
 - *Proposed Lynwood Quarry, Marulan Groundwater Impact Assessment* (Peter Dundon and Associates 2005);
 - *Lynwood Quarry Extraction Area Modification, Groundwater Assessment* (Scientific Systems 2015);
- the collation and assessment of baseline and operational groundwater monitoring data;
- a desktop review of local and regional groundwater users;
- an update of the project area hydrogeological conceptualisation;
- a review of the groundwater licensing requirements;

- the preparation of an analytical groundwater flow model;
- an assessment of the potential risks and impacts to the groundwater resource and receptors; and
- recommendations for environmental mitigation and management measures.



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Source: EMM (2015); LPI (2011)

Project location
 Gunlake Quarry
 Groundwater Assessment

Figure 1.1



2 Project description

2.1 Background

Gunlake supplies hard rock products to the local and greater Sydney Metropolitan area and is a major supplier of rhyodacitic rock for the construction industry. Gunlake produce material suitable for use in a wide range of applications, including concrete and sealing aggregates, rail ballast, manufactured sand and road base. These products are used by Gunlake for concrete production in its own operations in Sydney as well as for other markets. Gunlake is in the process of establishing concrete plants in the Sydney region and has three plants currently in operation at Smeaton Grange, Glendenning and Silverwater.

Key components of the existing quarry include:

- a quarry pit providing hard rock resources;
- overburden and excess product emplacement areas;
- drilling and blasting to release the rock material;
- crushing and screening of the quarried rock;
- truck loading and transport of hard rock; and
- ancillary infrastructure to support operations including offices, amenity buildings and other minor infrastructure.

2.2 Resource

Quarry operations extract a hard rock resource from the Devonian Bindook Volcanic Complex. The Complex comprises a north to north-east trending series of volcanics. A resource of 180 million tonnes of tuffaceous rhyodacite has been proven to depths in excess of 100 m below surface. The resource is suitable for use in a range of quarry products including concrete and sealing aggregates, rail ballast, manufactured sand and road base.

2.3 The extension project

The extension project seeks an increased extraction rate to meet an increased demand for construction materials, including quarried aggregate, in the local area and Sydney. The extension project includes the production of 2 million tonnes per annum (Mtpa) of saleable product for 30 years. Gunlake seeks a new project approval under Part 4, Division 4.1 of the EP&A Act that allows:

- 2 Mtpa of saleable products to be produced;
- an increase in truck movements to an average of 440 movements per day and a maximum of 690 movements per day;
- extension of the quarry pit footprint;
- an additional overburden emplacement to accommodate the increase in production;
- 24 hour per day primary crushing; and

- blasting twice weekly.

The approved disturbance footprint is approximately 45 ha and the pit extension area footprint is 54 ha, so the total disturbance footprint (project area) will be 99 ha.

2.3.1 Pit development

The proposed pit development has been designed in four stages over a 30 years lifespan (Table 2.1).

Table 2.1 Indicative staged quarry development

| Stage | Timing (years) | Depth to quarry floor (m BGL) | Elevation of quarry floor (m AHD) |
|-------|----------------|-------------------------------|-----------------------------------|
| 1 | 1–5 | 13 | 650 |
| 2 | 5–10 | 26 | 637 |
| 3 | 10–20 | 65 | 598 |
| 4 | 20–30 | 91 | 572 |

Notes: m BGL = metres below ground level.

m AHD = m Australian height datum.

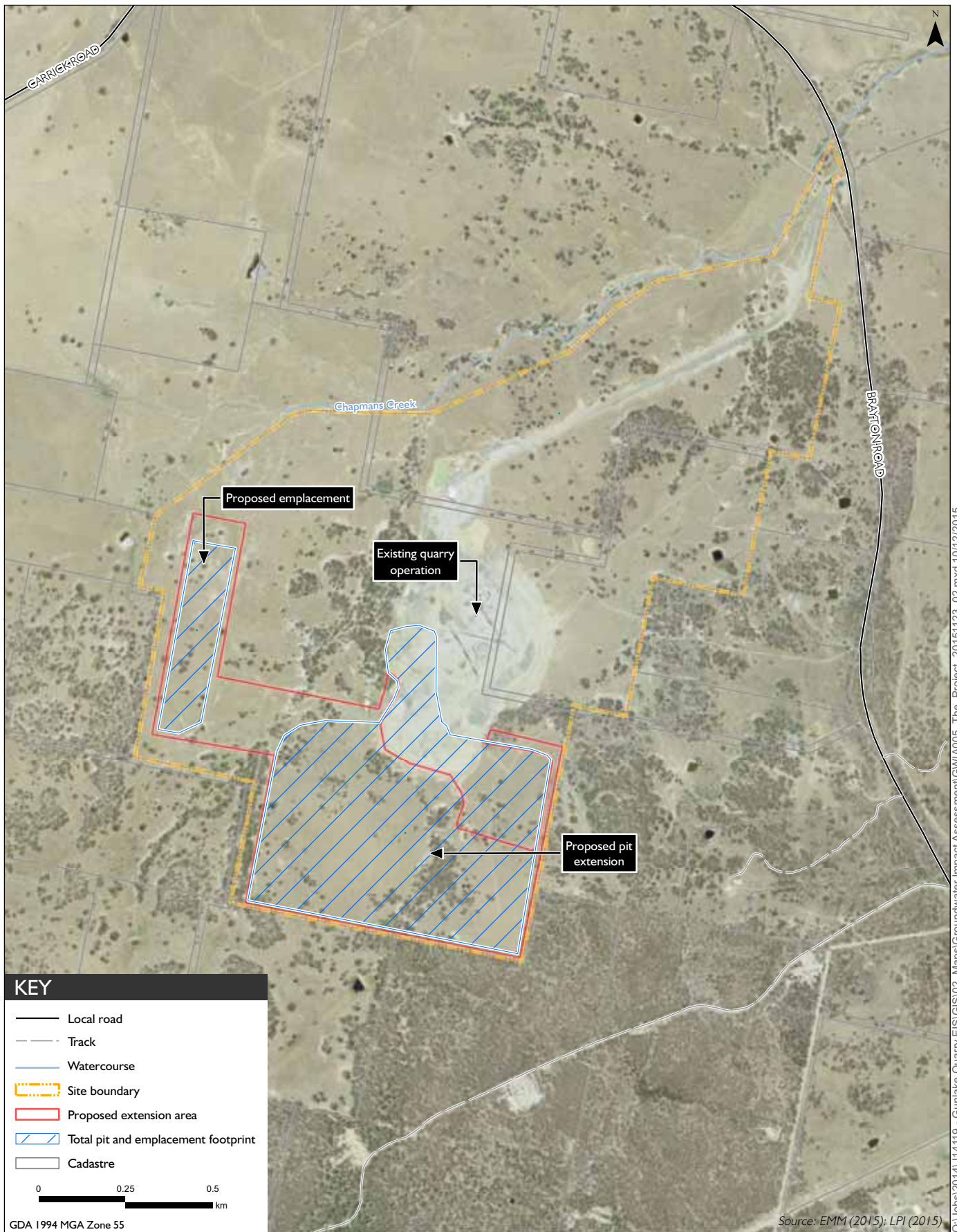
Development of the pit will commence within the current footprint and migrate to the south and south-east before expanding laterally to the west during the first five years of development. The pit depth will remain at approximately 650 m AHD for the first five years.

During Years 5 to 10 an additional bench will be extracted taking the elevation of the pit floor to approximately 637 m AHD. Over Years 10 to 20 the pit will be further deepened with the extraction of three benches and over Years 20 to 30 the final two benches will be extracted taking the pit floor to a final elevation of 572 m AHD.

2.3.2 Proposed emplacement area

As the approved overburden emplacement area will not be able to accommodate all of the overburden from the extension area, an additional emplacement area is proposed west of the approved pit footprint (Figure 2.1).

The proposed emplacement area will comprise overburden and reject material from the crushing and screening process. The proposed emplacement area will be progressively shaped and vegetated to stabilise the landform.



Proposed quarry layout

Gunlake Quarry
Groundwater Assessment

Figure 2.1

3 Regulation

The *Water Act 1912* (Water Act) and the *Water Management Act 2000* (WM Act) are the two key pieces of legislation for the management of water in NSW.

3.1 Water Act 1912

The Water Act has historically governed the management of groundwater resources in NSW. This Act is being progressively repealed and replaced by the WM Act. However some provisions of the Water Act are still in force. The licensing of monitoring bores continues to be regulated under the Water Act.

3.2 Water Management Act 2000

The WM Act has progressively come into force across NSW since 1 July 2004. The licensing provisions of the WM Act are introduced for a water source once the water sharing plans (WSPs) for that water source commences. The WM Act recognises the need to provide water for the environment and to provide security to licence holders. One of the key components of the WM Act is the separation of the water licence from the land, providing for a greater opportunity for water to be traded to the highest value use.

The WM Act requires that Gunlake licence the volume of predicted 'take' of surface water and groundwater in accordance with the NSW Aquifer Interference Police (AIP). This includes water taken for use on site and water intercepted as a result of quarrying activities. Sufficient water access licences (WALs) must be held to account for the take from the water source at all times.

3.2.1 Water sharing plans

Water sharing plans are statutory documents under the WM Act that apply to one or many defined water sources. Water sharing plans establish rules for sharing water between the environmental needs of rivers and/or aquifers and extractive water users. They differentiate between different types of water use such as town supply, rural domestic supply, stock watering, industry and irrigation. Water sharing plans are designed to ensure sustainable management and sharing of the water resources in NSW; they are in place for 10 year periods.

The WSPs define how much water is available to be shared across all uses, and have provisions to provide water for environmental purposes such as the needs of rivers, and high priority groundwater dependent ecosystems (GDEs) as a priority. Remaining water is then available to be shared across the existing and future extractive uses (such as town water supply, irrigation and domestic and stock).

The two WSPs that manage the water resources in the Gunlake area are:

- The *Water Sharing Plan for the Greater Metropolitan Region Unregulated River Water Sources 2011 (Surface Water WSP)*; and
- The *Water Sharing Plan for the Greater Metropolitan Region Groundwater Sources 2011 (Groundwater WSP)*.

Both the *Surface Water* and *Groundwater WSP* cover an area of approximately 32,500 km² on the south-eastern coast of NSW. The region includes rivers of the Illawarra and metropolitan Sydney, and the Hawkesbury and Shoalhaven Rivers.

There are approximately 62,348 unit shares of entitlement (under licence) in the area covered by the *Groundwater WSP*. The majority of these licenses are for industrial and mining purposes. The provisions in the *Surface Water WSP* are addressed in the Surface Water Assessment (RHDHV 2015).

3.3 Aquifer Interference Policy

Water licensing of aquifer interference activities is addressed by the AIP (NOW 2012). The AIP defines the regime for protecting and managing the impacts of aquifer interference activities and assists proponents in the preparation of necessary information for activities (or developments) with aquifer interference.

The AIP aims to:

- clarify water license and impact assessment requirements for aquifer interference activities;
- ensure equitable water sharing among different types of water users;
- ensure that water taken by aquifer interference activities is properly licensed and accounted for in the water budget and water sharing arrangements; and
- enhance existing regulation, resulting in a comprehensive framework to protect the rights of all water users and the environment.

The AIP states that the assessment of an activity must address potential water table, water pressure and water quality impacts of aquifer interference activities. Combined, these are called 'minimal impact considerations'. The AIP requires that a plan is prepared that describes groundwater monitoring and mitigation of impacts should actual impacts exceed predicted impacts.

3.4 Water licence requirements

The extension project is within the Goulburn Fractured Rock Groundwater Source (GFRGS) within the *Groundwater WSP*. This water source covers an area of approximately 8,175 km². The recharge and available water for the GFRGS is listed in Table 3.1 and an overview of water availability is presented in Figure 3.1.

Table 3.1 Recharge and share components in the Goulburn Fractured Rock Groundwater Source

| Use | Share component |
|---|--|
| Recharge | 259,784 ML/year |
| Environmental Water | 75% of recharge in non high environmental value areas 100% of recharge in high environmental value areas Plus all groundwater in storage |
| Long-term average annual extraction limit | 53,074 ML/year |
| Town water supply | 100 ML/year |
| Basic rights (domestic and stock) | 3,114 ML/year |
| Native title | 0 ML/year |
| Aquifer access licenses | 3,051 unit shares ¹ |
| Total water requirements | 6,265 ML/year ² |
| Unallocated water | 46,809 ML/year |

Notes: 1. A unit share is defined in section 29(2)(b) of the Greater Metropolitan Groundwater Sources WSP as being a maximum of 1 ML per unit share, or a lower amount if the volume of water extraction from the water source is deemed to be in excess of the LTAAEL over a three year rolling period.
2. This is not listed in the WSP, it has been calculated by summing all requirements for water under Part 5 of the plan for the GFRGS and assuming 1 unit share is equal to 1 ML.

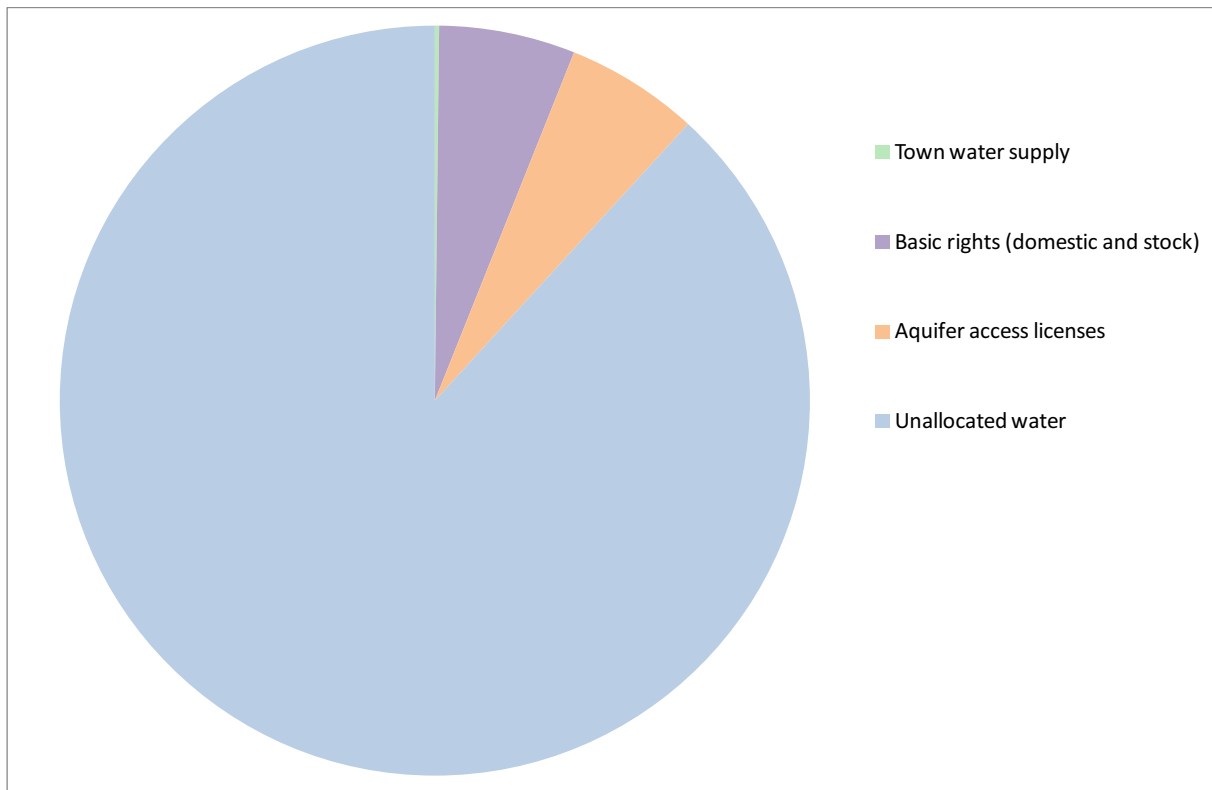


Figure 3.1 Share components in the Goulburn Fractured Rock Groundwater Source

The estimated annual recharge to the GFRGS is 259,784 ML/year, and the majority of this water is reserved for the environment (206,710 ML/year). The existing storage within this groundwater source is also reserved for the environment. The water available for extraction from the GFRGS, termed the long-term average annual extraction limit, is 53,078 ML/year. Of this, 100 ML/year has been licensed to the Goulburn town water supply and 3,114 ML/year is reserved for basic landholder rights. There are 3,051 unit shares assigned to water access licences within the water source. This leaves 46,809 unit shares (ML/year) of unallocated water within the GFRGS (Table 3.1).

Gunlake will be required to hold a WAL within the GFRGS equivalent to the volume of water intercepted during each year of operation at the extension project. The licenses can be obtained by trading from other users or via a controlled allocation release.

Trading can occur from within the pool of 3,051 shares that currently exist. However, a simpler method would be to apply for an entitlement via an application under Section 65 of the WMA when the next controlled allocation order is announced by the NSW Government. This is likely to occur in mid 2016 as controlled allocation orders are generally undertaken every 18 months, and the last one was on 9 September 2014.

The maximum volume expected to be intercepted and dewatered during any one year of operations is 37 ML (Section 8.2.4). Therefore there is sufficient volume within the market or within the next controlled allocation order from which to obtain a water license. Controlled allocation orders generally make available 5% of the remaining unallocated water, and the 9 September 2014 order made 2,273 share units available.

3.5 NSW policies and strategies

Other relevant NSW policies, guidelines and strategies include:

- *NSW State Groundwater Policy Framework Document* (DLWC 1997), which comprises three policies:
 - *NSW State Groundwater Quantity Management Policy* (DLWC 2001 (unpublished));
 - *NSW State Groundwater Quality Protection Policy* (DLWC 1998);
 - *NSW State Groundwater Dependent Ecosystem Policy* (DLWC 2002);
- *NSW Water Conservation Strategy* (DLWC 2000);
- *Guidelines for Groundwater Protection in Australia, National Water Quality Management Strategy* (ANZECC and ARM CANZ 1995);
- State Environmental Planning Policy (Sydney Drinking Water Catchment) 2011; and
- Neutral or Beneficial Effect on Water Quality Assessment Guideline (Sydney Catchment Authority).

Guidelines listed in the SEARs not relevant to this project are:

- *Groundwater Monitoring and Modelling Plans - Information for Prospective Mining and Petroleum Exploration Activities*, DPI Office of Water, 2014b;
- *Office of Water Guidelines for Controlled Activities* (DPI Water 2012); and

- *Guidelines for the Assessment & Management of Groundwater Contamination* (EPA 2007).

3.6 Commonwealth legislation and guidelines

3.6.1 Commonwealth Environmental Protection and Biodiversity Conservation Act 1999

The Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) provides a legal framework to protect and manage nationally and internationally important flora, fauna, ecological communities and heritage places which are defined as matters of national environmental significance.

The EPBC Act was amended in 2013 to include water resources as a matter of national environmental significance, in relation to coal seam gas and large coal mining developments (the ‘water trigger’). The Gunlake Project is not subject to the water trigger as it is not a coal mine or coal seam gas development.

3.6.2 Australian Groundwater Modelling Guidelines

The *Australian Groundwater Modelling Guidelines* (SKM and NCGRT 2012) were developed to provide a consistent and sound approach for the development of groundwater flow modelling in Australia. Measured groundwater data is used to conceptualise and describe all observed groundwater behaviour in the region. Groundwater level data is used to calibrate a groundwater model until there is acceptable agreement between model estimated and actual groundwater levels (SKM and NCGRT 2012).

3.6.3 National Water Quality Management Strategy Guidelines for Groundwater Protection in Australia

The National Water Quality Management Strategy *Australia and New Zealand Guidelines for Fresh and Marine Water Quality (Water Quality Guideline)* (ANZECC and ARMCANZ 2000) provides a framework for protecting environmental water quality. The protection framework involves the identification of specific beneficial uses and values for major aquifers, and protection strategies including a monitoring framework.

4 Environmental setting

4.1 Overview

The Marulan area comprises rural and rural-residential properties, with livestock grazing the predominant rural land use. The area immediately surrounding the extension project comprises cleared pasture land with areas of native vegetation to the south and east. There are pockets of remnant native vegetation on steeper slopes in the extension area and along Chapmans Creek and its tributaries (Figure 4.2).

4.2 Topography

The topography around the extension project is undulating, the elevation ranges from approximately 636 m AHD in the north to 680 m AHD in the south.

4.3 Climate

The climate in Goulburn is temperate, on average January is the hottest month of the year and July the coldest. A Bureau of Meteorology weather station (Goulburn TAFE station, 070263) is located approximately 12 km west of the extension project. This is the closest station that monitors temperature, rainfall and evaporation.

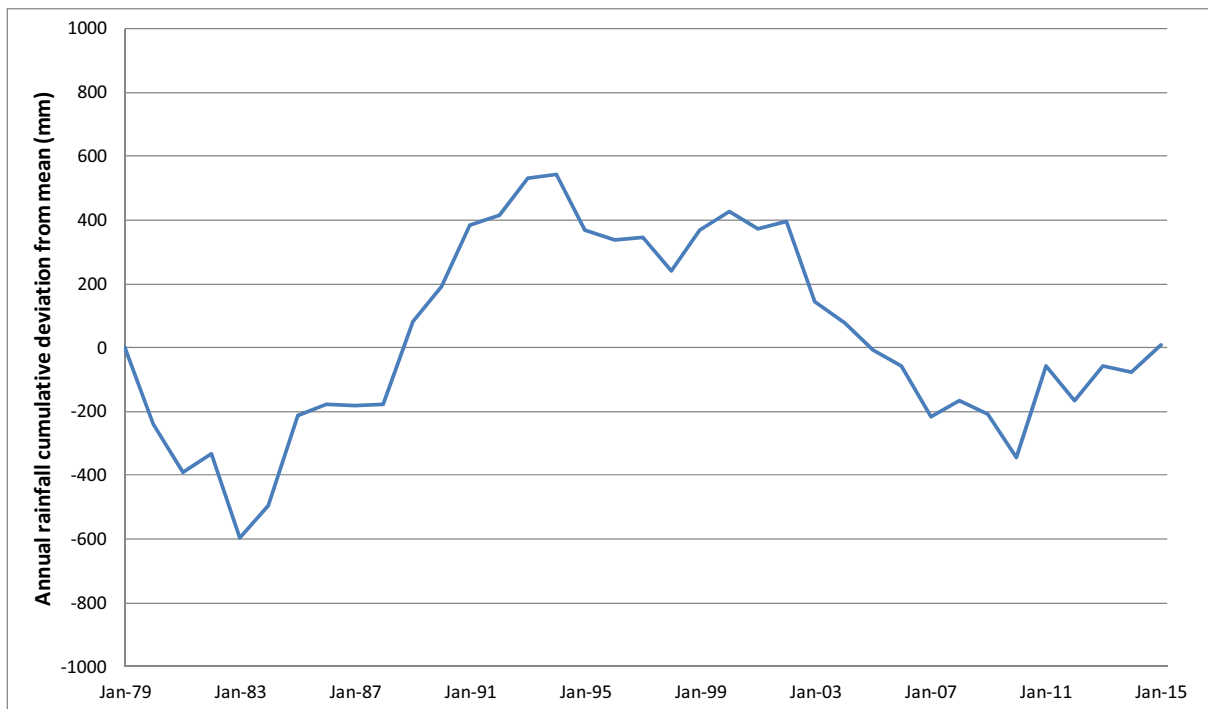
The Goulburn TAFE station reports a mean monthly maximum temperature of 28°C in January and a mean monthly minimum temperature of 2°C in July.

The mean annual evaporation of 1,643 mm/year exceeds rainfall for all months of the year, with an annual moisture deficit of over 1,015 mm (Goulburn TAFE Station, 070263).

Rainfall data was obtained from the Bureau of Meteorology Brayton (Longreach) and Goulburn TAFE weather stations. The Brayton station is 3.5 km north of the Quarry site and maintains an intermittent rainfall record from 1959 to present. The Goulburn TAFE station is 25 km west south-west of the Quarry site and maintains a constant rainfall record from 1971 until present.

The annual mean rainfall is 670 mm for Brayton and 628 mm for Goulburn TAFE. Monthly mean rainfall is low at both stations (55 mm/month) and has a low degree of variability over the year. At Brayton station January has the highest mean rainfall (71 mm) and July has the lowest mean rainfall (38 mm).

Cumulative deviation of rainfall from the mean is (shown in Figure 4.1) using the Goulburn TAFE Station data. The Goulburn TAFE Station has the most complete rainfall dataset, allowing cumulative deviation to be determined. The long-term cumulative deviation of rainfall from the mean represents discrete rainfall events as a continual trend over time. Periods of below average rainfall are plotted as downward trending slopes while periods of above average rainfall are upward trending slopes. Below average rainfall conditions were observed between 1993 and 2009, with above average conditions for the ten year period between 1993 and 2009. Since mid 2009 above average rainfall conditions have been observed.



Data source: Bureau of Meteorology, Goulburn TAFE weather station (site number: 070263).

Figure 4.1 Annual rainfall cumulative deviation from the mean

4.4 Surface water

There are two surface water resources in the immediate vicinity of the extension project, Chapmans Creek and Jaorimin Creek (Figure 4.2).

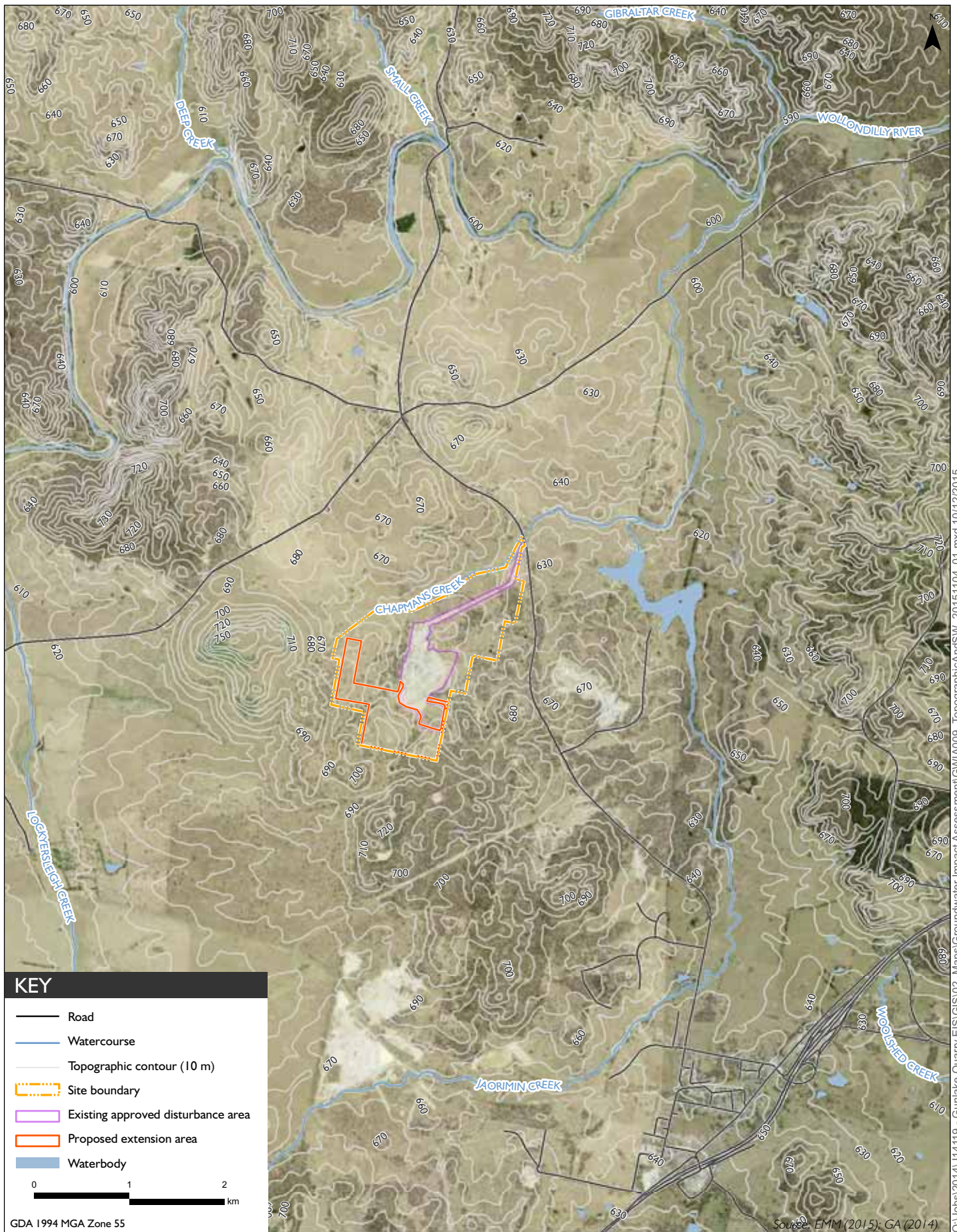
Chapmans Creek and Jaorimin Creek are ephemeral watercourses that flow during and immediately following large rainfall events. Chapmans Creek flows north-east alongside the western boundary of the extension project and discharges to Jaorimin Creek. Jaorimin Creek is located to the east of the extension project and flows to the north.

Runoff from Chapmans Creek and Jaorimin Creek eventually discharges to the Wollondilly River. The Wollondilly River is a major perennial river in the region and forms part of the Warragamba Dam catchment area.

4.5 Geology

The extension project is located within the Palaeozoic Lachlan Fold Belt. The Lachlan Fold Belt is a Palaeozoic litho-tectonic assemblage which extends over much of central southern NSW.

The extension project will intercept the Bindook Porphyry Complex, a sequence of folded and deformed Devonian volcanics. The Bindook Porphyry Complex incorporates a series of volcanic members that dip steeply with a series of anticline and syncline structures. The broad orientation of this sequence is north north-west (Cook 2008).



Topography and surface water features

Gunlake Quarry
Groundwater Assessment

Figure 4.2



The Bindook Porphyry Complex is segregated into geological units (Figure 4.3). The extension project will extract the Barralier Ignimbrite and Joaramin Ignimbrite. The Joaramin Ignimbrite is observed in the south-east of the Quarry site, while the Barralier Ignimbrite is more widespread (Cook 2008).

Ignimbrites are poorly sorted, pyroclastic rocks comprised of pumice and ash. The Barralier Ignimbrite is a blue-grey, welded ignimbrite with fractured phenocrysts of quartz, plagioclase, hornblend, enstatite and minor biotite. The groundmass is fine-grained, aphanitic recrystallised quartz-feldspar. The Joaramin Ignimbrite is a densely welded, crystal-rich ignimbrite of rhyolitic composition. The Joaramin Ignimbrite is more acidic than the Barralier Ignimbrite due to a greater composition of potassium feldspar.

4.5.1 Structural geology

The rocks in the area have been subjected to several phases of progressive deformation (including folding, faulting and thrusting). Such tectonic upheavals have resulted in the imposition of structural discontinuities that dissect the rock masses and potentially create fluid pathways and conduits, or barriers to flow.

An extensive network of faults exists within the north north-east trending early Devonian sequence. The major Towrang and Yarralaw Faults, and some unnamed faults run north north-east to the west of the extension project (Figure 4.3).

Cook (2008) speculates that the most recent tectonic activity in the area has been largely compressive, causing a closure of the fractures. Surface traces of pervasive sub-vertical structural discontinuities are likely represented as creek lines. This is expected to be the case for the linear segments of Chapmans Creek and Wollondilly River.

4.6 Hydrogeology

There are two groundwater sources of relevance to the extension project. An alluvial system associated with Chapmans Creek and a fractured rock system within the Bindook Porphyry Complex.

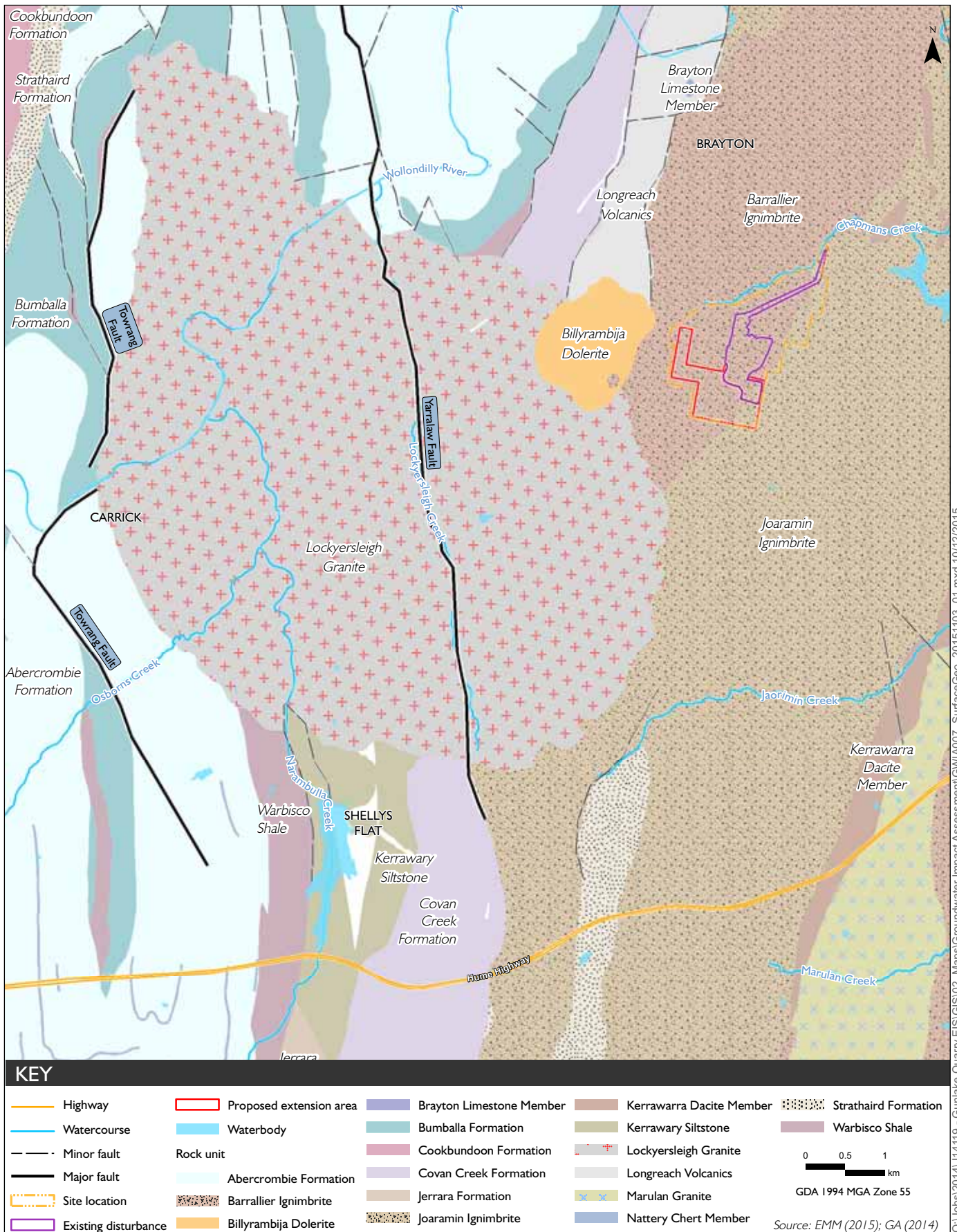
4.6.1 Alluvial deposits

The poorly developed alluvial deposits along the alignment of Chapmans Creek and Joaramin Creek (and associated drainage channels) host an unconfined, perched water source. The alluvial deposits are typically less than 5 m thick with low storage (Dundon 2005). Groundwater residence time is low with rapid recharge and discharge following rainfall. The groundwater flow direction is consistent with the overlying surface water drainage features. The extent of the alluvium associated with Chapmans Creek is confined to a narrow band along the creek banks.

The alluvial sands and gravels are set within a matrix comprised of fine particles (clay and silt) and have a low permeability. Given the low permeability and limited extent (and therefore storage capacity), the alluvial aquifers are considered to be a marginal water source for extractive water supply. No registered groundwater users access this alluvial water source.

4.6.2 Fractured rock water bearing zone

The porphyry rock mass hosts a fractured rock groundwater source with marginal extraction value (ie high electrical conductivity (EC) and low yield).



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Surface geology and faults
Gunlake Quarry
Groundwater Assessment



Figure 4.3

Regional groundwater flow is towards the north-east, with eventual discharge to the Wollondilly River. On a local scale, the groundwater flows north-east, following a muted reflection of topography. Groundwater flow may also follow structural discontinuities in the rock mass, as shown by spring discharges.

Dundon (2010) notes there is a weathering profile within the uppermost 10 m of the porphyry rock mass. The weathered zone has a marginally higher permeability than the underlying unweathered rock. The underlying, unweathered porphyry has very low primary permeability and low secondary permeability (ie the permeability associated with structural discontinuities). Secondary permeability is not anticipated to increase the overall rock mass groundwater flow given the compressive nature of tectonic activity that has resulted in minor and poorly connected fractures (see Section 4.5.1).

4.6.3 Groundwater recharge

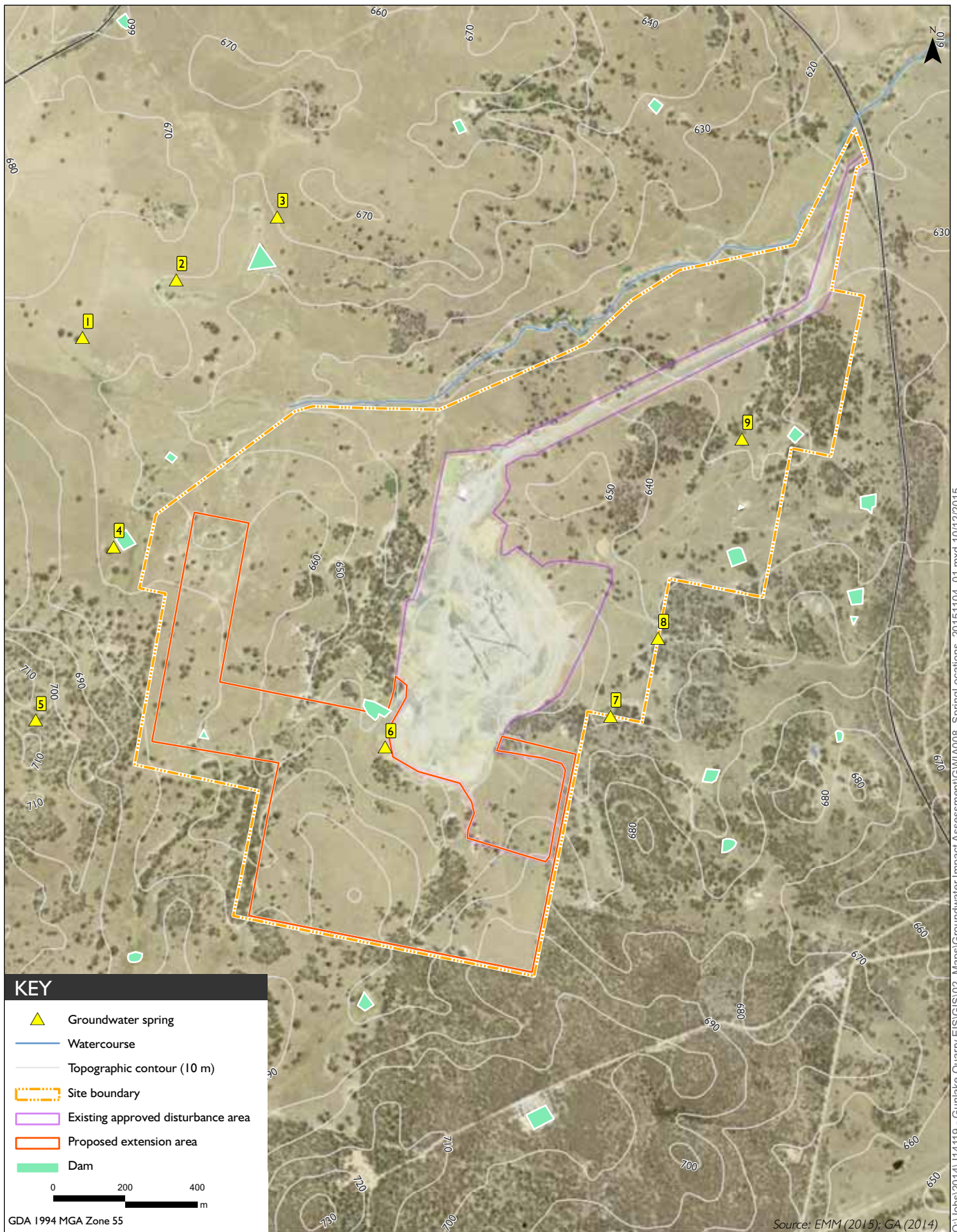
The groundwater systems are recharged via the infiltration of rainfall and overlying surface water sources where alluvium is located. Recharge rates to alluvium and low lying areas are expected to be higher than the fractured rock mass. This is because alluvium has a relatively high permeability and low lying areas receive more inundation with surface water flow.

4.6.4 Springs

Nine springs have been identified within a 1.5 km radius of the centre of the extension project (Figure 4.4). The springs are associated with sub-vertical geological discontinuities which allow discrete groundwater discharge (fracture springs).

Cook (2008) made the following comments on the nature of the springs:

- Springs 1, 2, 3 and 4 are at elevations between 660 and 665 m AHD. These springs appear to be controlled by sub-vertical discontinuities (such as a major joint or fracture or a network of closely spaced sub-parallel joints or fractures).
- Spring 5 is 20 m higher in elevation (685 m AHD);
- Spring 6 (655 m AHD), is close to the originally approved quarry. Spring 6 is structurally controlled predominantly via a sub-vertical discontinuity oriented north north-west, parallel to the western extremity of the approved pit footprint. Spring 6 is broadly associated with a small farm dam, likely constructed to retain spring discharge. Cook (2008) reports the dam retained water that during the drought between 2001 and 2008. Spring 6 is dammed by an access track crossing the drainage line between the existing dam and the spring location, causing secondary damming (pers comm. International Environmental Consultants 2015).
- Springs 7, 8 and 9 are at elevations between 640 and 650 m AHD. These springs appear to be controlled by a north north-east trending linear and continuous sub-vertical fracture. During field investigations in 2015, Spring 7 was difficult to locate and was considered to be in a general drainage depression that would also capture surface runoff.



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Spring locations

Gunlake Quarry
Groundwater Assessment

Figure 4.4



4.7 Surface water and groundwater connectivity

The local surface water features in the vicinity of the project area are ephemeral and do not receive large contributions from groundwater. The Wollondilly River to the north of the project area may receive some baseflow contributions from groundwater.

Groundwater fed springs are associated with sub-vertical geological discontinuities in the area providing (Figure 4.4).

4.8 Surrounding quarries

Holcim (Australia) Pty Ltd (Holcim) own and operate two quarrying operations (Johnniefields and Lynwood) in the vicinity of the Gunlake extension project.

Johnniefields Quarry is approximately 1 km east of the Gunlake Quarry extension project. Holcim have announced that Johnniefields Quarry will be decommissioned once Lynwood Quarry is fully operational.

Lynwood Quarry has development consent (DA 128-5-205) to extract a hard rock quarry resource to a depth of 570 m AHD (Approved Pit). The approved pit is located approximately 1.5 km south of the Gunlake site boundary. Groundwater inflows to the approved pit are predicted to peak at 26.6 ML/year (Dundon 2005).

Holcim are seeking a modification to DA 128-5-205 to include an additional extraction area (Granite Pit) and reduce the extent of the approved pit. The proposed Granite Pit is located approximately 700 m south-west of the Gunlake site boundary. Groundwater inflows to the Granite Pit are predicted to peak at 14.1 ML/year with a peak of 1.2 ML/year predicted the reduced Approved Pit (Scientific Systems 2015).

5 Field investigation program

5.1 Groundwater monitoring network

A groundwater monitoring network was installed at the Quarry site in April 2007 (Cook 2008). The monitoring network comprises four standpipe piezometers (monitoring bores) installed into the Bindook Porphyry.

Figure 5.1 presents the location of the groundwater monitoring network and Table 5.1 provides construction details.

Table 5.1 Groundwater monitoring network

| Bore ID | Coordinates MGA grid | | Depth (m BGL) | Surface elevation (m AHD) | TOC elevation (m AHD) |
|---------|----------------------|--------------|---------------|---------------------------|-----------------------|
| | Easting (m) | Northing (m) | | | |
| GM6 | 771916 | 6159367 | 25.9 | 657.4 | 657.9 |
| GM13 | 771816 | 6159042 | 22.4 | 665.2 | 665.7 |
| GM24 | 771676 | 6158934 | 21.0 | 659.9 | 660.4 |
| GM36 | 771920 | 6158843 | 17.1 | 666.0 | 667.2 |

Notes: TOC: top of casing.

m BGL = metres below ground level.

m AHD: metres Australian Height Datum.

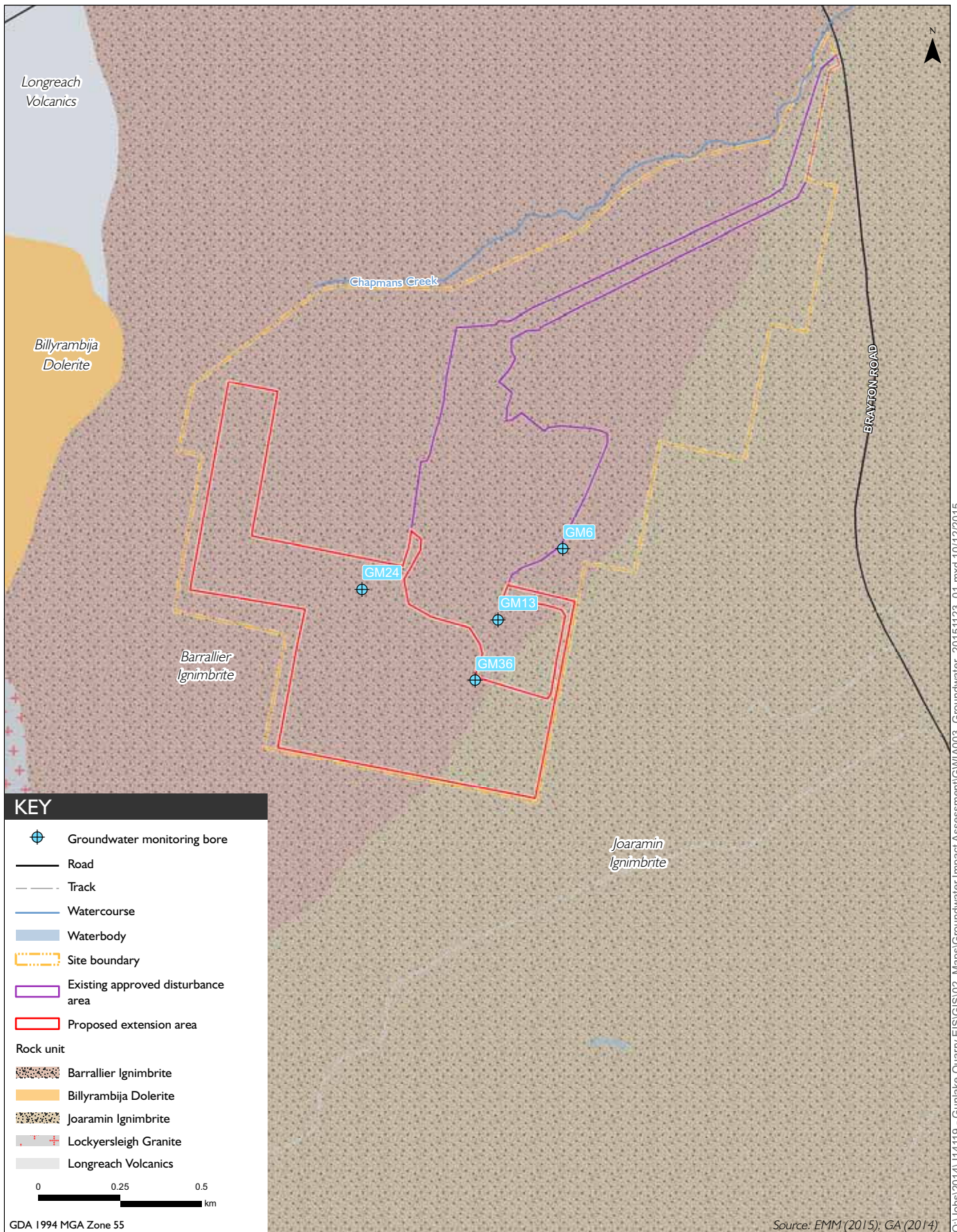
The monitoring bores were constructed by installing 50 mm uPVC casing into old exploration holes, a 3 m screened interval was installed at the base of each monitoring bore to enable targeted monitoring of the Porphyry fractured rock.

Groundwater monitoring has been completed at Gunlake since 2007. Monitoring comprises quarterly measurements of water level and water quality indicators (pH, EC and temperature) at the four monitoring bores (GM6, GM13, GM24 and GM36).

5.2 Groundwater levels

Comprehensive groundwater level monitoring data are available across the site monitoring network from May 2007 to July 2015. Groundwater levels in the vicinity of the site range from 634.9 to 659.5 m AHD (or 6.3–22.5 m BGL). Groundwater level and cumulative deviation from the mean rainfall are plotted on Figure 5.2.

The groundwater level in GM6 generally reflects rainfall; the groundwater level rises following heavy rainfall events or sustained periods of rainfall, and declines in dryer periods. The groundwater level at GM6 shows the highest degree of fluctuation, likely associated with an immediate and direct response to rainfall recharge. More gradual or muted groundwater level fluctuations are observed in the remaining bores (GM13, GM24 and GM36).



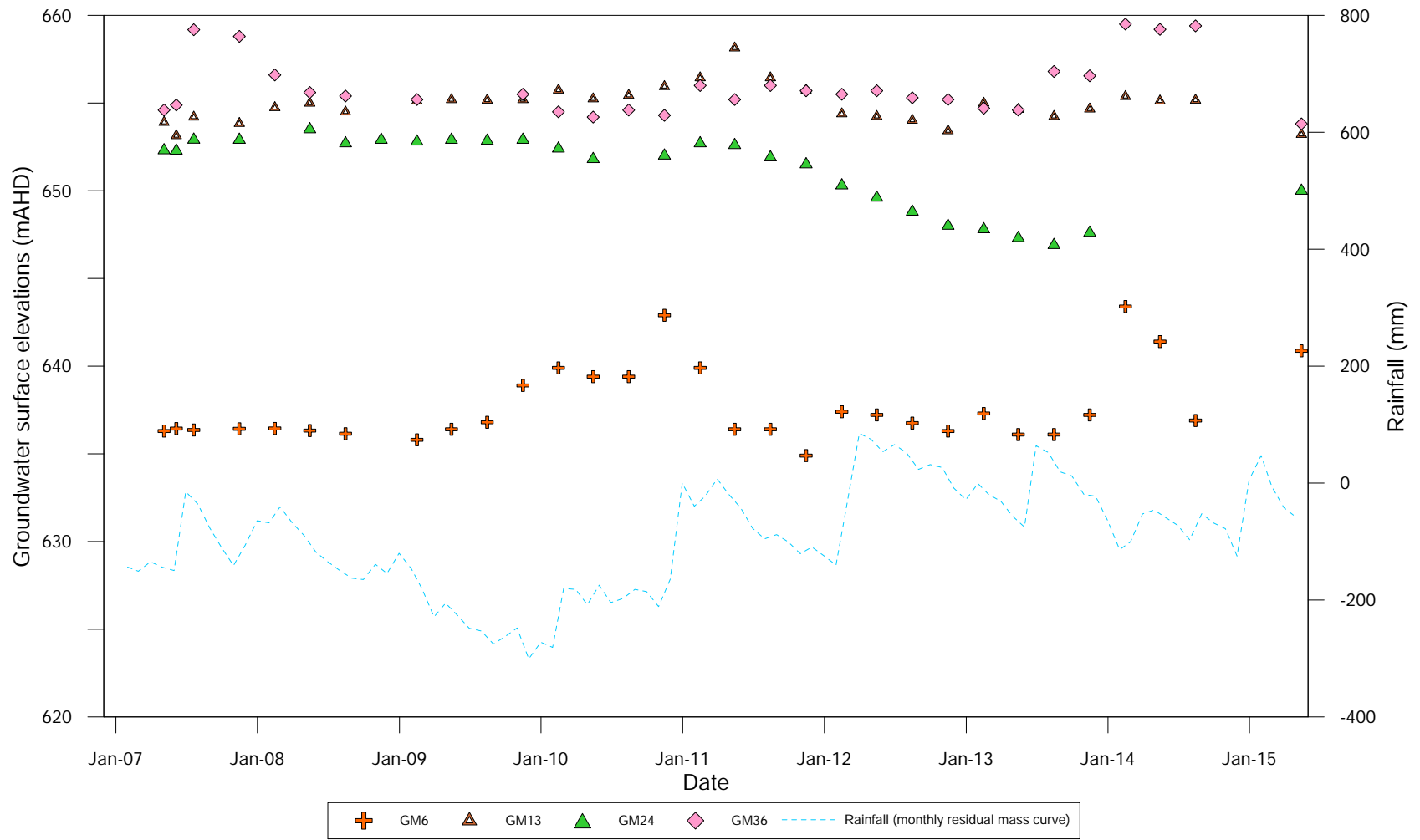
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Source: EMM (2015); GA (2014)

Groundwater monitoring network
 Gunlake Quarry
 Groundwater Assessment

Figure 5.1





Groundwater surface elevation
 Gunlake Project
 Groundwater Assessment
 Figure 5.2

Source: Bureau of Meteorology - Goulburn tafe Weather Station (station 070263)

5.3 Groundwater quality

Groundwater quality monitoring data in the project area is available for July 2007 and from December 2014 to June 2015. Groundwater quality summary tables are included in Appendix A.

Groundwater in the project area is generally of poor quality (as per the AIP total dissolved solids classification). According to the trigger values in the *Aquatic Ecosystem Protection Guideline* (ANZECC and ARMCANZ 2000) groundwater in the area is marginally suitable for stock purposes.

The groundwater quality has been assessed against the default trigger values for the water quality objectives based on the end users. The receiving water catchment area, Warragamba Dam catchment, is a drinking water catchment and therefore groundwater quality results are compared against the *Australian Drinking Water Guidelines (Drinking Water Guideline)* (NRMCC 2011) for Health and Aesthetic categories. Groundwater quality results have also been compared to the *Aquatic Ecosystem Protection Guideline* (ANZECC and ARMCANZ 2000) trigger values for the 95% protection of freshwater species, and moderately disturbed upland rivers.

5.3.1 Field results

Groundwater is generally brackish to saline (Table 5.2) and neutral to slightly alkaline (Table 5.3). Groundwater salinity levels generally exceed the ANZECC (2000) guideline trigger value.

Table 5.2 Field water quality monitoring: electrical conductivity

| Monitoring Bore | Range ($\mu\text{S/cm}$) | Average ($\mu\text{S/cm}$) |
|-----------------|----------------------------|------------------------------|
| GM6 | 119–6,590 | 984 |
| GM13 | 1,120–6,080 | 3,438 |
| GM24 | 35–3,100 | 1,647 |
| GM36 | 720–3,541 | 2,093 |

Notes: $\mu\text{S/cm}$ = microsiemens per centimetre.

Measurements recorded in July 2007, December 2014 and January, February, April, May and June 2015.

Sample size = 14 samples.

Drinking Water Guideline upper limit: 402 $\mu\text{S/cm}$ (using TDS conversion of 0.67), Aquatic Ecosystem Protection Guideline range: 30-350 $\mu\text{S/cm}$.

Table 5.3 Field water quality monitoring: pH

| Monitoring Bore | Range | Average |
|-----------------|---------|---------|
| GM6 | 5.8–9.0 | 6.7 |
| GM13 | 6.8–7.9 | 7.4 |
| GM24 | 5.4–8.0 | 7.0 |
| GM36 | 6.6–8.2 | 7.1 |

Notes: Measurements recorded in July 2007, December 2014 and January, February, April, May and June 2015.

Sample size = 14 samples.

Drinking Water Guideline range: 6.5–8.5 and Aquatic Ecosystem Protection Guideline range: 6.5-7.5.

Overall, EC conditions range from fresh to slightly saline with no distinct trends. The pH has remained relatively neutral at GM6 with the notable exception of pH 9 recorded in May 2015. It is likely that the bore construction or sampling technique for GM6 is compromised and such fluctuations in results are not indicative of regional water quality trends.

i Laboratory results water type

The hydrogeochemistry of the porphyry groundwater has been evaluated by plotting a trilinear (Piper) diagram (Figure 5.3). The ion proportions in the groundwater samples are distributed across the diamond field suggests the chemical composition of the groundwater evolves as it moves through the porphyry rock mass. Carbonate is the dominant anion in the groundwater composition and there is no dominant cation.

The Piper diagram suggests that the groundwater chemistry at Gunlake has a composition typical of a mixed groundwater resource, where rainfall is introduced to the system.

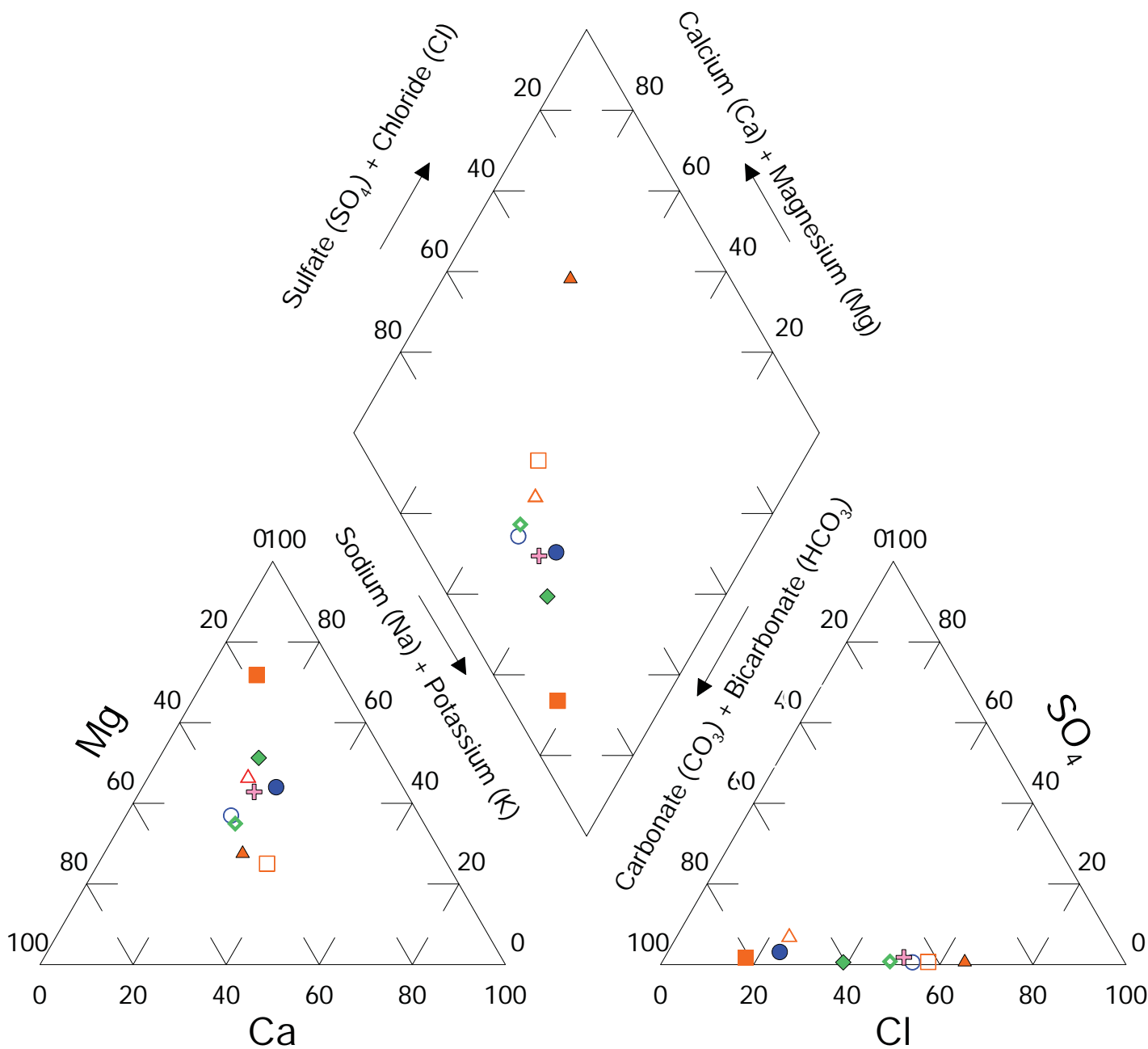
ii Dissolved metals

Groundwater concentrations of dissolved arsenic, cadmium, chromium, lead and nickel were greater than the *Drinking Water Guideline* values. Concentrations of nickel and zinc were also greater than the *Aquatic Ecosystem Protection Guideline* default trigger values. Elevated concentrations of dissolved metals are not attributable to quarry activities.

iii Nutrients

Groundwater ammonia, nitrite, nitrate and phosphorous concentrations were greater than *Aquatic Ecosystem Protection Guideline* values.

The nitrate concentration was generally greater than the *Aquatic Ecosystem Protection Guideline* trigger value (0.015 mg/L) but below the *Drinking Water Guideline* value of 50 mg/L. A maximum nitrate concentration of 4.19 mg/L was measured at GM6 in May 2015. Nutrient concentrations can be attributed to anthropogenic land use practices within the groundwater catchment (eg farming).



- | | | | | | |
|---|-----------|---|-----------|---|-------------|
| ▲ | GM6 2007 | ○ | GM13 2015 | + | In-pit sump |
| △ | GM6 2015 | ◆ | GM24 2007 | ■ | GM36 2007 |
| ● | GM13 2007 | ◇ | GM24 2015 | □ | GM36 2015 |



Trilinear (Piper) plot
 Gunlake Project
 Groundwater Assessment
 Figure 5.3

5.4 Hydraulic testing

Rising and falling head tests (slug tests) were completed in June 2007 at eight shallow exploration boreholes at Gunlake Quarry. Cook (2008) completed an assessment of the collected data using analytical solutions developed by Hvorslev (1951) and Bower and Rice (1976) to derive estimates of the physical properties of the fractured rock groundwater source (Table 5.4).

Table 5.4 Hydraulic testing results

| Borehole | Hvorslev solution | | | Bower & Rice solution | | |
|----------|-------------------|-------------------------|--------------------|-----------------------|-------------------------|--------------------|
| | K (m/day) | T (m ² /day) | S | K (m/day) | T (m ² /day) | S |
| GM5 | 0.78 | 5.06 | 5x10 ⁻⁴ | 0.53 | 3.44 | 5x10 ⁻⁴ |
| GM11 | 0.03 | 0.33 | 1x10 ⁻⁴ | 0.02 | 0.23 | 1x10 ⁻⁴ |
| GM13 | 0.04 | 0.17 | 5x10 ⁻⁴ | 0.03 | 0.11 | 1x10 ⁻⁴ |
| GM21 | 0.03 | 0.29 | 1x10 ⁻⁴ | 0.02 | 0.20 | 5x10 ⁻⁴ |
| GM22 | 0.77 | 2.82 | 5x10 ⁻⁴ | 0.42 | 1.53 | 5x10 ⁻⁴ |
| GM24 | 0.04 | 0.61 | 1x10 ⁻⁴ | 0.03 | 0.44 | 1x10 ⁻⁴ |
| GM35 | 0.02 | 0.28 | 1x10 ⁻⁴ | 0.01 | 0.21 | 1x10 ⁻⁴ |
| GM36 | 0.02 | 0.13 | 1x10 ⁻⁴ | 0.01 | 0.09 | 1x10 ⁻⁴ |

Notes: 1. Information provided by Cook et al (2008).

2. K = hydraulic conductivity, T = transmissivity, S = storativity (dimensionless).

Results from the slug tests indicate the weathered Bindook Porphyry has a low permeability with the derived hydraulic conductivity ranging from 0.01 to 0.78 m/day. This range is consistent with results from hydraulic testing at the nearby Lynwood Quarry reporting a range of 0.005 to 0.38 m/day (Dundon 2005). The groundwater salinity is also suggestive of a low flow system, such that groundwater residence times are sufficient enough to result in brackish to slightly saline conditions down hydraulic gradient.

6 Groundwater users

6.1 Registered groundwater works

A search of the PINNEENA database (version 10.1) undertaken in June 2015 that identified 15 groundwater works within a 5 km radius of the Quarry site (DPI Water 2014). Monitoring and private landholder bore details are tabulated in Table 6.1 with the location of the works presented in Figure 6.1.

Five local groundwater works are registered for private use (stock or domestic/stock purposes) (Table 6.1). GW056376 is the closest private groundwater work to the extension project, approximately 1.2 km east of the site boundary. Nine of the identified groundwater works are groundwater monitoring bores owned by the Holcim Lynwood Quarry.

The database contains varying levels of bore construction and formation information as this depends on the level information provided by drillers on the Form A.

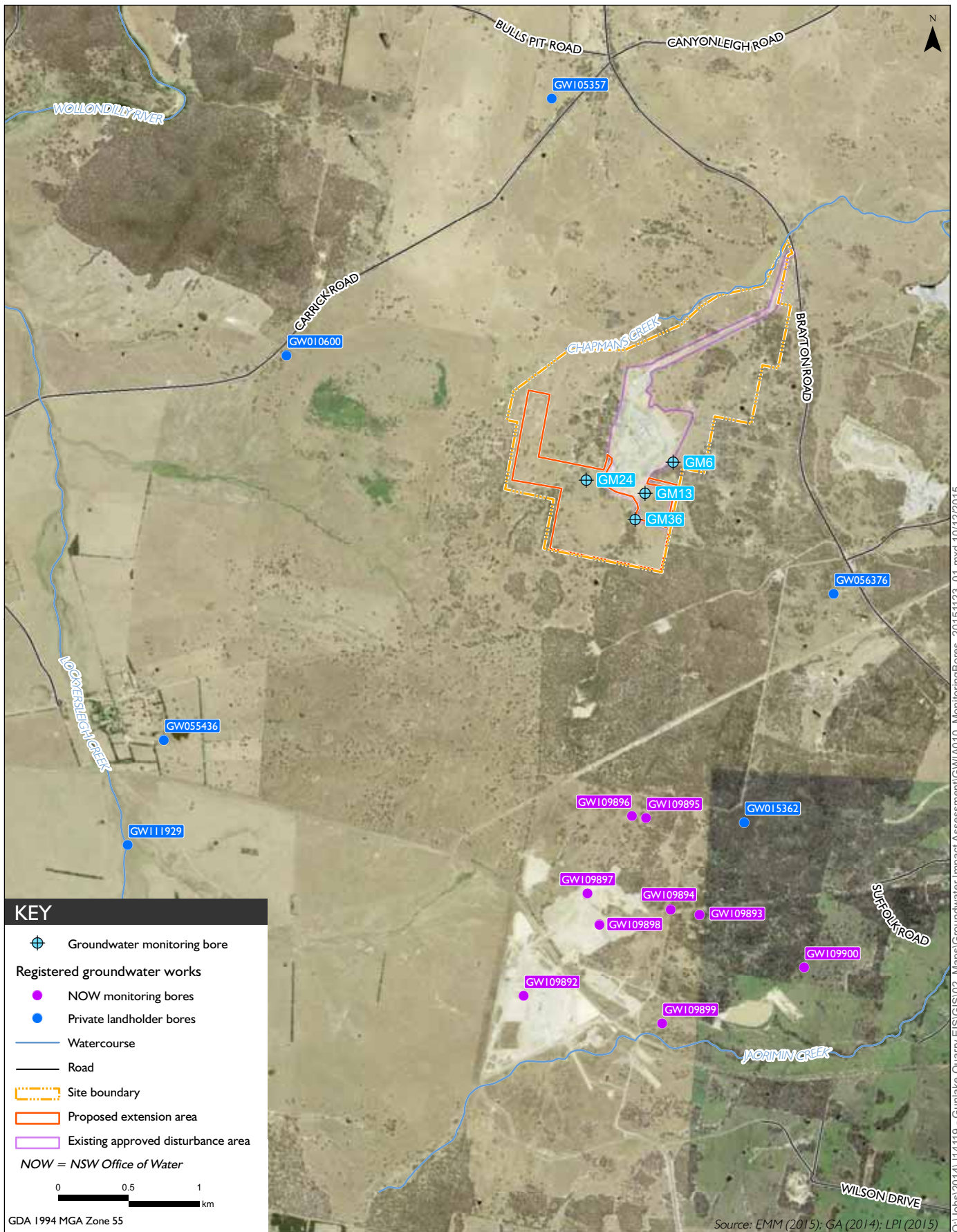
Table 6.1 Registered groundwater works

| Bore ID | Industry | Date drilled | Purpose | Depth (m) | Water level (m BGS) | Monitored formation |
|----------|------------|--------------|----------------|-----------|---------------------|---------------------|
| GW015362 | private | 1957 | stock | 52.7 | NA | Clay |
| GW056376 | private | 1982 | stock | 51 | 12 | Volcanics |
| GW105357 | private | 2002 | domestic/stock | 60 | NA | Volcanics |
| GW010600 | private | 1953 | stock | 91.4 | NA | Sand |
| GW055436 | private | 1981 | domestic/stock | 76.2 | 4.6 | Volcanics |
| GW109892 | extractive | 2004 | monitoring | 40 | 5.4 | Fractured porphyry |
| GW109893 | extractive | 2004 | monitoring | 33 | 18.4 | Fractured porphyry |
| GW109894 | extractive | 2004 | monitoring | 126 | 28.9 | Fractured porphyry |
| GW109895 | extractive | 2004 | monitoring | 110 | 16.0 | Fractured porphyry |
| GW109896 | extractive | 2004 | monitoring | 40 | 7.6 | Fractured porphyry |
| GW109897 | extractive | 2009 | monitoring | 40 | 9.2 | Fractured porphyry |
| GW109898 | extractive | 2004 | monitoring | 102 | 23.5 | Fractured porphyry |
| GW109899 | extractive | 2004 | monitoring | 40 | 6.2 | Fractured porphyry |
| GW109900 | extractive | 2004 | monitoring | 40 | 26.4 | Fractured porphyry |

Notes: m BGS = meters below ground surface NA = not available.

All water levels are from July 2014 with the exception of GW056376, GW055436 and GW111929 which were recorded during drilling.

Data source = DPI Water PINNEENA database version 10.2 and Peter Dundon & Associates (2005).



Groundwater users
 Gunlake Quarry
 Groundwater Assessment

Figure 6.1

6.2 Groundwater dependent ecosystems

There are no high priority groundwater dependent ecosystems (GDEs) listed in the Greater Metropolitan Region Groundwater WSP, for the Goulburn Fractured Groundwater Source. A search of the National Atlas of Groundwater Dependent Ecosystems (BoM 2015) identified four creeks within the vicinity of the extension project with the potential for groundwater interaction: Chapmans Creek, Jaorimin River, Lockyersleigh River and Wollondilly River.

The ecological study of the project area identified the Box Gum Woodland as an ecosystem potentially reliant on the subsurface presence of shallow groundwater (EMM 2015). This Woodland community is also identified in the Atlas of Groundwater Dependent Ecosystems (BoM 2015).

There are nine springs identified in the vicinity of the project area (see Section 4.6.4). The ecological study did not identify any GDEs associated with surface expression of groundwater at these springs (EMM 2015). The springs are considered to be of low environmental value with no identified users.

6.3 Lynwood and Johnniefields Quarry

Holcim's Lynwood and Johnniefields operations are groundwater user in the local area. Groundwater is accessed via inflows to the pit and used onsite for operational activities.

The Johnniefields operation is concluding operations in the near future and will not require ongoing groundwater supply. A maximum groundwater inflow rate of 14.1 ML/year is predicted at the Lynwood operation (Scientific Systems 2015).

7 Groundwater modelling

7.1 Analytical approach

An analytic element groundwater flow model was used to predict the potential groundwater impacts from the extension project. The model was developed in accordance with the Australian groundwater modelling guidelines and satisfies the requirements for a class 1 flow model (SKM & NCGRT 2012).

An analytical approach is considered appropriate for the extension project given the:

- low hydraulic conductivities of the intercepted and surrounding strata (see Section 5.4);
- low numbers of sensitive groundwater receptors in the project area (see Section 6); and
- hydrogeological data available in the project area is considered insufficient to support the preparation of a class 2 numerical model.

The model was developed in AnAqSim (Fitts Geosolutions 2015). AnAqSim is a sophisticated software package capable of superimposing multiple analytical calculations (flow calculations) to derive solutions as a function of location and time. The analytical model writes equations in two-dimensions and allows the representation of three-dimensional flow by using multiple, planar layers.

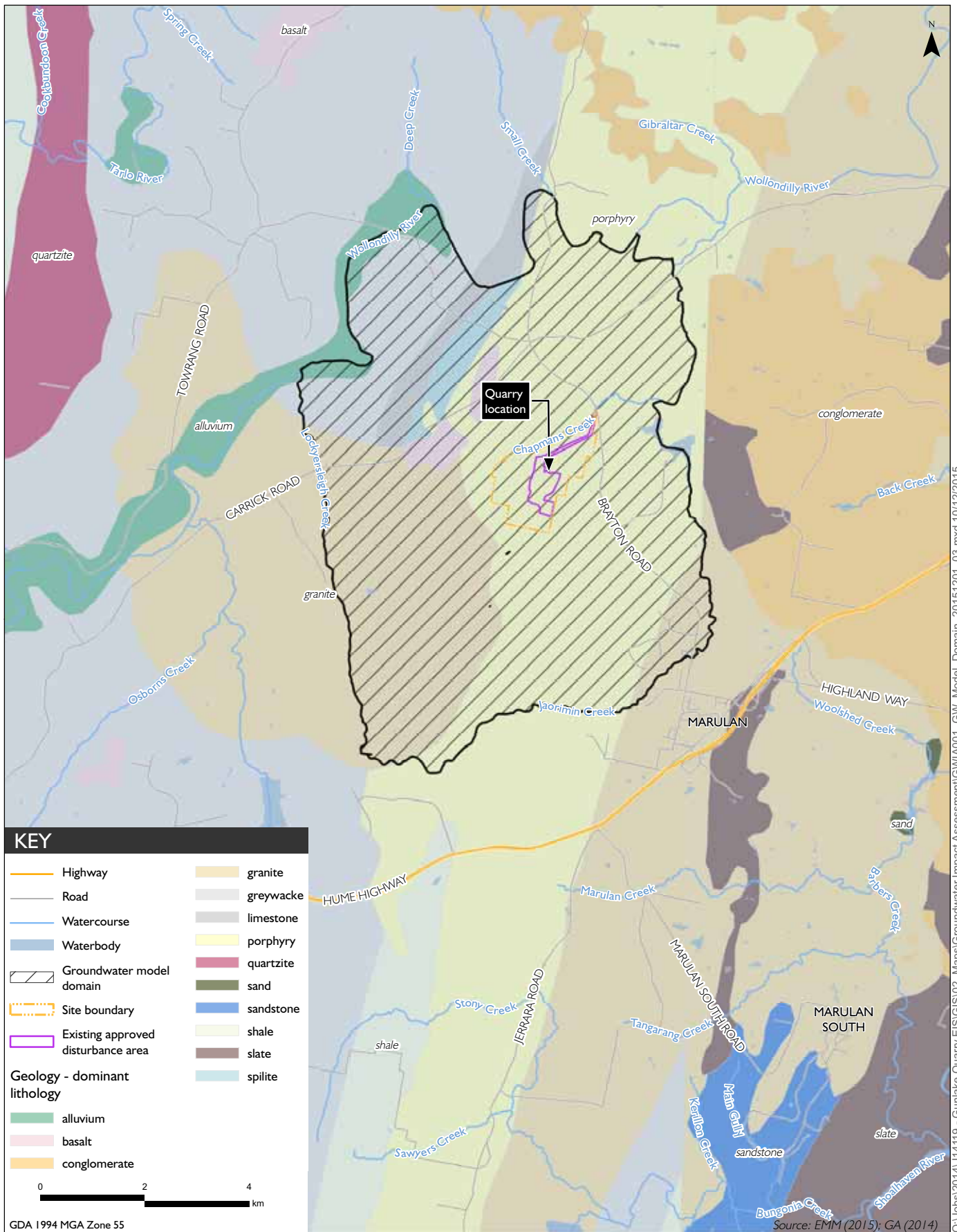
7.2 Model setup

7.2.1 Model domain and boundary conditions

The model domain encompasses a surface area of 6,190 ha (Figure 7.1). The model domain is constrained by surface watercourses represented in the model as head-specified boundaries:

- Lockyersleigh Creek defines the western boundary with a head distribution of 645 to 580 m AHD;
- Jaorimin Creek defines the southern and eastern boundary with a head distribution of 670 to 590 m AHD; and
- Wollondilly River defines the northern boundary with a head distribution of 600 to 590 m AHD.

The head-specified model boundaries maintain a constant head to represent an inferred groundwater table within the underlying hard rock strata. The depth of the groundwater table in the hard rock was interpreted using available surface topography, water levels and surface water flow regimes.



Groundwater model domain
 Gunlake Quarry
 Groundwater Assessment

Figure 7.1



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7.2.2 Model geometry

The model domain is divided into six sub-units and three layers providing a simplified representation of the geological complexities at the extension project. The model has three layers in the project area allowing three-dimensional flow and facilitating the calculation of pressure head losses within the surrounding strata.

Layer 1 includes Chapmans Creek, alluvial deposits, weathered Bindook Porphyry, Lockyersleigh Adamellite (granite) and the Billyrambija Dolerite (Table 7.1). Layer 2 includes weathered and unweathered Bindook Porphyry and layer 3 includes unweathered Bindook Porphyry.

Flow at Chapmans Creek is simulated in the model using the stream function. Chapmans Creeks flows from an elevation of 650 m AHD in the west to 600 m AHD in the east where it discharges to Jaorimin Creek. The creek was allowed to run dry to simulate its ephemeral properties.

7.2.3 Model hydraulic properties

Hydraulic properties assigned to the model are based on the results from monitoring and hydraulic testing at the extension project (see Section 5) and groundwater studies completed in the area (Dundon 2005, Cook 2008 and Scientific Systems 2015). Minor adjustments to the hydraulic properties were made during calibration of the steady state model (see Section 7.4.1).

The Bindook Porphyry is represented in all three layers and assigned hydraulic conductivities to represent the influence of the weathering profile and increased overburden pressure with depth. The hydraulic parameters assigned to each geological formation are listed in Table 7.1.

Table 7.1 Hydraulic parameters adopted in the groundwater flow model

| Model layer | Geological description | Hydraulic conductivity (m/day) | | Storativity | Specific yield |
|-------------|------------------------------|--------------------------------|----------|-------------|----------------|
| | | horizontal | vertical | | |
| 1 | Alluvium | 1.00 | 0.01 | 0.05 | 0.05 |
| 1 | Weathered Bindook Porphyry | 0.008 | 0.0001 | 0.05 | 0.03 |
| 1 | Lockyersleigh Adamellite | 0.006 | 0.0001 | 0.05 | 0.01 |
| 1 | Billyrambija Dolerite | 0.004 | 0.0001 | 0.05 | 0.01 |
| 2 | Weathered Bindook Porphyry | 0.003 | 0.0001 | 0.0001 | 0.01 |
| 2 | Unweathered Bindook Porphyry | 0.001 | 0.00001 | 0.0001 | 0.01 |
| 3 | Unweathered Bindook Porphyry | 0.0008 | 0.00001 | 0.0001 | 0.01 |

Notes: m/day = metres per day.
NA = not applicable.

A recharge rate of 0.004 to 0.008 mm/day was applied across the model domain representing 0.2% to 0.5% of the annual average rainfall (see Section 4.3). Minor variations in the recharge rates were defined during calibration of the steady state model.

Elevated recharge of 0.01 mm/day was applied to the alluvial deposits associated with Chapmans Creek representing 5% of the annual average rainfall.

7.3 Assumptions

The groundwater model is a simplified representation of a complex groundwater system. Model inputs are based on monitoring data, hydraulic testing, previous studies and a series of assumptions. The simplifications and assumptions used in this model are:

- the representation of complex geological units as homogeneous, porous medium layers;
- the exclusion of discrete structural unconformities;
- the application of instantaneous stress at the commencement of each development stage to simulate progressive quarry extraction; and
- the exclusion of nearby quarry operations (deemed outside of the zone of influence or not yet approved – see Section 8.2.6i).

The above assumptions result in a level of uncertainty in the model predictions. This uncertainty has been managed by undertaking sensitivity analyses on results and by using conservative model input parameters where the available data results in some uncertainty.

Using conservative model input parameters results in predictions of the ‘worst possible scenario’ or the upper limit of adverse impacts. Actual impacts are anticipated to be within model predictions.

7.4 Model simulations

7.4.1 Steady state modelling

A steady state model was developed to simulate groundwater levels prior to any extraction or quarrying activity at Gunlake Quarry as derived from steady state modelling (Figure 7.1).

The steady state model was calibrated to groundwater levels measured at Gunlake Quarry monitoring network in July 2007 (Table 5.1) and at registered groundwater works with a recorded water level.

7.4.2 Transient modelling

A series of four transient model runs were completed to simulate the staged expansion of the extension project (see Table 2.1). Progressive model runs incorporate an expanded pit allowing the simulation of a transient stress on the groundwater system. The initial heads of each progressive model run is equal to the predicted heads at the end of the previous run.

Figure 7.3 presents the groundwater drawdown contours at the end of each development stage:

- during the first 5 years (Stage 1) excavation will occur above the groundwater table and no groundwater impacts are predicted;
- during Years 5 to 10 (Stage 2) the groundwater table will be intercepted and the 2 m drawdown contour is predicted to extend up to 300 m from the edge of the pit footprint;
- during Years 10 to 20 (Stage 3) the 2 m drawdown contour is predicted to extend up to 1 km from the edge of the pit footprint; and

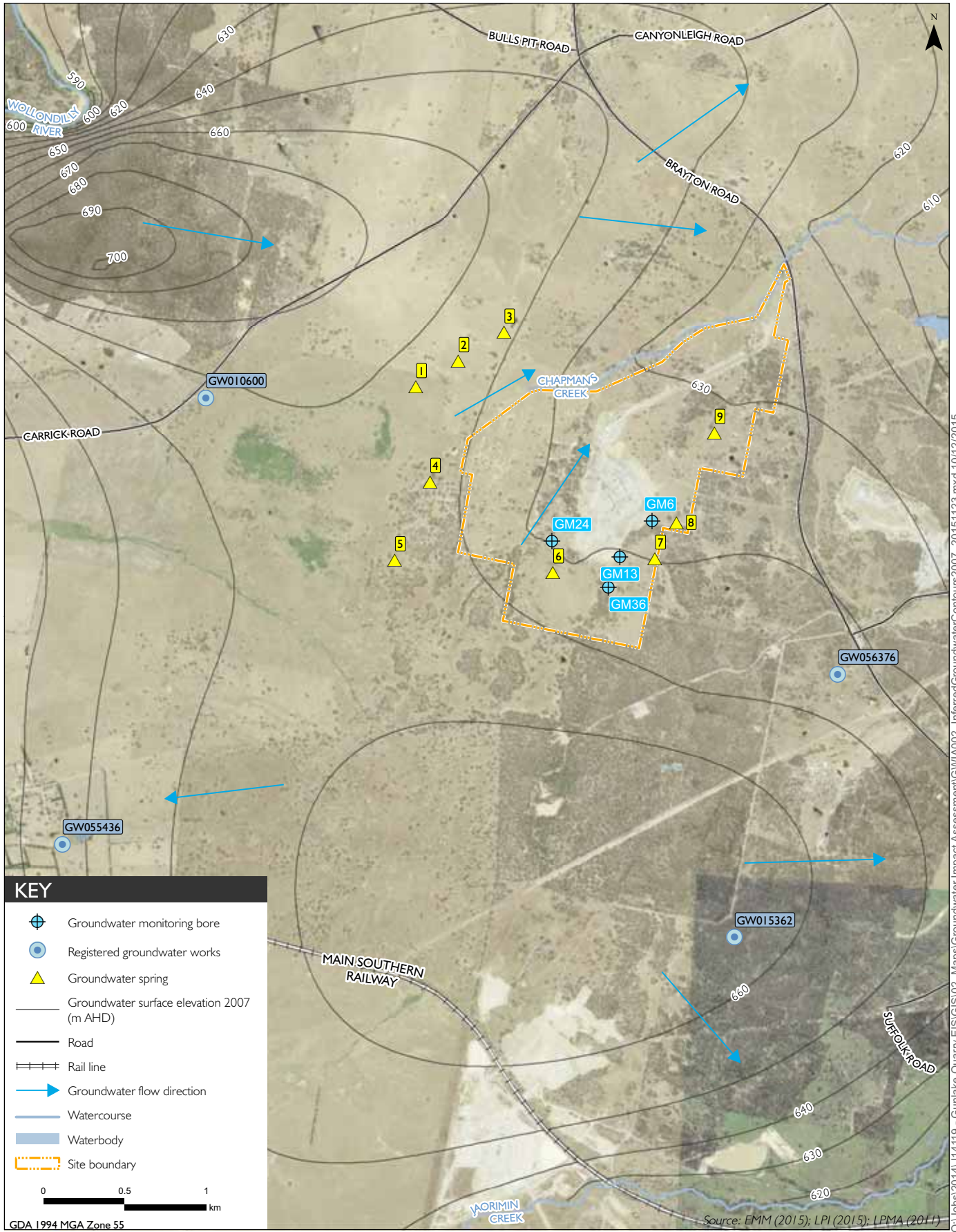
- during Years 20 to 30 (Stage 4) the 2 m drawdown contour is predicted to extend up to 1.5 km from the edge of the pit footprint.

A maximum drawdown of 78 m is predicted in the south-western corner of the pit during Years 20 to 30 of the extension project. A drawdown of 2 m is predicted up to 1.5 km from the edge of the pit footprint with a predicted drawdown in excess of 20 m confined to within 200 m of the edge of the pit footprint.

7.4.3 Final pit void

The recovery of groundwater level was simulated with a transient model run of 100 years. The modelled scenario assumes that the pit footprint remains as per Year 30 with the gradual formation of a pit lake to a level of 600 m AHD.

Partially recovery is predicted following the completion of the extension project (Year 30) however, a permanent cone of depression will remain around the excavated pit (Figure 7.4).



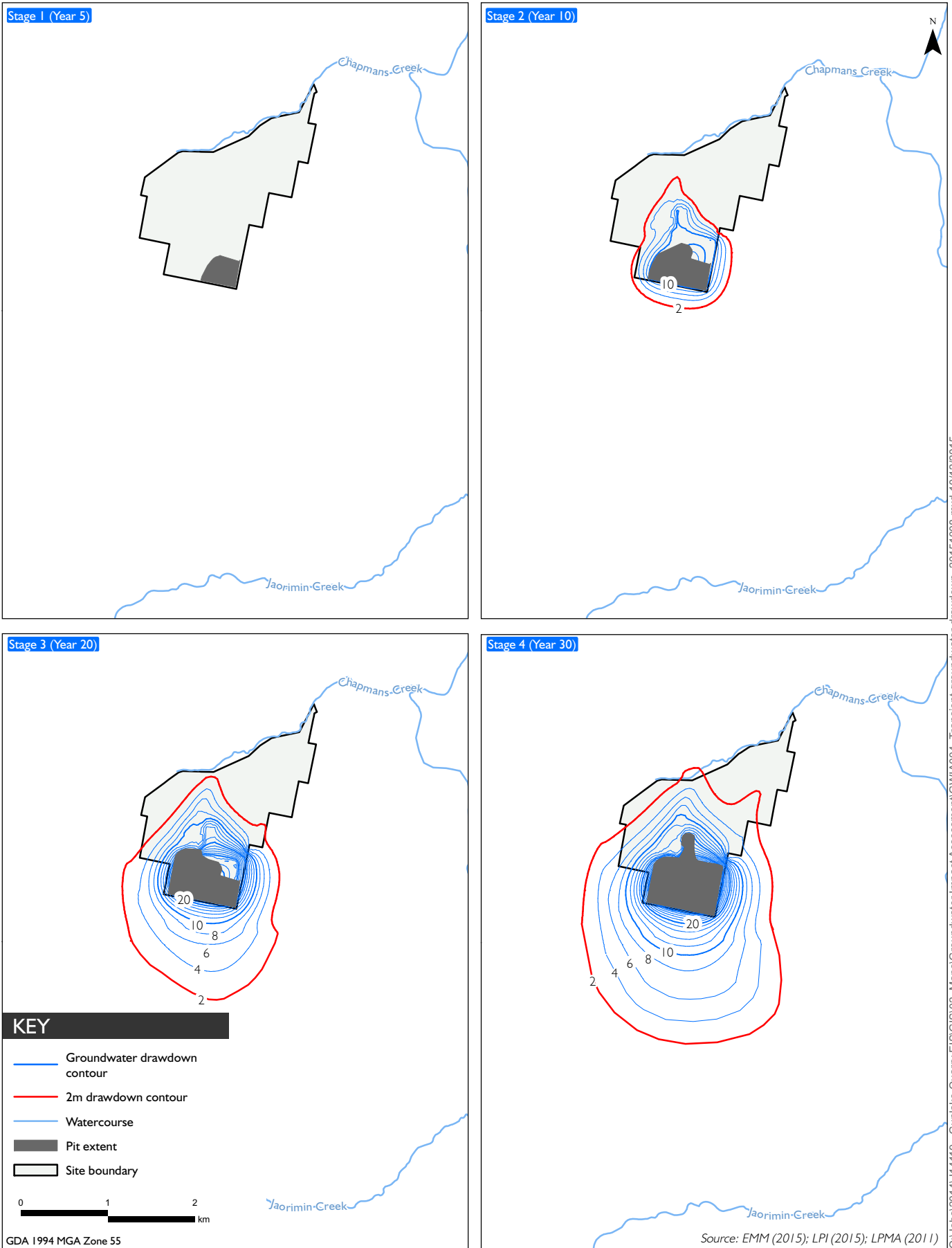
C:\Users\2014\1\14\119 - Gunlake Quarry EIS\GIS\02_Maps\Groundwater Impact Assessment\GWI\A002_InferredGroundwaterContours2007_20151123.mxd 10/12/2015

Pre-quarrying groundwater surface elevation (2007)

Gunlake Quarry
Groundwater Assessment

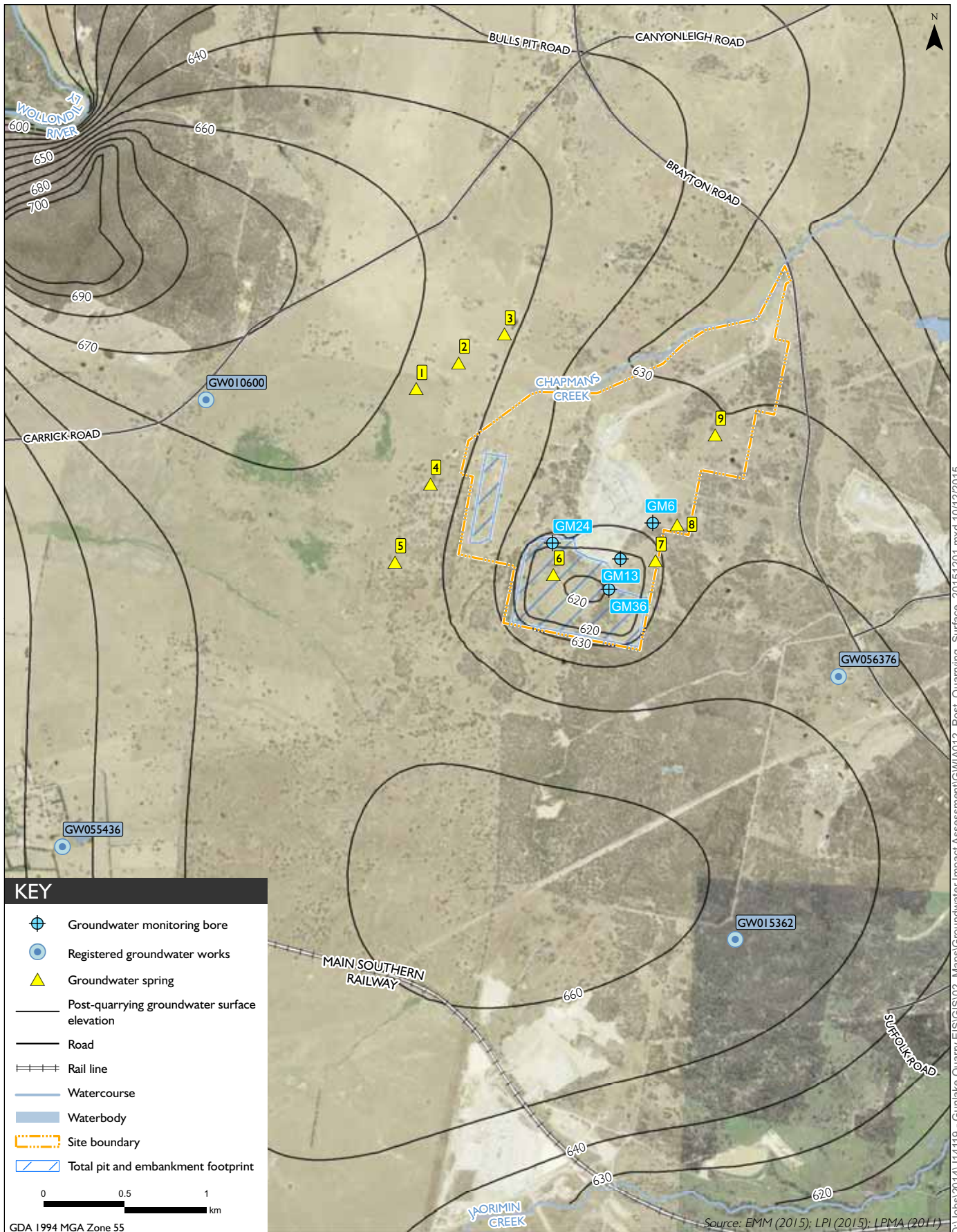
Figure 7.2





Transient groundwater drawdown
 Gunlake Quarry
 Groundwater Assessment

Figure 7.3



Post-quarrying groundwater surface elevation

Gunlake Quarry
Groundwater Assessment

Figure 7.4



8 Groundwater impact assessment

8.1 Potential impacts

The interception and dewatering of groundwater at the extension project has the potential to impact on:

- the availability of the groundwater resource;
- the groundwater level and/or pressures;
- the local and regional groundwater flow patterns; and
- the chemical composition (quality) of the groundwater resource.

The sensitive groundwater receptors considered in this groundwater assessment include springs, registered landholder bores, the Box Gum Woodland and the local watercourses (Figure 6.1).

8.2.1 Minimal impact considerations for porous and fractured rock sources

The minimal impact considerations for a groundwater impact assessment are defined within the AIP and provide the framework for assessing a proposed aquifer interference activity (NOW 2012).

Minimal impact considerations provide the basis for the assessment of impacts to the water table, water pressure and water quality. The AIP divides groundwater sources into two categories 'highly productive' and 'less productive.' The groundwater resource at Gunlake is classified as less productive with the measured yields of less than 5 L/s (see Table 6.1) and marginal water quality (see Section 5.3).

The minimal considerations for porous and fractured rock units of less productive groundwater systems are adopted for this assessment. Thresholds for key minimal impact considerations for less productive groundwater sources have been developed and deal with water table and groundwater pressure drawdown as well as groundwater and surface water quality changes (Table 8.1).

Table 8.1 Minimal impact considerations for the less productive for porous and fractured rock sources

| Water table | Water pressure | Water quality |
|---|--|---|
| <p>1. Less than or equal to 10% cumulative variation in the water table, allowing for typical climatic “post-WSP” variations, 40 m from any:</p> <p>(a) high priority GDE; or</p> <p>(b) high priority culturally significant site;</p> <p>listed in the schedule of the relevant WSP.</p> <p>A maximum of a 2 m decline cumulatively at any water supply work.</p> | <p>1. A cumulative pressure head decline of not more than a 2 m decline, at any water supply work.</p> | <p>1. Any change in the groundwater quality should not lower the beneficial use category of the groundwater source beyond 40 m from the activity.</p> |
| <p>2. If more than 10% cumulative variation in the water table, allowing for typical climatic ‘post-WSP’ variations, 40 m from any:</p> <p>(a) high priority GDE; or</p> <p>(b) high priority culturally significant site;</p> <p>listed in the schedule of the relevant WSP if appropriate studies demonstrate to the Minister’s satisfaction that the variation will not prevent the long-term viability of the dependent ecosystem, or significant site.</p> <p>If more than a 2 m decline cumulatively at any water supply work then make good provisions should apply.</p> | <p>2. If the predicted pressure head decline is greater than requirement 1 above then appropriate studies are required to demonstrate to the Minister’s satisfaction that the decline will not prevent the long-term viability of the affected water supply works unless make good provisions.</p> | <p>2. If condition 1 is not met then appropriate studies will need to demonstrate to the Minister’s satisfaction that the change in groundwater quality will not prevent the long-term viability of the dependent ecosystem, significant site or affected water supply works.</p> |

Notes: “post-WSP” – refers to the period after the commencement of the first WSP in the water source, including the highest pressure head (allowing for typical climatic variations) within the first year after commencement of the first WSP.

Source: NSW Aquifer Interference Policy (NOW 2012).

8.2 Predicted impacts

8.2.1 Groundwater level

The pre-quarrying water level is shown in Figure 7.2. A cone of depressurisation (drawdown) will form around the pit following the interception of the groundwater table in years 5 to 10 of the extension project (Figure 7.3).

The minimal impact considerations define a drawdown (water level or pressure) of 2 m as a significant impact requiring mitigation (see Table 8.1). Modelling predicted a 2 m drawdown impact to extend up to 1.5 km from the edge of the pit footprint (Figure 7.4). The groundwater receptors within this zone required assessment and may require mitigation in accordance with the AIP (NOW 2012).

The groundwater receptors within the zone of predicted drawdown include groundwater springs 5, 6, 7 and 8 and areas of Box Gum Woodland (Figure 8.1).

8.2.2 Registered groundwater works

There are no predicted impacts to the registered groundwater works in the project area (Figure 8.1). The closest registered groundwater works (GW056376) is 800 m outside of the predicted extent of drawdown.

8.2.3 Groundwater dependant ecosystems

i Chapmans Creek and alluvium

Under natural conditions Chapmans Creek loses baseflow to the underlying fractured rock water source. The rate of this loss is governed by the hydraulic conductivity of the strata underlying the creek. The extension project will not impact on the hydraulic conductivity of strata outside of the pit therefore no impacts to baseflow at Chapmans Creek are predicted as a result of changes to the groundwater regime.

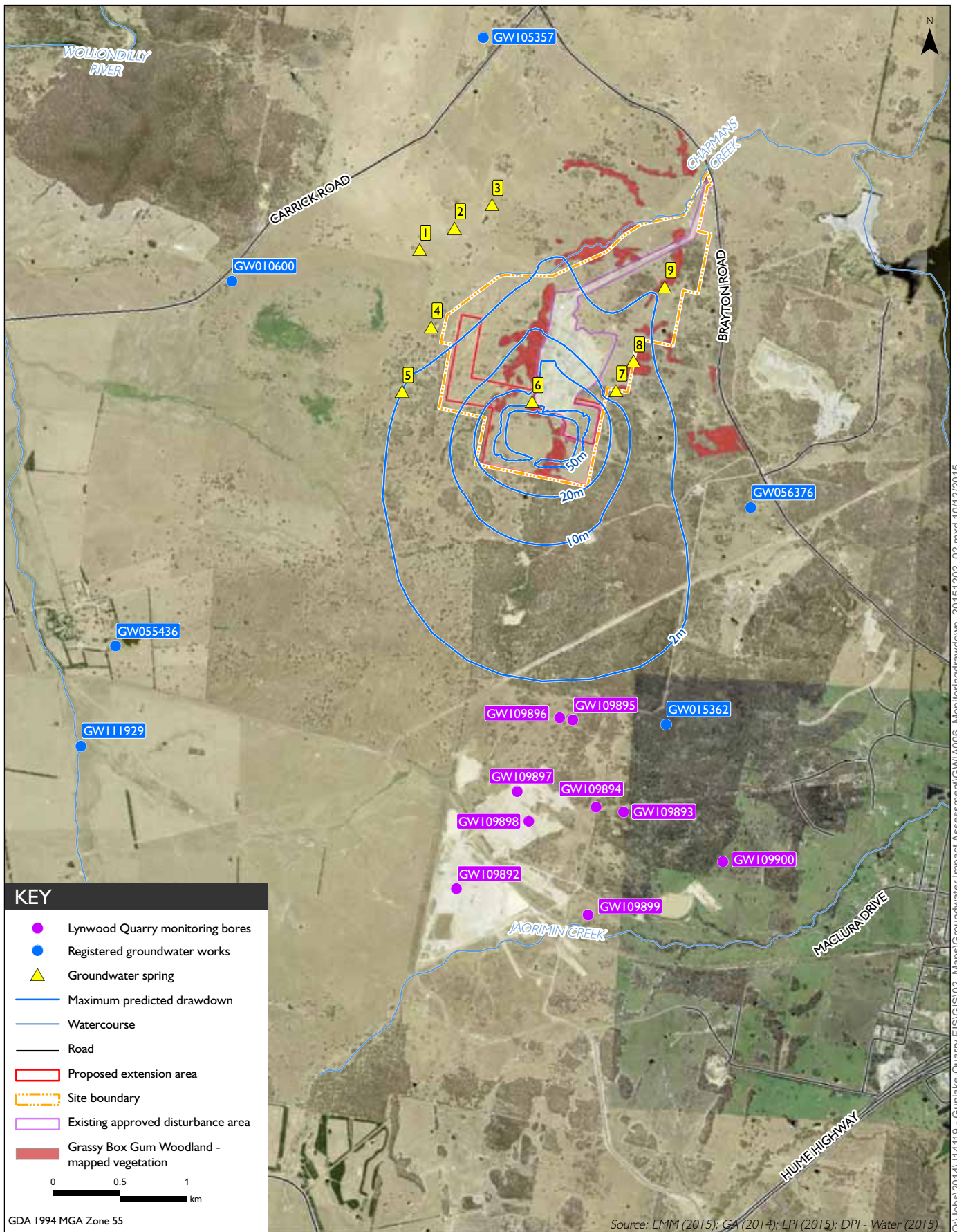
The perched aquifers within the poorly developed alluvial deposits are disconnected from the underlying fractured rock groundwater source. Depressurisation of the underlying strata will therefore have a negligible impact on the alluvial groundwater. However, the pit development will reduce surface runoff and resulting recharge to the alluvial system.

ii Groundwater dependant ecosystems

Groundwater drawdown is predicted within the fractured rock water source underlying areas of mapped Box Gum Woodland (Figure 8.1).

The distribution of the Box Gum Woodland suggests the vegetation is reliant on rainfall and shallow perched groundwater systems within the alluvial deposits. Drawdown in the fractured rock is not expected to impact vegetation health, further discussion is provided in the Gunlake Ecology Assessment (EMM 2015).

Groundwater springs 5, 6, 7 and 8 are predicted to be impacted by drawdown (Figure 8.1). These springs will receive reduced groundwater contributions and those closest to the extension project (ie springs 6 and 7) will cease to flow. The springs do not support GDEs or hold any significant environmental value and predicted reductions in flow are not considered to require mitigation.



Groundwater receptors and predicted drawdown

Gunlake Quarry
Groundwater Assessment

Figure 8.1

8.2.4 Groundwater inflows

As extraction progresses below the water table, a hydraulic gradient will be created directing groundwater flow towards the depressurised strata and into the pit (groundwater inflow). The pore pressure behind the pit walls will reduce causing the formation to deform and expand slightly (pore pressure unloading). This leads to an expansion of the pore space and a reduction in pore pressure within the zone of relaxation (Read and Stacey 2009).

The predicted groundwater inflow rates for each development stage are listed in Table 8.2. The inflow rates are consistent with the low hydraulic conductivities of the intercepted strata combined with the effect of pore pressure unloading.

Table 8.2 Groundwater inflow (seepage to pit)

| Stage (years) | Pit floor level | Average inflow rate | |
|-----------------------|-----------------|---------------------|---------|
| | (m AHD) | m ³ /day | ML/year |
| Stage 1 (years 1-5) | 650 | 0 | 0 |
| Stage 2 (years 5-10) | 637 | 62 | 23 |
| Stage 3 (years 10-20) | 598 | 101 | 37 |
| Stage 4 (years 20-30) | 572 | 94 | 34 |

Notes: m AHD = metres Australian height datum.
 m³/day = cubic metres per day.
 ML/year = mega litres per year.

A maximum inflow rate of 37 ML/year is predicted during Stage 3 of the extension project. The depth of extraction will progress to 598 m AHD during this stage, approximately 45 m below the pre-quarrying water level. Inflow rates are predicted to remain relatively constant as extraction progresses to a final depth of 572 m AHD and then gradually recede as the strata around the pit is dewatered.

The predicted inflows form the entire groundwater take from the extension project. The maximum annual take of 37 ML is within the volumetric entitlements allocated for the GFRGS license pool (Table 3.1).

8.2.5 Final void

Following the completion of quarrying operations dewatering will be discontinued. The final void will continue to receive runoff from direct rainfall and a relatively small contribution from groundwater inflows. Water loss from the void will occur solely through evaporation.

Initially, water inputs are predicted to exceed outputs resulting in the gradual formation of a pit lake (RHDHV 2015). The pit lake will gradually rise with equilibrium predicted to occur 60 to 70 years after the completion of quarrying at an elevation of 600 to 605 m AHD (RHDHV 2015).

The elevation of the pit lake will remain below the pre-quarrying groundwater level and consequently, the final landform will form a perpetual evaporative sink. Groundwater levels in the surrounding strata will partially recover however, a permanent depression will remain around the final void (Figure 7.4).

Groundwater inflow to the final void is predicted at a rate of 75 m³ per day (27 ML/year) at Year 30. Over time, as the surrounding strata dewater the inflow rate will decline. Groundwater inflows are predicted to decline to insignificant rates 20 years after the completion of the extension project.

The final void will contain all captured surface water and groundwater following the completion of the extension project. The final landform will not discharge to the surrounding environment.

8.2.6 Water quality

Groundwater seepage to the pit is expected to have similar water quality to the established baseline groundwater quality data (Section 5.3).

Groundwater inflows and captured surface water will be stored and/or re-used onsite during the extension project (RHDHD 2015). With no discharge to the surrounding environment the potential risks to the quality of groundwater and surface water resources is deemed low.

The final landform will create an inward hydraulic gradient preventing the discharge of water from the pit into the fractured rock groundwater source. The risk of contamination of the groundwater resource is therefore considered to be low with a neutral impact on the beneficial use class (stock).

i Assessment against Neutral or Beneficial Effect on Water Quality Guideline

The *Neutral or Beneficial Effect on Water Quality Assessment Guideline* (SCA, 2015) was developed in response to the State Environmental Planning Policy (Sydney Drinking Water Catchment) 2011. The guideline supports the implementation of the policy by providing a clear direction on what a neutral or beneficial effect means and how to achieve it.

The guideline defines that a neutral or beneficial effect is satisfied if the development:

- has no identified potential impact on water quality; or
- will contain any water quality impact on the development site and prevent it from reaching any watercourse, waterbody, or drainage depressions on the site; or
- will transfer any water quality impact outside the site where it is treated and disposed of to the standards approved by the consent authority.

As detailed above, all groundwater inflows are contained on-site, an inwards hydraulic gradient prevents the outward seepage of water from the pit. There is no groundwater quality impact predicted to any watercourse, waterbody, or drainage depressions on the site satisfying the defined requirement for a neutral or beneficial effect on water quality.

8.2.7 Cumulative impacts

There is potential for cumulative impacts from simultaneous extraction at the extension project and the adjacent Holcim Lynwood Quarry. Groundwater drawdown from the two quarries may create additional drawdown in the area between the adjacent operations. There are with no groundwater receptors in this area and therefore no additional impacts to receptors are predicted.

Each operation will licence their predictive groundwater take from within the GFRGS license pool (Table 3.1). Gunlake Quarry and Lynwood Quarry have a predicted combined take of up to 48.1 ML/year. There is 46,809 unit shares (ML/year) of unallocated water within the GFRGS (Table 3.1) and therefore sufficient volume within the market for the two operations.

9 Management and monitoring

9.1 Groundwater management and mitigation

Gunlake have an approved groundwater and surface water monitoring program (GWSMP) detailing water management for the existing operations. Quarterly groundwater quality and level monitoring program is to be undertaken to facilitate the early identification of adverse impacts and confirm model predictions.

Following approval of the extension project the GWSMP will be updated to include the following measures:

- triggers values to facilitate the identification of groundwater impacts outside of predictions;
- use of monitoring data to calibrate and update the model at significant stages in the project;
- spring health be monitored in conjunction with the quarterly groundwater level and quality program;
- monitoring areas of Box Gum Woodland for impacts;
- management procedures for the re-use of site water; and
- response protocols to identified incidents.

The GWSMP will provide an updated impact identification and response plan with mitigation measures to be implemented in the event of an adverse impact.

9.2 Groundwater licence requirement

Gunlake are required to hold water access licences for the predicted groundwater take over the lifespan of extension project. A peak groundwater take of 37 ML/year is predicted during years 20 to 30 of the extension project constituting 0.08% of the 46,809 unit shares (ML/year) of unallocated water within the GFRGS (Table 3.1 and Table 8.2). There are mechanisms to obtain the required shares (see Section 3.4).

10 Conclusion

Gunlake is seeking development consent to increase the production rate at their hard rock quarry. The proposed pit will intercept the underlying fractured rock groundwater resource. A detailed groundwater assessment has established the baseline hydrogeological conditions and identified the potential groundwater impacts.

Groundwater flow is generally towards the north-east across the Quarry site and associated with structural discontinuities. Groundwater discharges occurs at nine discrete springs associated with sub-vertical geological discontinuities in the area.

The fractured rock groundwater source is classified as less productive. The hard rock strata has a low hydraulic conductivity and reported yields of less than 5 L/s. The groundwater quality is suitable for stock purposes.

An analytic element groundwater flow model was used to predict the potential groundwater impacts from the extension project. Groundwater impacts predicted to be minor and locally confined to around the pit. The impacts can be managed so as to not adversely impact on the surrounding environment.

10.1 Potential Impacts

A drawdown of 2 m is predicted to extend up to 1.5 km from the edge of the pit footprint by Year 30 of the extension project. Groundwater inflows to the pit of up to 37 ML/year are predicted and require licensing from within the unallocated water in the GFRGS under the WM Act. There is sufficient water volume within the market or within the next controlled allocation order to allow the required WAL (or WALs) to be obtained.

Possible impacts to springs include a declined flow rate at groundwater springs 5 and 8 and ceasing of flow at springs 6 and 7. The springs do not support GDEs and are not considered to hold significant environmental value.

Areas of Box Gum Woodland within the zone of predicted drawdown do not rely on groundwater from within the hard rock strata. No impacts are predicted on the alluvial aquifer. Therefore the Box Gum Woodland is not predicted to be impacted by groundwater drawdown as a result of the extension project.

Groundwater inflows to the pit are not predicted to reduce baseflows to the local watercourses (Chapmans Creek and Jaorimin Creek). No impacts to registered groundwater works are predicted and a neutral impact is predicted on water quality in the hydrological catchment.

10.2 Recommendations

The following actions are recommended to be instigated following approval of the extension project:

- the monitoring program is updated in accordance with Section 9;
- staged drawdown predictions are validated by monitoring data;
- spring health be monitored in conjunction with the quarterly groundwater level and quality program;
- the model is calibrated and updated at significant stages in the project; and
- mapped areas of Box Woodland are monitored for impacts.

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Glossary of Terms

| | |
|-------------------------------|---|
| Acidity | Base neutralising capacity. |
| Alkalinity | Acid neutralising capacity. |
| Alluvium | Unconsolidated sediments (clays, sands, gravels and other materials) deposited by flowing water. Deposits can be made by streams on river beds, floodplains, and alluvial fans. |
| Alluvial aquifer | Permeable zones that store and produce groundwater from unconsolidated alluvial sediments. Shallow alluvial aquifers are generally unconfined aquifers. |
| Analytical model | Mathematical models that have a closed form solution, ie the solution to the equations used to describe changes in a system can be expressed as a mathematical analytic function. |
| Anion | An ion with a negative charge. |
| Anthropogenic | Occurring because of, or influenced by, human activity. |
| Annual exceedance probability | The probability that a given rainfall total accumulated over a given duration will be exceeded in any one year. |
| Aquatic ecosystem | The stream channel, lake or estuary bed, water, and (or) biotic communities and the habitat features that occur therein. |
| Aquitard | A very low-permeability unit that forms either the upper or lower boundary of a groundwater flow system and does not transmit water or allow water to migrate from upper and lower horizons. |
| Aquifer | Rock or sediment in a formation, group of formations, or part of a formation that is saturated and sufficiently permeable to transmit economic quantities of water. |
| Aquitard | A low permeability unit that can store groundwater and also transmit it slowly from one formation to another. Aquitards retard but do not prevent the movement of water to or from adjacent aquifers. |
| Artesian water | Groundwater that is under pressure when tapped by a bore and is able to rise above the level at which it is first encountered. It may or may not flow at ground level. The pressure in such an aquifer commonly is called artesian pressure, and the formation containing artesian water is a confined aquifer. |
| Baseflow | The part of stream discharge that originates from groundwater seeping into the stream. |
| Beneficial formation | An aquifer with a water resource of sufficient quality and quantity to provide either ecosystem protection, raw water for drinking water supply, and agricultural or industrial water. |
| Bore | A structure drilled below the surface to obtain water from an aquifer or series of aquifers. |
| Borehole | The hole in the ground drilled by a drill rig for monitoring |
| Boundary | A lateral discontinuity or change in the formation resulting in a significant change in hydraulic conductivity, storativity or recharge. |
| Cation | An ion with a positive charge – usually metal ions when disassociated and dissolved in water. |
| Confined formation | An aquifer that is overlain by low permeability strata. The hydraulic conductivity of the confining bed is significantly lower than that of the aquifer. |
| Concentration | The amount or mass of a substance present in a given volume or mass of sample, usually expressed as microgram per litre (water sample) or micrograms per kilogram (sediment sample). |

| | |
|---|--|
| Conceptual model | A simplified and idealised representation (usually graphical) of the physical hydrogeologic setting and the hydrogeological understanding of the essential flow processes of the system. This includes the identification and description of the geologic and hydrologic framework, media type, hydraulic properties, sources and sinks, and important aquifer flow and surface-groundwater interaction processes. |
| Cone of depressurisation | A depression of the water table or potentiometric surface that has the shape of an inverted cone, which develops around a production bore/gas well/pit from which water is being drawn. |
| Confining layer | Low permeability strata that may be saturated but will not allow water to move through it under natural hydraulic gradients. |
| Contamination | Contamination is the presence of a non-natural compound in soil or water, or unwanted compound in chemicals or other mixtures. |
| Discharge | The volume of water flowing in a stream or through an aquifer past a specific point in a given period of time. |
| Discharge area | An area in which there are upward or lateral components of flow in an aquifer. |
| Drawdown | A lowering of the water table in an unconfined aquifer or the pressure surface of a confined aquifer caused by pumping of groundwater from bores and wells. |
| Electrical conductivity (EC) | A measure of a fluid's ability to conduct an electrical current and is an estimation of the total ions dissolved. It is often used as a measure of water salinity. |
| Elevation | The height above a given level, often sea level (Australian Height Datum) |
| Fault | A fracture in rock along which there has been an observable amount of displacement. Faults are rarely single planar units; normally they occur as parallel to sub-parallel sets of planes along which movement has taken place to a greater or lesser extent. Such sets are called fault or fracture zones. |
| Fracture | Breakage in a rock or mineral along a direction or directions that are not cleavage or fissility directions. |
| Fractured rock aquifer | These occur in sedimentary, igneous and metamorphosed rocks which have been subjected to disturbance, deformation, or weathering, and which allow water to move through joints, bedding planes, fractures and faults. Although fractured rock aquifers are found over a wide area, they generally contain much less groundwater than alluvial and porous sedimentary rock aquifers. |
| Groundwater | The water contained in interconnected pores or fractures located below the water table in the saturated zone. |
| Groundwater dependent ecosystems (GDEs) | Groundwater dependent ecosystems are communities of plants, animals and other organisms whose extent and life processes are dependent (or partially dependent) on groundwater. |
| Groundwater flow | The movement of water through openings in sediment and rock within the zone of saturation. |
| Groundwater system | A system that is hydrogeologically more similar than different in regard to geological province, hydraulic characteristics and water quality, and may consist of one or more geological formations. |
| Hydraulic conductivity | The rate at which water of a specified density and kinematic viscosity can move through a permeable medium (notionally equivalent to the permeability of an aquifer to fresh water). |
| Hydraulic gradient | The change in total hydraulic head with a change in distance in a given direction. |
| Hydraulic head | Is a specific measurement of water pressure above a datum. It is usually measured as a water surface elevation, expressed in units of length. In an aquifer, it can be calculated from the depth to water in a monitoring bore. The hydraulic head can be used to determine a hydraulic gradient between two or more points. |
| Hydrochemistry | Chemical characterisation of water (both surface water and groundwater). |
| Hydrogeology | The study of the interrelationships of geologic materials and processes with water, especially groundwater. |
| Hydrology | The study of the occurrence, distribution, and chemistry of all surface waters. |

| | |
|---|---|
| Infiltration | The downward flow of water from the land surface into and through the upper soil layers. |
| Major ions | Constituents commonly present in concentrations exceeding 10 milligram per litre. Dissolved cations generally are calcium, magnesium, sodium, and potassium; the major anions are sulphate, chloride, fluoride, nitrate, and those contributing to alkalinity, most generally assumed to be bicarbonate and carbonate. |
| MicroSiemens per centimetre ($\mu\text{S}/\text{cm}$) | A measure of water salinity commonly referred to as EC (see also electrical conductivity). Most commonly measured in the field with calibrated water quality meter. |
| Monitoring bore | A non-pumping bore, is generally of small diameter that is used to measure the elevation of the water table and/or water quality. Bores generally have a short well screen against a single aquifer through which water can enter. |
| Numerical model | A model of groundwater flow in which the aquifer is described by numerical equations (with specified values for boundary conditions) that are usually solved in a computer program. In this approach, the continuous differential terms in the governing hydraulic flow equation are replaced by finite quantities. Computational power is used to solve the resulting algebraic equations by matrix arithmetic. In this way, problems with complex geometry, dynamic response effects and spatial and temporal variability may be solved accurately. This approach must be used in cases where the essential aquifer features form a complex system (ie high complexity models). |
| Permeability | The property or capacity of a porous rock, sediment, clay or soil to transmit a fluid. It is a measure of the relative ease of fluid flow under unequal pressure. The hydraulic conductivity is the permeability of a material for water at the prevailing temperature. |
| Permeable material | Material that permits water to move through it at perceptible rates under the hydraulic gradients normally present. |
| pH | Potential of hydrogen; the logarithm of the reciprocal of hydrogen-ion concentration in gram atoms per litre; provides a measure on a scale from 0 to 14 of the acidity or alkalinity of a solution (where 7 is neutral, greater than 7 is alkaline and less than 7 is acidic). |
| Porosity | The proportion of open space within an aquifer, comprised of intergranular space, pores, vesicles and fractures. |
| Porous rock | Consolidated sedimentary rock containing voids, pores or other openings (joints, cleats, fractures) which are interconnected in the rock mass and may be capable of storing and transmitting water. |
| Precipitation | (1) in meteorology and hydrology, rain, snow and other forms of water falling from the sky (2) the formation of a suspension of an insoluble compound by mixing two solutions. Positive values of saturation index (SI) indicate supersaturation and the tendency of the water to precipitate that mineral. |
| Pumping test | A test made by pumping a bore for a period of time and observing the change in hydraulic head in the aquifer. A pumping test may be used to determine the capacity of the bore and the hydraulic characteristics of the aquifer. |
| Quaternary | The most recent geological period extending from approximately 2.5 million years ago to the present day. |
| Recharge | The process which replenishes groundwater, usually by rainfall infiltrating from the ground surface to the water table and by river water reaching the water table or exposed aquifers. The addition of water to an aquifer. |
| Recharge area | A geographic area that directly receives infiltrated water from surface and in which there are downward components of hydraulic head in the aquifer. Recharge generally moves downward from the water table into the deeper parts of an aquifer then moves laterally and vertically to recharge other parts of the aquifer or deeper aquifer zones. |

| | |
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| Recovery | The difference between the observed water level during the recovery period after cessation of pumping and the water level measured immediately before pumping stopped. |
| Residence time | The time that groundwater spends in storage before moving to a different part of the hydrological cycle (ie it could be argued it is a rate of replenishment). |
| Salinity | The concentration of dissolved salts in water, usually expressed in EC units or milligrams of total dissolved solids per litre (mg/L TDS). |
| Salinity classification (Australia Water Resources Council 1988) | <p>Fresh water quality – water with a salinity <800 $\mu\text{S}/\text{cm}$.</p> <p>Marginal water quality – water that is more saline than freshwater and generally waters between 800 and 1,600 $\mu\text{S}/\text{cm}$.</p> <p>Brackish quality – water that is more saline than freshwater and generally waters between 1,600 and 4,800 $\mu\text{S}/\text{cm}$.</p> <p>Slightly saline quality – water that is more saline than brackish water and generally waters with a salinity between 4,800 and 10,000 $\mu\text{S}/\text{cm}$.</p> <p>Moderately saline quality – water that is more saline than brackish water and generally waters between 10,000 and 20,000 $\mu\text{S}/\text{cm}$.</p> <p>Saline quality – water that is almost as saline as seawater and generally waters with a salinity greater than 20,000 $\mu\text{S}/\text{cm}$.</p> <p>Seawater quality – water that is generally around 55,000 $\mu\text{S}/\text{cm}$.</p> |
| Saturated zone | The zone in which the voids in the rock or soil are filled with water at a pressure greater than atmospheric pressure. |
| Screen | A type of bore lining or casing of special construction, with apertures designed to permit the flow of water into a bore while preventing the entry of aquifer or filter pack material. |
| Semi-confined formation | An aquifer overlain by a low-permeability layer that permits water to slowly flow through it. During pumping, recharge to the aquifer can occur across the leaky confining layer – also known as a leaky artesian or leaky confined aquifer. |
| Specific storage | Relating to the volume of water that is released from an aquifer following a unit change in the hydraulic head. Specific storage normally relates to confined aquifers. |
| Specific yield | The ratio of the volume of water a rock or soil will yield by gravity drainage to the volume of the rock or soil. Specific yield generally relates to unconfined aquifers. Gravity drainage may take many months to occur. |
| Standing water level (SWL) | The height to which groundwater rises in a bore after it is drilled and completed, and after a period of pumping when levels return to natural atmospheric or confined pressure levels. |
| Storativity | The volume of water an aquifer releases from or takes into storage per unit surface area of the aquifer per unit change in head. It is equal to the product of specific storage and aquifer thickness. In an unconfined aquifer, the storativity is equivalent to specific yield. |
| Stratigraphy | The depositional order of sedimentary rocks in layers. |
| Surface water-groundwater interaction | This occurs in two ways: (1) streams gain water from groundwater through the streambed when the elevation of the water table adjacent to the streambed is greater than the water level in the stream; and (2) streams lose water to groundwater through streambeds when the elevation of the water table is lower than the water level in the stream. |
| Total Dissolved Solids (TDS) | A measure of the salinity of water, usually expressed in milligrams per litre (mg/L). See also EC. |

| | |
|----------------------|--|
| Transmissivity | The rate at which water of a prevailing density and viscosity is transmitted through a unit width of an aquifer or confining bed under a unit hydraulic gradient. It is a function of properties of the liquid, the porous media, and the thickness of the porous media. |
| Unconfined formation | Also known as a water table aquifer. An aquifer in which there are no confining beds between the zone of saturation and the surface. The water table is the upper boundary of an unconfined aquifer. |
| Unsaturated zone | That strata between the land surface and water table. It includes the root zone, intermediate zone and capillary fringe. |
| Water quality | Term used to describe the chemical, physical, and biological characteristics of water, usually in respect to its suitability for a particular purpose. |
| Water quality data | Chemical, biological, and physical measurements or observations of the characteristics of surface and ground waters, atmospheric deposition, potable water, treated effluents, and waste water and of the immediate environment in which the water exists. |
| Water table | The top of an unconfined aquifer. It is at atmospheric pressure and indicates the level below which soil and rock are saturated with water. |

List of units

| | |
|-------------------|--------------------------------|
| °C | degrees Celsius |
| L/s | litres per second |
| m | metres |
| m AHD | metres Australian Height Datum |
| m BGL | metres below ground level |
| m BTOC | metres below top of casing |
| m/d | metres per day |
| m ³ /d | cubic metres per day |
| mm/year | millimetres per year |
| ML | mega litres |
| ML/year | mega litres per year |
| µS/cm | microSiemens per centimetre |
| mg/L | milligrams per litre |

Abbreviations

| | |
|-----------|--|
| ANZECC | Australia New Zealand Environment Conservation Council |
| ARMCANZ | Agriculture and Resource Management Council of Australia and New Zealand |
| BoM | Bureau of Meteorology |
| DPI Water | NSW Department of Primary Industries, Water |
| EC | Electrical conductivity |
| EIS | Environmental Impact statement |
| EP&A Act | Environmental Protection & Assessment Act |
| EPBC Act | Environment Protection and Biodiversity Conservation Act |
| GFRGS | Goulburn Fractured Rock Groundwater Source |
| K | Hydraulic conductivity |
| LTAAEL | Long-term average annual extraction limit |
| NSW | The Australian state of New South Wales |
| NWC | National Water Commission |
| NHMRC | National Health and Medical Research Council |
| PFS | Pre-feasibility study |
| SDLs | Sustainable Diversion Limits |
| SEARs | Secretary's environmental assessment requirements |
| SSD | State Significant Development |
| TDS | Total Dissolved Solids |
| W Act | Water Act |
| WAL | Water access license |
| WM Act | Water Management Act |
| WSP | Water Sharing Plan |

Appendix A

Groundwater quality monitoring data

Table A.1 Water quality monitoring results – GM6

| Analyte | Unit | NHMRC (2011) guidelines | | ANZECC (2000) guidelines | GM6 | | | |
|---|-------|-------------------------|-----------|--------------------------|-----------|----------|----------|----------|
| | | Health | Aesthetic | | 1/06/2007 | 21/04/15 | 15/05/15 | 23/06/15 |
| Field parameters | | | | | | | | |
| pH | | ID | 6.5-8.5 | 6.5-8.0* | 6.7 | 6.1 | 6.5 | 6.4 |
| Electrical conductivity | µs/cm | - | - | 125-2200 | 6600 | 230 | 190 | 190 |
| Dissolved Oxygen | mg/L | - | - | - | - | - | - | - |
| Redox | mV | - | - | - | - | - | - | - |
| Laboratory results | | | | | | | | |
| Total dissolved solids | mg/L | - | 600 | ID | - | 920 | 170 | 130 |
| Alkalinity | | | | | | | | |
| Hardness as CaCO ₃ | mg/L | - | 200 | - | - | 28 | 28 | 69 |
| Bicarbonate Alkalinity as CaCO ₃ | mg/L | - | - | - | 760 | 150 | 36 | 39 |
| Carbonate Alkalinity as CaCO ₃ | mg/L | - | - | - | <1 | <0.1 | <0.1 | <1 |
| Hydroxide Alkalinity | mg/L | - | - | - | - | <0.1 | <0.1 | <1 |
| Total Alkalinity | mg/L | - | - | - | - | 150 | 36 | 39 |
| Cations and anions | | | | | | | | |
| Chloride | mg/L | ID | 0.25 | - | 2500 | 25 | 10 | 24 |
| Sulfate | mg/L | ID | 0.25 | - | 34 | 27 | 16 | 10 |
| Calcium | mg/L | - | - | - | 500 | 4 | 3 | 11 |
| Magnesium | mg/L | - | - | - | 430 | 4 | 5 | 10 |
| Potassium | mg/L | - | - | - | 18 | 4 | 3 | 3 |
| Sodium | mg/L | - | 0.18 | - | 520 | 22 | 24 | 26 |
| Total metals | | | | | | | | |
| Arsenic | µg/L | 10 | - | 24 (As V) | <1 | 24 | <1 | 1 |
| Cadmium | µg/L | 2 | - | 0.2 | <0.2 | 2.3 | 0.09 | <1 |
| Chromium | µg/L | 5 | - | 1 (Cr VI) | <1 | 210 | 2 | 2 |
| Copper | µg/L | 2 | 1 | 1.4 | 2 | 110 | 4 | 4 |

Table A.1 Water quality monitoring results – GM6

| Analyte | Unit | NHMRC (2011) guidelines | | ANZECC (2000) guidelines | GM6 | | | |
|------------------------|------|-------------------------|-----------|--------------------------|------------|-------------|-------------|-------------|
| | | Health | Aesthetic | | 1/06/2007 | 21/04/15 | 15/05/15 | 23/06/15 |
| Lead | µg/L | 0.01 | - | 3.4 | <1 | 1200 | 14.6 | 6 |
| Mercury | µg/L | 1 | - | 0.6 (inorganic) | <0.1 | 0.4 | <0.1 | 0.01 |
| Nickel | µg/L | 0.02 | - | 11 | <1 | 330 | 216 | 300 |
| Zinc | µg/L | ID | 3 | 8 | 5 | 1050 | 27 | 20 |
| Selenium | mg/L | 10 | - | 11 (Total) | - | - | - | <0.01 |
| Fluoride | mg/L | 1500 | - | - | - | - | - | 0.2 |
| Iron (dissolved) | mg/L | - | - | - | <0.01 | 0.82 | 0.09 | 0.1 |
| Iron | mg/L | ID | 300 | ID | 35 | 200 | 2 | 0.9 |
| Nutrients | | | | | | | | |
| Ammonia as N | mg/L | ID | 0.5 | 0.013* | 0.8 | 1.1 | <0.1 | 0.05 |
| Nitrite as N | mg/L | 3 | - | 0.015* | 0.1 | 0.05 | <0.01 | <0.01 |
| Nitrate as N | mg/L | 50 | - | 0.015* | 3.5 | 2.1 | 4.2 | 1.1 |
| Total Phosphorous as P | mg/L | - | - | 0.02* | 2 | 1.9 | 0.05 | 0.1 |
| Reactive phosphorous | mg/L | - | - | - | | <0.02 | 0.02 | <0.01 |

Notes: NHMRC (2011) guidelines = Australian drinking water guidelines, NSW government.

ANZECC (2000) guidelines = Australian and New Zealand guidelines for the 95% protection of freshwater species.

* = guideline value for south east Australian lowland rivers (ANZECC/ARMCANZ 2000).

ID = insufficient data to create value.

Shading = result above Drinking Water Guideline, Bold = result above ANZECC (2000) guidelines.

Table A.2 Water quality monitoring results – GM13

| Analyte | Unit | NHMRC (2011) guidelines | | ANZECC (2000) guidelines | GM13 | | | |
|---|-------|-------------------------|-----------|--------------------------|-----------|-------------|-------------|-------------|
| | | Health | Aesthetic | | 1/06/2007 | 21/04/15 | 15/05/15 | 23/06/15 |
| Field parameters | | | | | | | | |
| pH | | ID | 6.5-8.5 | 6.5-8.0* | 6.8 | 7.3 | 7.3 | 7.1 |
| Electrical conductivity | µs/cm | - | - | 125-2200 | 1300 | 6100 | 5600 | 5900 |
| Dissolved Oxygen | mg/L | - | - | - | - | - | 13 | - |
| Redox | mV | - | - | - | - | - | -77 | - |
| Laboratory results | | | | | | | | |
| Total dissolved solids | mg/L | - | 600 | ID | - | 4200 | 3900 | 3900 |
| Alkalinity | | | | | | | | |
| Hardness as CaCO ₃ | mg/L | - | 200 | - | - | 1900 | 1700 | 1900 |
| Bicarbonate Alkalinity as CaCO ₃ | mg/L | - | - | - | 430 | 620 | 700 | 730 |
| Carbonate Alkalinity as CaCO ₃ | mg/L | - | - | - | <1 | <0.1 | <0.1 | <1 |
| Hydroxide Alkalinity | mg/L | - | - | - | - | <0.1 | <0.1 | <1 |
| Total Alkalinity | mg/L | - | - | - | - | 620 | 700 | 730 |
| Cations and anions | | | | | | | | |
| Chloride | mg/L | ID | 0.25 | - | 250 | 1800 | 1600 | 1500 |
| Sulfate | mg/L | ID | 0.25 | - | 44 | 23 | 24 | 22 |
| Calcium | mg/L | - | - | - | 85 | 250 | 230 | 270 |
| Magnesium | mg/L | - | - | - | 49 | 300 | 260 | 300 |
| Potassium | mg/L | - | - | - | 7.6 | 27 | 26 | 21 |
| Sodium | mg/L | - | 0.18 | - | 140 | 480 | 480 | 500 |
| Total metals | | | | | | | | |
| Arsenic | mg/L | 10 | - | 24 (As V) | <1 | 10 | 7 | 10 |
| Cadmium | mg/L | 2 | - | 0.2 | <0.2 | 0.2 | 0.2 | <1 |
| Chromium | mg/L | 5 | - | 1 (Cr VI) | <1 | 4 | 3 | 2 |
| Copper | mg/L | 2 | 1 | 1.4 | 3 | 3 | 8 | 4 |

Table A.2 Water quality monitoring results – GM13

| Analyte | Unit | NHMRC (2011) guidelines | | ANZECC (2000) guidelines | GM13 | | | |
|------------------------|------|-------------------------|-----------|--------------------------|------------|-------------|------------|-------------|
| | | Health | Aesthetic | | 1/06/2007 | 21/04/15 | 15/05/15 | 23/06/15 |
| Lead | mg/L | 0.01 | - | 3.4 | <1 | 1.3 | 3 | 3 |
| Mercury | mg/L | 1 | - | 0.6 (inorganic) | <0.1 | <0.1 | <0.1 | <0.1 |
| Nickel | mg/L | 0.02 | - | 11 | <1 | 21 | 20 | 10 |
| Zinc | mg/L | ID | 3 | 8 | 9 | 76 | 170 | 400 |
| Selenium | mg/L | 10 | - | 11 (Total) | - | - | - | <0.01 |
| Fluoride | mg/L | 1500 | - | - | - | - | - | 0.5 |
| Iron (dissolved) | mg/L | - | - | - | 0.02 | <0.1 | <0.01 | <0.05 |
| Iron | mg/L | ID | 300 | ID | 16 | 0.4 | 1.5 | 1.3 |
| Nutrients | | | | | | | | |
| Ammonia as N | mg/L | ID | 0.5 | 0.013* | 0.5 | <0.1 | <0.1 | 0.01 |
| Nitrite as N | mg/L | 3 | - | 0.015* | 0.1 | 0.35 | <0.01 | <0.01 |
| Nitrate as N | mg/L | 50 | - | 0.015* | 7.1 | 3.3 | 0.8 | <0.01 |
| Total Phosphorous as P | mg/L | - | - | 0.02* | 0.3 | 0.02 | 0.02 | 0.04 |
| Reactive phosphorous | mg/L | - | - | - | 6.8 | <0.02 | 0.02 | <0.01 |

Notes: NHMRC (2011) guidelines = Australian drinking water guidelines, NSW government.

ANZECC (2000) guidelines = Australian and New Zealand guidelines for the 95% protection of freshwater species.

* = guideline value for south east Australian lowland rivers (ANZECC/ARMCANZ 2000).

ID = insufficient data to create value.

Shading = result above Drinking Water Guideline, Bold = result above ANZECC (2000) guidelines.

Table A.3 Water quality monitoring results – GM24

| Analyte | Unit | NHMRC (2011) guidelines | | ANZECC (2000) guidelines | GM24 | | | |
|---|-------|-------------------------|-----------|--------------------------|-----------|----------|----------|----------|
| | | Health | Aesthetic | | 1/06/2007 | 21/04/15 | 15/05/15 | 23/06/15 |
| Field parameters | | | | | | | | |
| pH | | ID | 6.5-8.5 | 6.5-8.0* | 6.9 | 7.5 | 7.6 | 7.4 |
| Electrical conductivity | µs/cm | - | - | 125-2200 | 880 | 3000 | 3100 | 3100 |
| Dissolved Oxygen | mg/L | - | - | - | - | - | 13 | - |
| Redox | mV | - | - | - | - | - | -21 | - |
| Laboratory results | | | | | | | | |
| Total dissolved solids | mg/L | - | 600 | ID | | 1800 | 2000 | 2000 |
| Alkalinity | | | | | | | | |
| Hardness as CaCO ₃ | mg/L | - | 200 | - | | 900 | 900 | 1100 |
| Bicarbonate Alkalinity as CaCO ₃ | mg/L | - | - | - | 220 | 410 | 420 | 440 |
| Carbonate Alkalinity as CaCO ₃ | mg/L | - | - | - | <1 | <0.1 | <0.1 | <1 |
| Hydroxide Alkalinity | mg/L | - | - | - | | <0.1 | <0.1 | <1 |
| Total Alkalinity | mg/L | - | - | - | | 410 | 420 | 440 |
| Cations and anions | | | | | | | | |
| Chloride | mg/L | ID | 0.25 | - | 250 | 760 | 760 | 750 |
| Sulfate | mg/L | ID | 0.25 | - | 5 | 12 | 12 | 16 |
| Calcium | mg/L | - | - | - | 45 | 130 | 140 | 160 |
| Magnesium | mg/L | - | - | - | 35 | 140 | 130 | 160 |
| Potassium | mg/L | - | - | - | 6.8 | 13 | 12 | 12 |
| Sodium | mg/L | - | 0.18 | - | 120 | 230 | 230 | 260 |
| Total metals | | | | | | | | |
| Arsenic | µg/L | 10 | - | 24 (As V) | <1 | 6 | 5 | 1 |
| Cadmium | µg/L | 2 | - | 0.2 | <0.2 | 0.07 | 0.07 | <0.1 |
| Chromium | µg/L | 5 | - | 1 (Cr VI) | <1 | 3 | <2 | 1 |
| Copper | µg/L | 2 | 1 | 1.4 | 2 | 5 | 5 | 10 |

Table A.3 Water quality monitoring results – GM24

| Analyte | Unit | NHMRC (2011) guidelines | | ANZECC (2000) guidelines | GM24 | | | |
|------------------------|------|-------------------------|-----------|--------------------------|------------|-------------|-------------|-------------|
| | | Health | Aesthetic | | 1/06/2007 | 21/04/15 | 15/05/15 | 23/06/15 |
| Lead | µg/L | 0.01 | - | 3.4 | <1 | 1.1 | 0.9 | <1 |
| Mercury | µg/L | 1 | - | 0.6 (inorganic) | <0.1 | <0.1 | <0.1 | <0.1 |
| Nickel | µg/L | 0.02 | - | 11 | <1 | 16 | 16 | 10 |
| Zinc | µg/L | ID | 3 | 8 | 5 | 29 | 33 | 50 |
| Selenium | mg/L | 10 | - | 11 (Total) | | - | - | <0.01 |
| Fluoride | mg/L | 1500 | - | - | | - | - | 0.7 |
| Iron (dissolved) | mg/L | - | - | - | 0.02 | <0.01 | <0.01 | <0.05 |
| Iron | mg/L | ID | 300 | ID | 43 | 1 | 0.8 | 0.2 |
| Nutrients | | | | | | | | |
| Ammonia as N | mg/L | ID | 0.5 | 0.013* | 0.2 | 0.2 | 0.2 | 0.07 |
| Nitrite as N | mg/L | 3 | - | 0.015* | <0.1 | 0.06 | 0.02 | <0.01 |
| Nitrate as N | mg/L | 50 | - | 0.015* | 0.2 | 0.6 | 0.7 | 0.5 |
| Total Phosphorous as P | mg/L | - | - | 0.02* | 0.8 | 0.02 | 0.02 | 0.1 |
| Reactive phosphorous | mg/L | - | - | - | 6.9 | 0.02 | 0.02 | <0.01 |

Notes: NHMRC (2011) guidelines = Australian drinking water guidelines, NSW government.

ANZECC (2000) guidelines = Australian and New Zealand guidelines for the 95% protection of freshwater species.

* = guideline value for south east Australian lowland rivers (ANZECC/ARMCANZ 2000).

ID = insufficient data to create value.

Shading = result above Drinking Water Guideline, Bold = result above ANZECC (2000) guidelines.

Table A.4 Water quality monitoring results – GM36

| Analyte | Unit | NHMRC (2011) guidelines | | ANZECC (2000) guidelines | GM36 | | | |
|---|-------|-------------------------|-----------|--------------------------|-----------|----------|----------|----------|
| | | Health | Aesthetic | | 1/06/2007 | 21/04/15 | 15/05/15 | 23/06/15 |
| Field parameters | | | | | | | | |
| pH | | ID | 6.5-8.5 | 6.5-8.0* | - | 7.1 | 8.2 | 7.1 |
| Electrical conductivity | µs/cm | - | - | 125-2200 | - | 2400 | 3500 | 3400 |
| Dissolved Oxygen | mg/L | - | - | - | - | - | 10 | - |
| Redox | mV | - | - | - | - | - | 98 | - |
| Laboratory results | | | | | | | | |
| Total dissolved solids | mg/L | - | 600 | ID | - | 1800 | 2000 | 2200 |
| Alkalinity | | | | | | | | |
| Hardness as CaCO ₃ | mg/L | - | 200 | - | - | 780 | 800 | 1200 |
| Bicarbonate Alkalinity as CaCO ₃ | mg/L | - | - | - | 290 | 280 | 290 | 340 |
| Carbonate Alkalinity as CaCO ₃ | mg/L | - | - | - | <1 | <0.1 | <0.1 | <1 |
| Hydroxide Alkalinity | mg/L | - | - | - | - | <0.1 | <0.1 | <1 |
| Total Alkalinity | mg/L | - | - | - | - | 280 | 290 | 340 |
| Cations and anions | | | | | | | | |
| Chloride | mg/L | ID | 0.25 | - | 110 | 640 | 650 | 810 |
| Sulfate | mg/L | ID | 0.25 | - | 14 | 13 | 13 | 13 |
| Calcium | mg/L | - | - | - | 17 | 150 | 160 | 230 |
| Magnesium | mg/L | - | - | - | 17 | 100 | 99 | 150 |
| Potassium | mg/L | - | - | - | 2.5 | 8.2 | 8.3 | 7 |
| Sodium | mg/L | - | 0.18 | - | 130 | 140 | 140 | 180 |
| Total metals | | | | | | | | |
| Arsenic | µg/L | 10 | - | 24 (As V) | <1 | 6 | 4 | 2 |
| Cadmium | µg/L | 2 | - | 0.2 | <0.2 | <0.05 | <0.05 | <0.1 |
| Chromium | µg/L | 5 | - | 1 (Cr VI) | <1 | 3 | <2 | 2 |
| Copper | µg/L | 2 | 1 | 1.4 | 1 | 3 | 4 | 4 |

Table A.4 Water quality monitoring results – GM36

| Analyte | Unit | NHMRC (2011) guidelines | | ANZECC (2000) guidelines | GM36 | | | |
|------------------------|------|-------------------------|-----------|--------------------------|------------|-----------|-----------|-----------|
| | | Health | Aesthetic | | 1/06/2007 | 21/04/15 | 15/05/15 | 23/06/15 |
| Lead | µg/L | 0.01 | - | 3.4 | <1 | 2.0 | 2.1 | 1 |
| Mercury | µg/L | 1 | - | 0.6 (inorganic) | <0.01 | <0.1 | <0.1 | 0.1 |
| Nickel | µg/L | 0.02 | - | 11 | <1 | 20 | 18 | 20 |
| Zinc | µg/L | ID | 3 | 8 | 3 | 24 | 32 | 90 |
| Selenium | mg/L | 10 | - | 11 (Total) | - | - | - | <0.01 |
| Fluoride | mg/L | 1500 | - | - | - | - | - | 0.1 |
| Iron (dissolved) | mg/L | - | - | - | 0.69 | 0.02 | 0.04 | 0.05 |
| Iron | mg/L | ID | 300 | ID | 82 | 0.8 | 0.8 | 0.05 |
| Nutrients | | | | | | | | |
| Ammonia as N | mg/L | ID | 0.5 | 0.013* | <0.1 | <0.1 | <0.1 | 0.01 |
| Nitrite as N | mg/L | 3 | - | 0.015* | 0.1 | <0.01 | <0.01 | 0.01 |
| Nitrate as N | mg/L | 50 | - | 0.015* | 1.1 | <0.05 | <0.05 | 0.01 |
| Total Phosphorous as P | mg/L | - | - | 0.02* | 0.5 | 0.03 | 0.03 | 0.01 |
| Reactive phosphorous | mg/L | - | - | - | 290 | <0.02 | 0.03 | 0.01 |

Notes: NHMRC (2011) guidelines = Australian drinking water guidelines, NSW government.

ANZECC (2000) guidelines = Australian and New Zealand guidelines for the 95% protection of freshwater species.

* = guideline value for south east Australian lowland rivers (ANZECC/ARMCANZ 2000).

ID = insufficient data to create value.

Shading = result above Drinking Water Guideline, Bold = result above Water Quality Guideline.

Table A.5 Water quality monitoring results – In-pit sump

| Analyte | Unit | NHMRC (2011) guidelines | | ANZECC (2000) guidelines | In-pit sump | |
|---|-------|-------------------------|-----------|--------------------------|-------------|------------|
| | | Health | Aesthetic | | 21/04/15 | 15/05/15 |
| Field parameters | | | | | | |
| pH | | ID | 6.5-8.5 | 6.5-8.0* | 8 | 7.8 |
| Electrical conductivity | µs/cm | - | - | 125-2200 | 1800 | 1800 |
| Dissolved Oxygen | mg/L | - | - | - | 6.9 | - |
| Redox | mV | - | - | - | -53 | - |
| Laboratory results | | | | | | |
| Total dissolved solids | mg/L | - | 600 | ID | - | 1200 |
| Alkalinity | | | | | | |
| Hardness as CaCO ₃ | mg/L | - | 200 | - | - | 460 |
| Bicarbonate Alkalinity as CaCO ₃ | mg/L | - | - | - | - | 180 |
| Carbonate Alkalinity as CaCO ₃ | mg/L | - | - | - | - | <0.1 |
| Hydroxide Alkalinity | mg/L | - | - | - | - | <0.1 |
| Total Alkalinity | mg/L | - | - | - | - | 180 |
| Cations and anions | | | | | | |
| Chloride | mg/L | ID | 250 | - | - | 350 |
| Sulfate | mg/L | ID | 250 | - | - | 17 |
| Calcium | mg/L | - | - | - | - | 79 |
| Magnesium | mg/L | - | - | - | - | 63 |
| Potassium | mg/L | - | - | - | - | 8.1 |
| Sodium | mg/L | - | 180 | - | - | 150 |
| Total metals | | | | | | |
| Arsenic | µg/L | 10 | - | 24 (As V) | - | 2 |
| Cadmium | µg/L | 2 | - | 0.2 | - | 0.06 |
| Chromium | µg/L | 5 | - | 1 (Cr VI) | - | <0.2 |
| Copper | µg/L | 2 | 1 | 1.4 | - | 2 |

Table A.5 Water quality monitoring results – In-pit sump

| Analyte | Unit | NHMRC (2011) guidelines | | ANZECC (2000) guidelines | In-pit sump | |
|------------------------|------|-------------------------|-----------|--------------------------|-------------|------------|
| | | Health | Aesthetic | | 21/04/15 | 15/05/15 |
| Lead | µg/L | 0.01 | - | 3.4 | - | <0.2 |
| Mercury | µg/L | 1 | - | 0.6 (inorganic) | - | <0.1 |
| Nickel | µg/L | 0.02 | - | 11 | - | 3 |
| Zinc | µg/L | ID | 3 | 8 | - | <5 |
| Iron (dissolved) | mg/L | - | - | - | - | <0.01 |
| Iron | mg/L | ID | 300 | ID | - | 0.04 |
| Nutrients | | | | | | |
| Ammonia as N | mg/L | ID | 0.5 | 0.013* | - | <0.1 |
| Nitrite as N | mg/L | 3 | - | 0.015* | - | 0.3 |
| Nitrate as N | mg/L | 50 | - | 0.015* | - | 39 |
| Total Phosphorous as P | mg/L | - | - | 0.02* | - | <0.01 |
| Reactive phosphorous | mg/L | - | - | - | - | <0.02 |

Notes: NHMRC (2011) guidelines = Australian drinking water guidelines, NSW government.

ANZECC (2000) guidelines = Australian and New Zealand guidelines for the 95% protection of freshwater species.

* = guideline value for south east Australian lowland rivers (ANZECC/ARMCANZ 2000).

ID = insufficient data to create value.

Shading = result above Drinking Water Guideline, Bold = result above Water Quality Guideline.



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