GILBERT SUTHERLAND

13 March 2019

The General Manager – Lismore City Council
PO Box 23A
Lismore NSW 2480

Attention: Eleisha Went – Commercial Services Compliance Coordinator

Dear Eleisha,

Re: Lismore City Council – Blakebrook Quarry – Groundwater Assessment Report

This correspondence has been prepared to address Attachment A to a 25 January 2019 email from the New South Wales Department of Planning & Environment (DPE) to Lismore City Council (LCC), with the subject *'Lismore City Council - Blakebrook Quarry – Groundwater Assessment Report'*.

For ease of reference we have reproduced and included as Attachment 1 to this letter a copy of DPE's 'Attachment A' table, augmented with an additional column containing our response to each comment. Also included as Attachment 2 to this letter is a revised '*Hydrogeological Review: Groundwater Monitoring & Management Blakebrook Quarry Nimbin Road, Lismore New South Wales'*, prepared by G&S and dated March 2019, together with its own revised associated appendixes prepared in response to DPE's comments.

We trust that this is acceptable. Please do not hesitate to contact this office if you require any further details or elaboration.

Yours sincerely,

Chris Anderson
Principal Environmental Engineer & Scientist
BEngEnv BScLan&WatMgt MEIANZ MIEAust

for Alison Fullagar
Senior Water Resource Engineer & Modeller
BE(Civ)(Hons) BE(Env)(Hons) MIEAust

Author(s) Chris Anderson & Alison Fullagar
Our Reference 11737_ADV_CA3F.docx
Your Reference
By ☐ Courier ☑ Email ☐ Facsimile ☐ Post
Enclosures 2 (Table and report)

Attachment 1 – Table A (reproduced and augmented) from 25 January 2019 DPE email

Attachment A
Blakebrook Quarry – Post Approval

Groundwater Assessment – MP 07-0020 – Condition 17, Schedule 3	**Satisfactory (Yes/No/Partial)**	**Comment**	**Action Required**	**LCC / G&S Comments**
The Proponent must undertake a detailed groundwater assessment to the satisfaction of the Secretary. This assessment must be:				
(a) prepared by a suitably qualified expert in consultation with DPI Water;	Partial	Please append evidence showing that the author is a suitably qualified expert. The Department has attached an approval for Lismore City Council's proposed suitably qualified experts, please append. Please append evidence of consultation with DoI – Lands and Water. Not satisfied.	To note comments and amend the plan accordingly.	Letter has been attached as Appendix 7 LCC has provided the documents to DoI for their review and comment.
(b) submitted to the Secretary for approval by 30 December 2018;	Yes	-	-	--
(c) approved by the Secretary before any extraction below 105 m AHD in the northern pit or below 118.5 m AHD in the southern pit;	-	-	-	--
(d) adequately assess groundwater resources affected by the northern and southern pits, to the proposed full extraction depths of those pits;	Yes	See Attachment 1 – Please provide an updated figure clearly indicating the depth of groundwater along each contour. Satisfied – See Appendix 1.	-	--
(e) adequately assess all groundwater impacts associated with proposed extraction;	Yes	See Section 3.2.2 – Please provide further justification of the model, in light of the noted constraints and limitations. Satisfied – See Section 3.2.2.	-	--
(f) provide data for predicted groundwater pit inflows during and following extraction; and	Partial	See Section 3.3 – The Department requires further justification for the calculated 2.2L/s, noting the information provided in Appendix 6. See Figure 3.3.1 – Please note that this is a concept only and the final void will need to be rehabilitated to the satisfaction of the Secretary.	To note comments and amend the plan accordingly.	Additional text has been added to ensure that it is understood that the final void form and rehabilitation requirements are subject to approval by, and to the satisfaction of the Secretary.
(g) propose management measures to address pit inflows and impacts to groundwater resources.	Partial	See Section 5 – Please provide further details of the SWMP in the document, or alternatively provide a provide a hyperlink to the SWMP. Not satisfied	To note comments and amend the plan accordingly.	The SWMP can be found at: https://www.dropbox.com/s/56n6xonlezak945/11737_SWMP_CMA3F_inclu_WB.pdf?dl=0
The Proponent must implement the management measures proposed in the groundwater assessment to the satisfaction of the Secretary.				
General Comments:				
1. The Department requires clear statements, please replace terms such as "should" or "may" with "will" etc. Not satisfied. 2. Amend the document in accordance with recommendations made by DoI – Lands and Water. Not satisfied. 3. Amend "DPI" to "DoI". 4. Append evidence of DoI – Lands and Water's satisfaction with the Groundwater Assessment.				Noted and amended where appropriate. No feedback was received from DoI.

Attachment 2 – Revised Groundwater Assessment Report

PROJECT

HYDROGEOLOGICAL REVIEW: GROUNDWATER MONITORING & MANAGEMENT BLAKEBROOK QUARRY NIMBIN ROAD, LISMORE NEW SOUTH WALES

PREPARED FOR

LISMORE CITY COUNCIL

DATE

MARCH 2019

GILBERT SUTHERLAND

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TITLE Hydrogeological Review: Groundwater Monitoring and Management, Blakebrook Quarry, Nimbin Road, Lismore, New South Wales

PROJECT MANAGER C. Anderson

AUTHOR(S) E. Rooke

CLIENT Lismore City Council

CLIENT CONTACT Elisha Went

CLIENT REFERENCE –

SYNOPSIS This report describes a hydrogeological review of Lismore City Council's (LCC) Blakebrook Quarry on Nimbin Road, Lismore with reference to previous studies pertaining to site and regional geology, soils, surface water and hydrogeology. In accordance with the requirements of LCC's approved Groundwater Monitoring and Management Sub-Plan (GWM&M Sub-Plan), this report then address issues raised by the New South Wales Department of Industry – Lands and Water (DoI) with respect to the Monitoring Well Implementation Plan (MWIP) that forms part of the GWM&M. This final report includes additional information addressing the NSW Department of Planning & Environment's comments with respect to the first (draft) report.

REVISION HISTORY

REVISION #	DATE	EDITION BY	APPROVED BY
1	12/18	E. Rooke	C. Anderson / L. Varcoe
2	1/19	E. Rooke	C. Anderson / L. Varcoe

DISTRIBUTION

	REVISION NUMBER									
Distribution	1	2	3	4	5	6	7	8	9	10
Lismore City Council	1	1								
G&S file	1	1								

SUMMARY

Lismore City Council (LCC) commissioned Gilbert & Sutherland Pty Ltd (G&S) to conduct a hydrogeological review of the Blakebrook Quarry, Nimbin Road, Lismore ('the site'). The review is necessary to address project approval requirements issued in 2016 by the New South Wales Department of Planning and Environment (DPE). Those requirements include, the preparation of a groundwater assessment report incorporating:

- The scope of monitoring described in LCC's approved Groundwater Monitoring and Management Sub-Plan ('the GWM&M Sub-Plan', dated April 2011).
- The scope of monitoring described in stages 1 and 2 of LCC's Monitoring Well Implementation Plan ('the MWIP', dated 15 April 2013).
- A response to the New South Wales Department of Industry – Lands and Water's (DoI's) 13 April 2016 comments to LCC pertaining to the Larry Cook Consulting groundwater monitoring report (dated 12 January 2016).
- At least two (2) years of monitoring data at all groundwater depths and locations outlined in the above plans.

This report presents a hydrogeological review of the site that considers previous studies pertaining to site and regional geology, soils, surface water and hydrogeology. In accordance with the requirements of LCC's approved GWM&M Sub-Plan, this report then address issues raised by the DoI with respect to the MWIP.

A draft copy of this report was provided to the NSW Department of Planning and Environment in December 2018. In finalising this report, G&S has addressed the Department's feedback and comments provided in its 20 December 2018 letter to Council.

CONTENTS

1 Introduction

Lismore City Council (LCC) commissioned Gilbert & Sutherland Pty Ltd (G&S) to review the hydrogeology of the Blakebrook Quarry, Nimbin Road, Lismore ('the site' or 'the Quarry') as part of project approval requirements issued in 2016 by the New South Wales Department of Planning and Environment (DPE). Those requirements include, inter alia, the preparation of this groundwater assessment report, incorporating:

- The scope of monitoring described in LCC's approved Groundwater Monitoring and Management Sub-Plan ('the GWM&M Sub-Plan', dated April 2011).
- The scope of monitoring described in stages 1 and 2 of LCC's Monitoring Well Implementation Plan ('the MWIP', dated 15 April 2013).
- A response to DoI Water's 13 April 2016 comments to LCC pertaining to the Larry Cook Consulting groundwater monitoring report (dated 12 January 2016).
- At least two (2) years of monitoring data at all groundwater depths and locations outlined in the above plans.

1.1 The site

Blakebrook Quarry is located on Lot 102 DP 817730 on Nimbin Road, and Lot 1 DP 845473 (184 and 184A Keerrong Road), approximately seven kilometres northwest of Lismore (refer Drawing 11737-001 site location plan in Appendix1).

LCC extracts rock resources at several locations within the quarry site namely the northern and southern pits. The New South Wales Minister for Planning has granted LCC a Project Approval under Section 75J of the Environmental Planning and Assessment Act, 1979 ('the Act') to expand its existing quarrying operations from 337,500 tonnes per annum to 600,000 tonnes per annum ('the Project'). This additional extraction will occur within both the northern and southern pits (Drawing 11737-002 in Appendix 1). The life of the Project is estimated to be 30 years (ERM, 2011).

1.2 Project background

As part of an Environmental Assessment (EA), the former New South Wales Department of Planning and Infrastructure (DPI) required evaluation of the extent of impact of the Project on the groundwater environment. The New South Wales Office of Water (NOW) indicated that it held a number of concerns over the limited nature of the original groundwater assessment (see Sub-section 1.4). In consultation with NOW, LCC committed to:

- undertake a detailed groundwater assessment (GWA) prior to any increase in depth of the Quarry; and
- implement a groundwater-monitoring program to observe the Project's impact.

The detailed GWA (as prescribed in condition 17 of modification approval dated 18 September 2017) is required before any vertical extraction of rock below 105 metres Australian Height Datum (mAHD) in the northern pit or below 118.5 m AHD in the southern pit.

The Project Proposal (Table 1, NSW Planning, 2009) sets final extraction depths of 55 mAHD for the northern pit and 105 mAHD for the southern pit. The final floor levels would be 50.8 m for the northern pit and 27.97 m for the southern pit below the then (2008) measured depth to groundwater (ibid.). Consequently, full extraction would require dewatering of the geological profile beneath and adjacent to the pit floors to at least this depth.

The EA predicted that:

- The elevated position of the quarry within Booerie Hill means dewatering of aquifers would be localised, as the hydraulic drawdown would be limited to a shallow cone of drawdown within this topographic feature.
- These drawdown depths would be above the surface elevation of surrounding properties and catchments of nearby creeks.
- All groundwater captured in the pits would be stored in unlined sediment capture dams within

the pits. This groundwater would infiltrate and eventually return to the shallow aquifer through the underlying fractured rock, and thus provide a similar amount of groundwater flow to surrounding areas as the existing landform.

- Groundwater storage capacity in the fractured rocks is very low.

The Quarry does not draw upon groundwater for its water supply and no groundwater extraction bores are known to occur within a one kilometre radius of the quarry site. Accordingly, the EA considered that the potential impact of the proposal on groundwater availability to local users for consumption or environmental flows would be minimal. Nevertheless, LCC has committed to supplementing loss of groundwater to the environment or to local users, if required, by treating and pumping water captured within the quarry pits to the local gullies, which feed the nearby creeks.

The regulatory and approvals history of the Blakebrook Quarry project is summarised in Section 2 below, whilst the terms of reference for the latest GWA are given in Section 3. Section 4 outlines the objectives of this report. Section 5 provides a succinct history of previous investigations and studies in order to appreciate and inform this current study.

Section 6 details site works undertaken to complete the MWIP.

Section 7 presents the groundwater assessment including further development of a hydrogeological conceptual model presented as Attachments 1 and 2 in G&S (2017), a discussion of the standing water level (SWL) reduced water-level (RSWL) data, and an interpretation of a test pumping exercise carried out between 30 September and 2 October 2017.

Section 8 details analysis of the test pumping data by means of an analytical model. A brief description of this model is provided.

Section 9 presents and comments on the latest rounds of water quality analyses (from a sampling round done in May 2018 and from sampling done during the test pumping in September/October).

Section 10 briefly examines potential impacts to sensitive users of the groundwater

In section 11 conclusions are made from integrating these interpretations concerning any potential implications of quarry excavations to the groundwater flow systems. Section 12 provides recommendations concerning further investigations to inform the Project in term of proposed expansions of the Quarry.

1.2.1 Submissions concerning the Project

Whilst NOW did not object to the Project (NSW Planning, 2009a), it noted that the depth of the boreholes used to assess groundwater recharge rates did not reach the final depth of the extraction pits. NOW was satisfied with commitments made by Council to undertake a detailed GWA prior to any vertical extraction below the existing quarry pit floors. In late 2007, LCC consulted with the community concerning the project. The residents of Booerie Creek Road sent a petition to LCC expressing concerns in relation to disturbance of the groundwater table by quarrying and its influence on local springs.

1.3 The project approval

Under Section 75J of the Environmental Planning and Assessment Act, 1979 (NSW Planning, 2009b) for Project Approval of 24 November 2009, the pertinent parts are given under ‘Schedule 3 Environmental Performance Conditions’, specifically Conditions 20, 21 and 25 – ‘Soil and Water Management’.

Part 20 states:

> *‘The Proponent shall undertake and implement a detailed ground water assessment to the satisfaction of the Director-General. This assessment must be:*
>
> *(a) Prepared by a suitably qualified expert in consultation with NOW*
>
> *(b) Submitted to the Director-General for approval by 30 June 2010*

- (c) *Approved by the Director-General before any vertical extraction below 105 mAHD in the northern pit or the commencement of extraction in the southern pit*
- (d) *Adequately assess groundwater resources affected by the northern and southern pits, to the proposed full extraction depths of those pits*
- (e) *Adequately assess all groundwater impacts associated with proposed extraction*
- (f) *Provide data for predicted groundwater pit inflows during and following extraction*
- (g) *Propose satisfactory management measures to address pit inflows and impacts to groundwater resources.'*

Part 21 (relevant part) states:

> *'The Proponent shall prepare and implement a Soil and Water Management Plan for the project to the satisfaction of the Director-General. This assessment must:*
>
> - (a) *be prepared in consultation with DECCW and NOW, and be submitted to the Director-General for approval prior to 30 June 2010; and include a:*
> - (b) *Groundwater Monitoring Program' (GWMP).*

Part 25 states: 'The Ground Water Monitoring Program must include:

- (a) *Detailed baseline data on groundwater levels and quality, based on statistical analysis*
- (b) *Groundwater impact assessment criteria, including trigger levels for investigating any potentially adverse groundwater impacts*
- (c) *A program to monitor groundwater levels and quality*
- (d) *A protocol for further groundwater modelling to confirm the limits to excavation depth across the site would not adversely affect groundwater availability for the environment or local users*
- (e) *A protocol for the investigation, notification and mitigation of identified exceedances of the groundwater impact assessment criteria.'*

In September 2017 a modified approval was granted by NSW Department of Planning.

Part 17 states:

> *The Proponent must undertake a detailed groundwater assessment to the satisfaction of the Secretary. This assessment must be:*
>
> - (a) *prepared by a suitably qualified expert in consultation with DPI Water;*
> - (b) *submitted to the Secretary for approval by 30 December 2018;*
> - (c) *approved by the Secretary before any extraction below 105 m AHD in the northern pit or below 118.5 m AHD in the southern pit;*
> - (d) *adequately assess groundwater resources affected by the northern and southern pits, to the proposed full extraction depths of those pits;*
> - (e) *adequately assess all groundwater impacts associated with proposed extraction;*
> - (f) *provide data for predicted groundwater pit inflows during and following extraction; and*
> - (g) *propose management measures to address pit inflows and impacts to groundwater resources.*
>
> *The Proponent must implement the management measures proposed in the groundwater assessment to the satisfaction of the Secretary.*

Part 19 states:

> *The Proponent must prepare a Soil and Water Management Plan for the project to the satisfaction of the Secretary. This plan must:*
>
> - (a) *be prepared by suitably qualified and experienced person/s approved by the Secretary;*

(b) be prepared in consultation with the EPA and DPI Water;

(c) be submitted to the Secretary for approval within 3 months of the determination of Modification 1, unless otherwise agreed by the Secretary; and

(d) include a:

(i) Site Water Balance that includes:

- *details of:*
  - *sources and security of water supply;*
  - *water use and management on site;*
  - *any off-site water transfers; and*
  - *reporting procedures; and*
- *measures to be implemented to minimise clean water use on site;*

(ii) Surface Water Management Plan, that includes:

- *a program for obtaining detailed baseline data on surface water flows and quality in water bodies that could potentially be affected by the project;*
- *a detailed description of the surface water management system on site including the:*
  - *o clean water diversion system;*
  - *o erosion and sediment controls;*
  - *o dirty water management system; and*
  - *o water storages; and*
- *a program to monitor and report on:*
  - *any surface water discharges;*
  - *the effectiveness of the water management system,*
  - *the quality of water discharged from the site to the environment;*
  - *surface water flows and quality in local watercourses;*

(iii) Groundwater Management Plan that includes:

- *a provision that requires the Proponent to obtain appropriate water licence(s) to cover the volume of any unforeseen groundwater inflows into the quarry from the quarry face or floor;*

and

- *a monitoring program to manage potential impacts, if any, on any alluvium and associated surface water source near the proposed extraction area that includes:*
  - *identification of a methodology for determining threshold water level criteria;*
  - *contingency measures in the event of a breach of thresholds; and*
  - *a program to regularly report on monitoring.*

The Proponent must implement the approved Soil and Water Management Plan as approved from time to time by the Secretary.

1.4 Study objectives

The objectives of this current report are to satisfy the monitoring requirements per the Groundwater Monitoring and Management Sub-Plan (GWM&M Sub-Plan) as follows:

- demonstrate the establishments of a Monitoring Well Implementation Plan (MWIP)
- via the MWIP, collect detailed baseline information on groundwater levels and groundwater quality in the vicinity of the Quarry to confirm the understanding of the groundwater flow regime, including its natural variability;
- via the MWIP, provide ongoing monitoring of groundwater levels and groundwater quality in the vicinity of the Quarry, to identify any changes over time; and,
- demonstrate impacts or otherwise of quarrying deepening on the groundwater flow system.

To meet these objectives, G&S conducted a hydrological review of the site (referencing previous studies of site and regional geology, soils, surface water and hydrogeology). In accordance with the requirements of LCC's approved GWM&M Sub-Plan, this report then address issues raised by the New South Wales DoI with respect to the MWIP.

2 Hydrogeological review methodology

The hydrogeology of the site was reviewed by means of a desktop assessment of available site and project information and previous studies pertaining to local and regional geology, soils, surface waters and hydrogeology.

2.1 Geology, soils, surface waters and hydrogeology

The Quarry is located within Booerie Hill, an igneous outcrop composed of Tertiary-age basalts ascribed to the Lamington Group. The Quarry extracts these basalts that comprise a series of sub-horizontal, stacked and layered, massive and vesicular, ancient lavas of varying thickness and composition.

The site's soils are classified as red-brown Krasnozem soils, which are free draining with rapid infiltration and a low run-off coefficient.

No local springs are present on neighbouring properties, with seeps only being observed after days of prolonged heavy rainfall. Surface water flows from the site in a northwesterly and southeasterly direction via ephemeral gullies, which feed Terania Creek to the west and Blakebrook Creek to the east. Both creeks feed Leycester Creek, which joins Wilsons River at Lismore.

The bulk of the Quarry workings are hosted within a near-surface, local scale, unconfined aquifer that is, in turn, hosted in the Krasnozem soils and an underlying regolith of weathered, fractured massive and vesicular basalt (ERM, 2011). Below this aquifer, there is a deeper, intermediate-scale confined to semi-confined groundwater flow system within the interlayered and fractured horizons of the basalt (ibid.) Deeper aquifers are effectively separated and confined by a relatively thick sequence of massive, poorly fractured basalt.

The shallow aquifer responds to rainfall-recharge reflected in the formation of seeps. Groundwater flow in this shallow regolith-hosted aquifer is a function of topography whereby groundwater is recharged via the surrounding hills and ridge slopes. The deeper aquifers do not respond quickly to rainfall-recharge events (ibid.).

A characteristic of aquifers such as these is that the groundwater flow systems are likely isolated into groundwater flow 'cells', rather than homogenous aquifer systems (ibid.). This implies that the overall effect of quarrying on these aquifers is predicted to be only in the immediate vicinity of the Quarry, with minor and localised groundwater drawdown occurring. Hence, ERM (2011) concluded that any impacts to groundwater would be restricted to Blakebrook Hill at the Quarry site.

2.2 Previous investigations

Relevant previous investigations pertaining to the site and locale are discussed in this section.

2.2.1 Groundwork Environmental Management Services Pty Ltd 2008

As part of the EA, Groundwork Environmental Management Services carried out a groundwater investigation in 2008 ('Groundwork 2008'). The results of this investigation indicated that:

- Quarry operations reside in a near-surface, local scale, unconfined aquifer
- The proposed expansion of the Quarry would likely intersect only the shallow, unconfined aquifer.
- This aquifer is situated between surficial soils, and weathered, fractured, massive and vesicular basalts
- This aquifer is directly recharged by rainfall
- This aquifer would likely be affected by quarrying activities
- Minor groundwater inflow would occur to the Quarry from this aquifer
- Site infrastructure would be able to deal with this volume of water
- A deeper, 'intermediate-scale flow system' is located below this aquifer
- This deeper aquifer is unlikely to be affected by quarry operations

- Due to the favourable topography of the site, and low groundwater yields, the hydraulic drawdown caused by the proposed quarry's expansion would be limited to the immediate vicinity of the Quarry, and is unlikely to impact on local groundwater conditions beyond Blakebrook Hill.
- Groundwater quality at the Quarry is good (in terms of pH, conductivity, turbidity and suspended solids).
- The groundwater contains very low levels of coliforms, hydrocarbons and metals below the pertinent guidelines for water quality for industrial use.
- The potential for pollution to aquifers is considered low.

Groundwater investigations undertaken for the EA was limited, and consisted of:

- Measuring SWLs in each of seven rock resource exploration drill-holes completed in late 2006.
- Depths to SWLs measured in these seven holes varied between 0.1 m and 14.9 m below ground level (mBGL).
- These SWLs are equivalent to RSWL[1] 105.8 mAHD beneath the existing pit floor to 132.97 mAHD toward the east and south of the site, where the northern and southern pits are to be expanded and excavated, respectively.
- One of these drill holes was pumped at a rate of about 0.6 - 0.7 L/s from depths of 18 - 25 mBGL, and groundwater was sampled for analysis.
- SWLs were recorded for a further 31 exploration drill holes (out of 39) completed on site.
- Depths to SWLs varied between 0.1 m and 43 mBGL.
- These SWLs are equivalent to 197.3 mAHD and 92.3 mAHD.
- Most measurements were between 197.3 mAHD and 180 mAHD.
- The eight (8) holes for which no data are recorded are presumed to have been 'dry' holes.

Overall, this data indicates that the hydrogeology is complex, discontinuous and characterised by isolated groundwater flow 'cells'; their depth, extent, flow continuity being dependent on changes in basalt lithology, variable weathering, jointing and faulting.

2.2.2 Environmental Resources Management Australia Pty Ltd 2011

In 2011, on behalf of LCC, Environmental Resources Management Australia (ERM) prepared a Groundwater Monitoring and Management Sub-Plan (GWM&M Sub-Plan) for the Blakebrook Quarry Expansion Project. The GWM&M Sub-Plan's primary purpose was to provide procedures to:

- 'describe how Lismore City Council will manage and control risks associated with groundwater during the expansion of the quarry;
- ensure the protection of any previously undetected groundwater springs when carrying out the Project activities;
- ensure that the relevant stakeholders are involved in the formulation and implementation of this GWM&M Sub-Plan;
- address the requirements of applicable legislation and any ongoing approvals as they are applicable to the Project;
- meet the Project Conditions of Approval (CoA); and
- address the requirements of the Project Environmental Assessment Report (EA) (ERM, 2009).'

The objectives of the GWM&M Sub-Plan were to:

- 'identify environmental obligations and legislative requirements applicable to groundwater monitoring and management during the Project;

[1] RSWL = reduced standing water level (depth to water) in metres AHD.

- describe the specific environmental management requirements and strategies for environmental elements, define objectives and set targets for environmental performance;
- to collect detailed baseline information on groundwater levels and groundwater quality in the vicinity of the quarry to provide an understanding of existing groundwater regimes, including natural variability;
- to provide ongoing monitoring of groundwater levels and groundwater quality in the vicinity of the quarry, to allow prompt identification of any changes over time;
- to demonstrate that quarrying does not adversely impact groundwater resources;
- consult with the New South Wales Office of Water (NOW), Department of Planning (DoP) and Lismore City Council (LCC) during the preparation and implementation (as required) of this GWM&M Sub-Plan; and
- define key roles and responsibilities.'

Table 5.2 of the GWM&M Sub-Plan presents a risk assessment and mitigation matrix. Risks (likelihood and consequence) posed to groundwater quality and quantity from quarrying lowering groundwater levels, reducing groundwater recharge, causing water discharge, and from post-quarrying activities were considered low. Risks posed to groundwater dependent ecosystems (GDE) from quarrying lowering water levels affecting moisture regimes, reducing groundwater quality, affecting surface water quality and/or vegetation health were consider low. The likelihood posed by hazardous chemical spills was considered moderate whilst the consequence of a spill occurring was considered low (ibid.).

Recommendations of managing identified risks (from Table 2.5, ibid.) were by monitoring quarry water, and groundwater levels and quality on a quarterly basis, and by visually monitoring vegetation health onsite and on adjoining lands.

The draft GWM&M Sub-Plan was distributed to NOW, NSW Planning, and Council for comment (as summarised in Table 5.1, ibid.). The feedback from NOW was as follows:

- Three nested piezometers should be used at each monitoring location.
- Piezometers or monitoring bores should be constructed using preferred drilling techniques such as air or water drilling, rather than diamond drilling.
- Drillers with appropriate drilling licences should be used.
- Test or monitoring bores must be licensed and appropriate drilling logs forwarded.
- Licence conditions on the completed bores would likely include monitoring and reporting measures.
- SWLs should be monitored more frequently than for water quality measurements.
- In the first two years SWLs be checked weekly after significant rainfall events to gauge aquifer responsiveness, until a pattern is established or it is shown that SWLs show little fluctuation, when measurement at three-monthly intervals is adequate.

LCC responded as follows:

- Accepted recommendation of NOW in relation to groundwater monitoring.
- Recommended that three nested bores be installed in one monitoring location initially to allow testing to evaluate groundwater conditions and confirm the optimum number of bores to be installed at the remaining monitoring locations at a later date.

To accord with the GWM&M Sub-Plan and with LCC, ERM proposed the construction of nested monitoring bores at three locations around the Quarry extraction areas with one nest of monitoring bores to be installed to three depths at one location initially. This would allow for testing of the three bores to evaluate groundwater conditions in each bore, and to make recommendations for the remaining two bore locations. Figure 6.1 (ibid.) provided indicative locations of these groundwater bores.

ERM specified the installation of nested bores to intercept up to three groundwater-bearing zones as follows:

- One piezometer to monitor the shallower water table below the pit; to be screened to monitor SWLs in the vesicular basalt, shown in the EA,[2] generally found below 100 mAHD (180 mRL). This is likely to be the most responsive to rainfall events and seepage.
- A second piezometer constructed and screened to monitor pressures in the deeper basalt, approximately below 70 mAHD (150 mRL) but above the final depth of 55 mAHD.
- A third piezometer constructed to gauge pressures below the proposed depth of the pit, (below 55 mAHD, 135 mRL) to attempt to identify whether there is any upward pressure or water movement from deeper aquifers which can influence the quarry water balance.

ERM (2011) stated that the local field investigation at the Quarry would form the basis of a quantitative data analysis that would analyse:

- borehole log data to characterise subsurface geology and aquifers;
- RSWLs[3] within bores to determine groundwater elevations;
- groundwater quality samples; and,
- permeabilities (hydraulic conductivities) of the geology.

Groundworks 2008 indicated that the majority of the environmental flows surrounding the Quarry are generated by large or prolonged rainfall events. This can potentially be supplemented by seepage of groundwater from springs at Blakebrook Hill.

Consultation with surrounding landholders by Council identified that springs are observed immediately following rainfall events. These springs dissipate quickly following the cessation of the rainfall event. No landholders in the area have directly spring fed dams.

Aquifer Testing

ERM recommended conducting aquifer test pumping to estimate the hydraulic properties of the water bearing zones beneath the Quarry with measurement of groundwater-level drawdown followed by a recovery test (upon cessation of pumping). The drawdown would be analysed using proprietary software[4] to obtain estimates of the hydraulic conductivity (K) for each bore.

Site Inspection

Ongoing inspection of quarry faces must be undertaken by a 'Quarry Operation Coordinator' to evaluate if water-bearing zones had been intercepted.

Groundwater Level and Quality Monitoring

Groundwater quality monitoring would comprise SWL gauging and sample collection to be tested by a NATA[5] registered laboratory (ibid.). Data collected during the groundwater monitoring would:

- Ensure the Quarry is operating as anticipated with respect to groundwater quality protection
- Gauge the impact (if any) of the extraction activities on SWLs across the site
- Identify any unforeseen impacts from quarrying operations
- Implement measures to prevent unforeseen impacts from quarrying
- Verify that the Quarry is achieving its environmental objectives.

Groundwater level and quality monitoring would be undertaken in the bores at the site. If plant movements, blasting or mass movement damaged bores, alternative groundwater testing sites would be established.

Initially, SWLs were to be checked weekly and after significant rainfall events to gauge aquifer responsiveness.

Initially, groundwater quality monitoring was to be undertaken quarterly to evaluate the influence of rainfall and quarrying activities on SWLs and

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[2] Figure 3, Appendix E, Groundworks (2008).

[3] RSWL = reduced standing water levels (metres Australian Height Datum).

[4] Using the Bouwer-Rice (1976) and the Hvorslev (1951) analytical methods applied to unconfined aquifers.

[5] National Association of Testing Authorities.

quality. The sampling frequency was to be reduced to annually following the collection of a substantial dataset and if water quality generally met performance criteria (ibid.).

Assessment criteria

The purpose of the ERM groundwater-monitoring program (GWMP) was to establish baseline groundwater conditions and track any changes over time as quarrying continues, to demonstrate that quarrying is not impacting on groundwater (ERM, 2011).

At the time there was insufficient data available to calculate statistically derived site-specific trigger levels for the range of analytes measured (ibid.). On that basis, and given the assessed low potential impact on groundwater from future quarrying operations, it was proposed to compare the data against criteria from the following published guidelines:

- ANZECC (2000) Australian and New Zealand Guidelines for fresh and marine water quality; and
- NHMRC (National Health and Medical Research Council) (2004) Australian Drinking Water Guidelines.

The assessment criteria for discharge water and groundwater were presented in Table 7.2 of ERM (2011). The need for calculating site-specific trigger levels would be reviewed after two years of operations once a larger data set is available (ibid.). ERM (2011) went on to recommend the preparation of quarterly and annual reviews of the GWMP, including the establishment of environmental 'trigger levels' and actions if an exceedance is triggered.

2.2.3 EAL Consulting, Southern Cross University 2012

In 2012, EAL Consulting Southern Cross University, undertook a revision of the GWMP (under Condition 25) pending the undertaking of the detailed GWA as specified in Condition 20 ('EAL 2012'). This GWA could not be completed until the nested groundwater bores had been installed.

LCC received DoPI's 12 September 2011 correspondence requesting that a MWIP be prepared. The purpose of EAL's (2012) report was to make recommendations for the installation of a GWMP network (i.e. sets of nested bores, per ERM, 2011) in order to carry out the GWA. The objectives of the MWIP were to:

- Describe the history of the Project's groundwater monitoring proposals
- Outline the proposed GWMP's network (locations, and bore constructions, construction staging, and completions)
- Define actions required to complete the monitoring bores for each stage
- Plan and describe the monitoring program.

ERM (2009) committed to two monitoring bores at three nominated locations. NOW (letter of 1 June 2010) requested an amendment by necessitating the installation of three nested groundwater monitoring bores at each of the three locations. NOW considered that the variable strata and the probability that the shallow piezometer (100 mAHD/180 mRL) might run dry as the pit was deepened. NOW also noted that Groundwork (2008) had provided no data on the stratum between 55 mAHD and 70 mAHD.

The agreed locations are shown on Figure 3 of Letter to the former DPI re. MWIP and identified as N1 and N2 (North Pit), and S1 (South Pit). Each monitoring site was located as far as practicable on the 130 mAHD contour (and surveyed prior to bore drilling). The planned installation details are summarised in Table 2.2.3.1 (on the following page). The as-constructed details of the monitoring bores are given in Table 2 of Cook (2016).

The MWIP recommended a staged approach of the GWMP network over a two years period. Stage 1 – installation of four MBs, N1-1, N1-2, N2-1 and N2-2 no later than 30 November 2013. Stage 2 – completion of MB nests, N1-3 and N2-3, and the installation of MB nest S1-1, S1-2 and S1-3 no later than two years after the completion of the Stage 1 works. Stage 1 allowed the commencement of data at the shallow and intermediate aquifer depths in two locations,

Table 2.2.3.1 Nested Monitoring Bore (Piezometers) Proposed Completions, Blakebrook Quarry to satisfy the MWIP (adapted from EAL, 2012)

Bore description	Elevation (mAHD)	Target total depth (mBGL)	Anticipated screened depth (mAHD)	Anticipated lithology
Shallowest				
N1-1	130	~ 30	100	Vesicular basalt
N2-1				
S1-1				
Intermediate				
N1-2	130	~ 60	70	Basalt / smectite-altered basalt
N2-2				
S1-2				
Deepest				
N1-3	130	~ 75	55	Basalt
N2-3				
S1-3				

within the zone of influence of the current working pit. The bores were to be completed using 50 mm NB Class 12 PVC pipe.

Recording of SWLs was recommended, initially weekly after significant rainfall events to gauge rainfall-recharge response. A significant rainfall event being defined as greater than 20 mm of rainfall received in a 24-hours period. When a pattern is established or no response to rainfall is noted then SWLS could be undertaken quarterly. Quarterly sampling of groundwater quality and analysis is to occur until such time that sufficient data is available to allow a reduction to annual sampling.

2.2.4 Lismore City Council 2013

Lismore City Council (LCC) sent the MWIP (as provided to and agreed by NOW) to the former DPI on 4 June 2013. It proposed an approach of staged implementation, stating that any changes to the MWIP would be considered in light of the Stage 1 drilling and groundwater monitoring results. LCC engaged Groundwork to implement Stage 1.

2.2.5 Larry Cook Consulting 2016

In 2016, Council commissioned Larry Cook Consulting Pty Ltd (‘Larry Cook’) to prepare a groundwater monitoring report. This report documented ongoing automated SWL measurements and groundwater quality testing in the bore network established by Groundwork.

Cook (2016) reported that a network of four monitoring bores[6] had been established following the preparation of the 2011 GWM&M Sub-Plan. It comprised two monitoring bores – a shallower, ‘proximal’, and a deeper bore constructed at two sites designated as ‘N1’ and ‘N2’ (refer Table 1 of this report, and Cook Figure 3). These bores were located to monitor groundwater levels, aquifer ‘depressurisation’, and the detection of any contaminants migrating beyond the Quarry.

Cook (2016) presented SWL data from these bores as a set of hydrographs, and rainfall data from Lismore Airport automatic weather station (BoM station code, 058214). One SWL was recorded in each bore on 19 September 2013 (see Table 3); thereafter, continuous SWL recordings commenced 28 October 2013. Pertinent observations from this SWL data, summarised after Cook (2016) follows:

BQN1-A

- *from September 2013 to mid-August 2015, SWL is noted to be relatively static; and,*

[6] Essentially, piezometers as their construction details indicate that they were screened against discrete water-bearing zones and isolated from the surface by grout above these zones.

- *from August 2014 to November 2015, a slight, but gradual rise in SWL.*

The gradual water-level rise is likely due to diffuse, distributed recharge characteristic of the deeper aquifer zone (consistent with the ERM 2011 conclusions). No impacts on the SWLs were detected on the intermediate groundwater flow system.

BQN1-B

- *from September 2013 to late April 2014 , SWL gradually decreases;*
- *from late April 2014 to late August 2014, SWL decreases more rapidly;*
- *from late August 2014 to February 2015, SWL remains relatively static*
- *from February 2015 to May 2015, SWL rises 0.5 metres; and,*
- *from May 2015 to November 2015, SWL decreases.*

BQN2-A

- *from September 2013 to late April 2014, SWL is relatively static;*
- *October 2013 and January 2014, a sudden drawdown of SWL is a response to pumping for groundwater sampling; and,*
- *post-April 2014, erratic nature of the hydrograph and breaks in data indicate a faulty water-level logger. The logger was removed in March 2015.*

No impacts from quarrying on this deeper aquifer zone were detected.

BQN2-B

- *from September 2013 to late January 2014, SWL gradually decreases by a cumulative total of approximately 1 m;*
- *from late January 2014 to February 2015, SWL slightly rises then proceeds to 'plateau';*
- *February 2015, 2 m decline in SWL;*
- *from February 2015 to November 2015, SWL is static; and,*
- *October 2013 and January 2014, a sudden drawdown of SWL is a response to pumping for groundwater sampling*

The decline in SWL in February 2015 was potentially due to impacts from quarrying, consistent with ERM (2011) stating that localised impacts to the groundwater system can be realised in the immediate vicinity of the Quarry.

Regular parasitic 'saw-tooth' SWL fluctuations observed in bores, BQN1-B and BQN2-B appear to correlate with rainfall events suggesting rapid rainfall-recharge of this shallow aquifer system (consistent with ERM, 2011's conclusions).

Groundwater sampling was undertaken in the monitoring bores between September 2015 and November 2016. The sampling was undertaken to characterise the groundwater quality, and to identify any risk posed from quarrying activities. The interpretation of the results (after Cook, 2016) follows:

- *Bores BQN1-A, BQN2-A and BQ2-B – pH nearly neutral to moderately alkaline*
- *BQN1B – pH is slightly acidic to near neutral*
- *EC is moderately to highly saline*
- *Detection of sporadic, low levels of oils and greases*
- *In some samples anomalously high concentrations of aluminium and total iron*
- *Concentration of other metals were either less than the LOR or at trace to low concentrations*
- *Low concentrations of nutrients.*

pH distribution is characteristic of slightly alkaline groundwaters in the deeper aquifer, and slightly acidic groundwater (BQN1-B) in the shallow aquifer associated with rainfall-recharge.

The EC of BQN1-A was consistently higher (1,800 to 2,600 μS/cm) than those in the other bores (approximately 750 to 1,500 μS/cm). TSS ranged from undetectable in BQN1-B to 1,340 mg/L in BQN2B. TSS levels fluctuated in bores BQN1-A and BQN2-A.

Low concentrations of nitrate and nitrite were recorded in most samples and ranged from undetectable to 1.033 mg/L in BQN2-A. The relative low levels of nitrite indicate the groundwater is generally subject to oxidising conditions (as would be expected in shallow to intermediate groundwater flow systems). The presence of nitrate might be associated with past agricultural activities (ibid.).

BQN1-A recorded 22.7 mg/L aluminium. The source of this aluminium is likely to be suspended clay particles from weathered basalt. The pH of the samples suggests that the aluminium is in suspension rather than in solution (ibid.).

An anomalously high concentration of total iron (19.4 mg/L) was recorded in BQN1-A. Cook (2016) did not comment on this anomaly.

Cook (2016) stated that the source of oils and greases detected on an intermittent basis in all four monitoring bores probably resulted from residual contamination from drilling additives.

Overall the groundwater quality data indicated little impact from quarrying activities to the underlying aquifers (ibid.).

2.2.6 DPI Water 13 April 2016 letter to LCC

In reviewing Cook (2016), the former DPI Water (2016) responded to Council. These responses are summarised below:

- The quality control of the monitoring program was questioned.
- The monitoring program was deemed adequate, but the SWL download frequency should be reviewed to ensure that the time period between potential logger malfunctions is minimised.
- The frequency of SWL logger downloads was unclear.
- A faulty SWL logger remained unaddressed for 75% of the 2-years period of record.
- Approved water quality parameters were sampled and analysed. Analysis for TPH BTEX was supported in order to identify the source of the hydrocarbons
- SWL monitoring should continue (in view of the finite 2 m SWL decline observed in the shallow aquifer system)
- A recommendation to commit to coordinate water level data collection activities at 6 monthly intervals or greater.

2.2.7 Gilbert & Sutherland 2016 site investigation and 2017 report

As part of requirements to fulfil the terms of the GWA, G&S staff made a site familiarisation visit on 7 July 2016 (G&S, 2017).

An interim letter report (G&S, 2017) summarised the work to that date. The letter also addressed the intent of the Quarry to expand to the north of the southern pit (at a location some 85 m from the southern bore cluster; see next paragraph) to enable extraction of 4 to 6 m depth of 'cap rock'. The natural ground surface at this location was stated to vary between 127.5 and 132 mAHD.

The letter report stated that two clusters of groundwater monitoring bores had been installed[7] including a 'southern cluster' comprising three bores, Bore BQS1S, BQS1I, and BQS1D, each targeting a different water bearing zone (see Table 2). It was stated that '*The water bearing zones interflow and are formed of vesicular and fractured basalt, and sediments between successive basalt flows, which form the ridge on which Blakebrook Quarry is situated*'.

It was also reported that groundwater levels had been recorded using down-hole loggers, and that this data was retrieved and downloaded regularly by GDCS.

[7] The installation of two deeper monitoring bores in the northern two monitoring bore clusters was not described.

Based on this southern cluster, a simple, layered hydrogeological conceptual model for the southern pit was produced (ibid.). Attachment 1 of that letter, showed the location of the conceptual model's section and the three water-bearing zones, and gave the maximum groundwater levels in each zone (see Figure 2). The depths to these water-bearing zones were obtained from the drilling bore logs. It was indicated that the shallowest SWL (RSWL 105.64 mAHD recorded in the period, 6 September 2016 to 6 June 2017) in the southern area is that of the shallow water-bearing zone. Based on the removal of cap rock, it was stated that the proposed extraction depth would be 122 mAHD. As such, the water-bearing zones would not be interfered with, and a buffer of some 15 m or more would be maintained.

3 Groundwater assessment – data interpretation

3.1 Hydrogeological conceptual model

A simple hydrogeological conceptual model (HCM) has been formulated by integrating and interpreting data collected as part of the drilling and bore completions. Data used in this interpretation was taken from:

- Bore logs (see Appendix 2)
  - The geologist's logs – to identify aquifers and non-aquifers.
- Table 3.1.1
  - Bore coordinates – for spatial orientation
  - Ground) Water strike - to bound the aquifers in conjunction with the geologist's logs.
  - SWL data (at time of bore completions) – to understand relative depths to the water table / potentiometric surface.
- Table 3.1.2 (following page);
  - Bore elevations – to establish a common SWL datum (mAHD) to interpret reduced level SWL (RSWL) and the tops and bottoms of aquifers.
  - RSWL data – to understand the potentiometry of the aquifers.
  - Using the interpreted water-bearing zone (monitored by each bore).

Table 3.1.1 Water bore completion details, Blakebrook Quarry

Bore ID	RN (NOW)	Easting	Northing	Completion date	TD (mBGL)	Water strike (mBGL)	Casing Depth (mBGL)	Screened (mBGL)	SWL (mBGL)
Northern Two Clusters of Monitoring Bores (re. BQN1A, BQN1B, BQN2A, BQN2B, NOW & Cook p4 (2016))									
BQN1-B (BQN1-S)	GW307 323	524993.7	6818662.9	25/7/13	30	15 - 19	30	12 - 21	4.5
BQN1-A (BQN1-I)	GW307 322	524757.0	6818728.0	26/7/13	60	52 - 60	48	48 - 60	42.5
BQN1-D		524994	6818654.5	29/8/16	115	56 - 63; 99 - 109	115	97 - 109	?
BQN2-B (BQN2-S)	GW307 325	524437.7	6818619	28/7/13	42	28 - 38	42	30 - 42	28.5
BQN2-A (BQN2-S)	GW307 324	524436.7	6818615.5	27/7/13	60	52 - 60	60	51 - 60	31.3
BQN2-D		524447.5	6818616.5	29/8/16	133	19 - 24; 44 - 46.5; 112 - 117	133	109 - 121	
Southern Cluster of Monitoring Bores (re. Form A - particulars of completed work, 25/08/16 & GS letter 27/07/17)									
Bore ID	RN (NOW)	Easting	Northing	Completion date	TD (mBGL)	Water strike (mBGL)	Casing Depth (mBGL)	Screened (mBGL)	SWL (mBGL)
BQS1-S		524684.5	6817848.6	25/8/16	55	38 - 43	55	40 - 52	30
BQS1-I		524681.5	6817842.8	24/8/16	73	34 - 39; 64 - 70	73	58 - 70	30
BQS1-D		524678	6817837.2	23/8/16	102.7	34 – 39; 64 – 72; 95 - 99	102.7	87.7 – 99.7	30
Test Pumping Bore									
Bore ID	RN (NOW)	Easting	Northing	Completion date	TD (mBGL)	Water strike (mBGL)	Casing Depth (mBGL)	Screened (mBGL)	SWL (mBGL)
BQPB-1		524757	6818728	/2017	127	56 - 127		97 - 127	37

Table 3.1.2 Water bore water-bearing zones and standing water-levels, Blakebrook Quarry

Bore ID	Easting (m)	Northing (m)	Ground surface elevation (mAHD)	Elevation MP (mAHD)	Stickup MP (m)	Water bearing zone monitored	SWL (mBGL) 19.9.2013*	RSWL (mAHD) 19.9.2013*
Northern Cluster								
BQN1B (BQN1S)	524993.7	6818662.9	127.47	128.08	0.61	Shallow	4.50	122.97
BQN1A (BQN1I)	524757.0	6818728.0	127.74	128.5	0.76	Intermediate (lower)	41.70	86.04
BQN1D	524994	6818654.5	128.04	128.84	0.8	Deeper		
BQN2B (BQN2S)	524437.7	6818619	108.08	108.91	0.83	Intermediate (upper)	26.81	81.27
BQN2I (BQN2A)	524436.7	6818615.5	108.14	108.78	0.64	Intermediate (lower)	30.10	78.04
BQN2D	524447.5	6818616.5	108.14	109.06	0.92	Deeper		

*SWL measured just after construction completion of the bores.

Southern Cluster								
Bore ID	Easting (m)	Northing (m)	Ground surface elevation (mAHD)	Elevation MP (mAHD)	Stickup MP (m)	Water bearing zone monitored	Minimum groundwater level (mAHD)'	Maximum groundwater level (mAHD)'
BQS1S	524684.5	6817848.6	133.59	134.42	0.83	Intermediate (upper)	101.55	105.64
BQS1I	524681.5	6817842.8	133.3	134.23	0.93	Intermediate (lower)	84.00	84.83
BQS1D	524678	6817837.2	132.92	133.68	0.76	Deeper	53.59	53.97

'Measured during the period 6 September 2016 to 6 June 2017 inclusive.

Test pumping bore								
Bore ID	Easting (m)	Northing (m)	Ground surface elevation (mAHD)	Elevation MP (mAHD)	Stickup MP (m)	Water bearing zone monitored	Minimum groundwater level (mAHD)'	Maximum groundwater level (mAHD)'
BQPB1	524757	6818728	--	--	0.3	Deeper	--	--

The groundwater bore locations are shown on Drawing 11737-002 attached as Appendix 1. A generalised, descriptive section of the HCM is represented in tabular form in Table 3.1.3. It is based on a 'normalised' datum of ground level being at 128 mAHD across the site. This is deemed appropriate given the horizontal layered geological system (of ancient basalt flow across the paleo-landscape), and to satisfy the analytical modelling described herein.

A comparison is made with the HCM presented as 'Drawing 002' in Attachment 1 of G&S (2017) and Table 3.1.3 below. The discrepancies in layer thicknesses between the current HCM and the southern pit HCM of G&S (2017) is due to the former integrating driller's geological logs from all of the bores (BQN and BQS series, and BQPB-1), whilst the latter considers only those logs of the BQS series (that is the 2017 only considered the southern pit). It is noted that the current report revises the notation of the 'Shallow aquifer' based on the log of bore, BQN1-B. G&S (2017)'s 'Shallow aquifer' becomes part of the 'Intermediate – upper aquifer' in the current study. BQN1-B intersects a shallower aquifer than the rest of the bores do. This aquifer is either discontinuous (pinches out) or bifurcates across the site. Also, it is potentially topographically isolated ('perched') as a result of its elevated situation (in the northern area of the quarry).

Table 3.1.3 Hydrogeological Conceptual Model of the Groundwater System underlying Blakebrook Quarry

Aquifer No.	Descriptor (relative position)	Lithology (from driller's logs)	Thickness (m)	RL depth (mAHD)	Thickness (m)* (G&S, 2017 southern pit only)
Semi-confining bed	Aquitard	Clay, weathered basalt, basalt	15	113	30 (Aquitard)
1	'Shallow'	Fractured basalt	4	109	
Semi-confining bed	Aquitard	Basalt	14	95	
2	'Intermediate – upper'	'Honeycomb' (vughy) basalt	7.5	87.5	9
Semi-confining bed	Aquitard	Basalt	15.5	72	21
3	'Intermediate – lower'	Fractured basalt	7	65	8
Semi-confining bed	Aquitard	Basalt	36.5	28.5	23
4	'Deeper'	Fractured and 'honeycomb' (vughy) basalt	6	22.5	4
Confining bed	Non-aquifer	Hard basalt	> 6	< 16.5	> 3.4

* based on interpretation of the driller's logs for the BQS series of monitoring bores, only.

Observing the differences in RSWL (refer Table 2, and the hydrographs in Appendix 3) between the bores reinforces the assignment of the shallow aquifer to BQN2-B only. As excavation continues and the geology is further explored it will be possible to refine the hydrogeological conceptual model and potentially integrate it with a digital elevation model, which can be represented in a 3-D block diagram format.

3.2 Groundwater analytical model

Using the HCM and the test pumping data as a basis, a groundwater analytical model has been developed using MLU. This analytical model has been used to obtain aquifer hydraulic parameters necessary for further predictions of potential impacts to the groundwater system (and to inform any potential requirements for dewatering of the Quarry during its planned progressive excavation).[8]

3.2.1 MLU and the local groundwater system

MLU for Windows[9] is an analytical groundwater-modelling tool to compute heads and drawdowns/head impress, analyse a variety of aquifer test data, and design well fields in layered aquifer systems.

MLU uses a combination of Laplace equations, the super-position principle, both in space (multiple wells) and time (variable discharges), and the Levenberg-Marquardt algorithm for parameter optimisation.

It is ideal for analysing multi-aquifer systems (aquifers and aquitards) and/or layered (stratified) aquifers. The former is the groundwater system prevailing at the Blakebrook Quarry site. It is constrained by the assumptions made that all layers are assumed homogeneous, isotropic and of infinite extent.[10]

An iterative process has produced the analytical model. Aquifer/aquitard RL and thickness information (using Table 4), and drawdown data from the field test pumping program has been entered. Calibration of the model follows using a variation of combinations of hydraulic conductivities

[8] A detailed study of the Quarry dewatering schedule does not form part of the scope of this report. Depending on quarrying activities and staging this must be considered as excavation progresses including satisfying any future permitting activities.

[9] See http://www.microfem.nl/products/mlu.html

[10] The Journal of Hydrology 90, p. 231-249 (1987) and 225: p. 1-18 & 19-44 (1999) provide theoretical background information on the applied analytical solution techniques for multiple aquifer systems.

and/or storativities (from sensible values from basaltic rock aquifers based on professional experience) until statistical meaningful convergence of values, and best possible matching curves to the drawdown graphs are found.

The groundwater system can be regarded for modelling purposes as a layered, multi-aquifer system. Conceptually, four layers represent the groundwater system with the top elevation being the top of the averaged RSWL in Bore, BQN1-B.[11] All the aquifers are confined with leakage through the separating confining layers ('aquitards'), C1, C2, C3 and C4.

The 'Shallow aquifer' (Layer A1 in Table 6) is 4 metres thick and its top lays 15 mBGL. The remaining three aquifers ('Intermediate – upper' and 'lower' and 'Deeper' – Layers A2, A3 and A4) are 7.5 m, 7 m and 6 m thick, respectively (Table 6). Below Layer A4, there is presumed to be no further aquifers; and, if present, they would not hydraulically impact on quarrying operations (given that the RL level of the model finishes at approximately 15 mAHD, i.e. some 40 metres below the deepest planned depth of excavation).

The confining layers between these three lower aquifers exhibit some minor permeability that allows leakage of water between the aquifers. Comparing RSWLs within all of the bores (refer Appendix 3) shows that all this leakage is downwards with no vertical upward flow component.

3.2.2 Modelling constraints and limitations

Modelling best practice requires that constraints and limitations be identified and considered for their influence on the overall aims of the modelling and its outcomes. Accordingly, the following constraints and limitations are acknowledged:

1. Drawdown data from monitoring bore, BQN2-A was 'switched off' whilst running the model as it was deemed to be bad data.
2. The model failed to adequately simulate the drawdown data from monitoring bore, BQN1-B (in the 'Shallow aquifer'). The layer-cake feature of the HCM does not reflect the natural situation of the 'Shallow aquifer', and MLU cannot handle anisotropic, structurally complex aquifers; e.g. atrophy, bifurcation, vertically isolated).

These constraints and limitations were assessed as not compromising the modelling outcomes for the following reasons:

1. The groundwater flow systems are likely isolated into groundwater flow 'cells', rather than homogenous aquifer systems (ERM 2011). This supports the prediction that the overall effect of quarrying on these aquifers will be in the form of minor and localised groundwater drawdown, limited to the immediate vicinity of the Quarry.
2. Quarry operations reside in a near-surface, local scale, unconfined aquifer (Groundwork 2008) with the proposed expansion likely to intersect only the shallow, unconfined aquifer. The minor groundwater inflow to the quarry (predicted by Groundwork 2008) is from this aquifer.
3. The site topography and low groundwater yields were identified (by Groundwork 2008) as favourable as the hydraulic drawdown caused by the proposed quarry expansion being limited to the immediate vicinity of the Quarry. Groundwork 2008 found drawdown would not impact on local groundwater conditions beyond Blakebrook Hill (noting most measured SWLs were between 197.3 and 180 mAHD.
4. Additional information sources have informed the understanding of localised near-surface groundwater behaviours. Council consultation with surrounding landholders identified that springs are observed immediately following rainfall events and quickly dissipate after the events cease.
5. Table 3.1.2 (above) demonstrates that bore BQN1-B intersects a shallower aquifer than the rest of the bores. This aquifer is either discontinuous ('pinches out') or bifurcates across the site. It is potentially topographically isolated ('perched') as a result of its elevated

[11] A formality to obey the model setup's protocol.

Table 3.2.3.1 Analytical Model of the Groundwater System underlying Blakebrook Quarry

Layer	Thickness (m)	Kh or Kv (m/min)	Kh or Kv (m/d)	T (m2/min)	T (m2/day)	Storage coefficient, S (dimensionless)	Name
C1	15	5.90E-09	8.50E-06				
A1	4	0.006679	9.62	0.026716	38.5	9.99E-04	Shallow aquifer
C2	14	5.22E-09	7.51E-06				
A2	7.5	0.001413	2.03	0.010598	15.3	7.71E-08	Intermediate (upper)
C3	15.5	1.69E-04	0.24				
A3	7	0.000412	0.59	0.002881	4.1	6.24E-08	Intermediate (lower)
C4	36.5	4.20E-05	0.06				
A4	6	0.000338	0.49	0.002025	2.9	1.60E-03	Deeper aquifer
C5	6	1.00E-06	1.44E-03				

situation in the northern area of the quarry. Observing the difference in RSWL between the bores (refer Table 3.1.2 and hydrographs in Appendix 3) reinforces the assignment of shallow aquifer to BQN1-B only.

6. The differences in RSWL in Table 3.1.2 demonstrate some 37 m difference in SWL levels from BQN1-B and the next deeper aquifer (intercepted by BQN-1A, in the northern bore cluster).
7. Similarly, the RSWL differences from Table 3.1.2 demonstrate that there is some 17 m difference in SWL levels from BQN1-B (N. Pit) and the next deeper aquifer in the S. Pit (intercepted by BQS1-S in the northern bore cluster).
8. The SWL hydrograph of BQN1-B shows that it is unconfined (phreatic), hence it is temporally sensitive to rainfall events. In this context, simple interception devices (such as drains and sumps) can be employed to adequately manage interflow.
9. The typical cross-section, refer to Appendix 1, Drawing 11737-101, clearly indicates that the shallow aquifer (Aquifer 1, in which BQN1-B is constructed) is both isolated from the main groundwater flow system as modelled and forms a spring line, consistent with observations reported by local landholders.

Accordingly, whilst the constraints and limitations are acknowledged, the modelling outcomes described in this report remain fit-for-purpose.

3.2.3 Model outcomes and predictions

The result of this analytical modelling using MLU is presented as Table 3.2.3.1.

Detailed results of the modelling are given as Appendix 4. The results are in three parts:

1. Tabulation of the simulated parameters and output parameters
2. Graphical representation of measured test pumping drawdowns and simulated 'best-fit' plots (of these measured drawdowns)
3. A schematic plan showing 48-hours drawdown contours (i.e. pumping drawdowns' areas ('cones') of influence against the local model grid domain depicting the pumping bore, BQPB-1 and the monitoring bores, BQN1, BQN2 and BQS1 clusters).[12]

The modelled transmissivities were 38.5 m^2/day, 15.3 m^2/d, 4.1 m^2/d, and 2.9 m^2/d, for Layers A1, A2, A3 and A4, respectively. Apart from the 'Shallow aquifer' these values are low, and indicate the limited thickness and permeabilities of these aquifers. The storage coefficients output by the model for Layers A2 and A3 are unusually small values. These will be refined in any future hydrogeological studies of the Quarry.

There is a relatively strong component of vertical hydraulic connectivity between Layers A2 and A3 (modelled vertical hydraulic conductivity, Kh of 0.24 m/d. The 'Intermediate aquifer' at BQS1-S did not appear to respond to pumping. The oscillation and slight fall in water level seen on the plot (Appendix 5) is suspect data.

[12] Note that the local model grid (Appendix 4) coincides with the UTM grid (Figure 4).

The modelled drawdown cone of influence (after 48-hours of pumping at 1.318 L/s (113.9 kL/d)), indicates that the radial limit of drawdown extends only to some 200 m or so (0.25 metre drawdown contour) in Layers 2 and 3, and a little less than 200 m in Layer 4 (0.25 metre drawdown contour). The 0.25 m drawdown contour encroaches upon the BQN1 cluster of monitoring bores and remains some 100 m distant from the BQN2 cluster. The BQS cluster of monitoring bores is unaffected by pumping area of influence.

Given the modelled low transmissivities of these layers ('Intermediate – upper and lower aquifers'), it is apparent that, even with an extended pumping duration, the radius of influence would not migrate much farther than the modelled values.

To assess this, the MLU model was extended to examine continuous pumping periods of 1-year and 5-years, respectively. Appendix 4 provides a figure depicting the modelled draw down cone.

After 1-year of continuous pumping at a rate of 113.9 kL/d centred on bore BQPB-1, the modelled cone of influence indicates that the radial limit of drawdown extends to approximately 3 km (0.25 metre drawdown contour) in Layer 2.

After a period of 5-years continuous pumping at a rate of 113.9 kL/d centred on bore BQPB-1, the modelled cone of influence indicates that the radial limit of drawdown extends to approximately 4 km (0.25 metre drawdown contour) in Layer 2.

As Layer 2 is the most transmissive (apart from the discontinuous Layer-1 uppermost aquifer), it is anticipated that it would have the largest migrating cone of influence. This was verified by running the same scenario for the other aquifer layers.

At the perimeter of the proposed limits of excavation of the quarry the maximum drawdown after 5-years of pumping (dewatering) at a rate of 113.9 kL/d is some 1.5 metres.

It is concluded that major drawdown remains locally restricted to a very small area around the pumping centre (within 200 metres of the centre of pumping). Towards the periphery of the cone of influence, dewatered depths are inconsequential.

Thus any impact of dewatering (natural or artificial) would be limited to a small area (no greater than several hundred metres, depending on the seepage and/or drainage/ pumping rate), and would certainly not extend beyond the Quarry site.

3.3 Estimation of groundwater inflow rates during extraction

To estimate the groundwater inflow to the pit, the Dupuit–Forchheimer equation was used. It assumes that groundwater flows horizontally in an unconfined aquifer and that the groundwater discharge is proportional to the saturated aquifer thickness.

Given that it is predicted that three separate aquifers will be intersected during the course of excavation, the rate of groundwater inflow will vary according to when these aquifers are intersected. However, the calculation of 2.2L/s gives a reasonable order of estimate of predicted groundwater inflow.

Given that Layer 1 has more than twice the transmissivity of Layer 2, then early inflows of a slightly higher order (than 2.2 L/s) are likely to occur. However, as the head decreases with an expanding cone of influence, rates of groundwater inflow are expected to lessen over time (even though the three aquifers will be intersected). The entire calculation and workings are included as Appendix 6.

As part of the hydrogeological impact appraisal undertaken for Blakebrook Quarry as described herein, an estimate of the predicted groundwater pit inflows during and following extraction was made. This estimate used the Dupuit-Forchheimer analytical equation. The data values input to this equation are averaged values (geometric means) derived from the HCM (refer Table 3.2.3.1 Analytical Model of the Groundwater System underlying Blakebrook Quarry).

Figure 3.3.1 (on the following page) shows an idealised conceptualisation of the Blakebrook Quarry final void. The ultimate form of this final void is subject to approval by the Secretary and rehabilitation to the satisfaction of the Secretary.

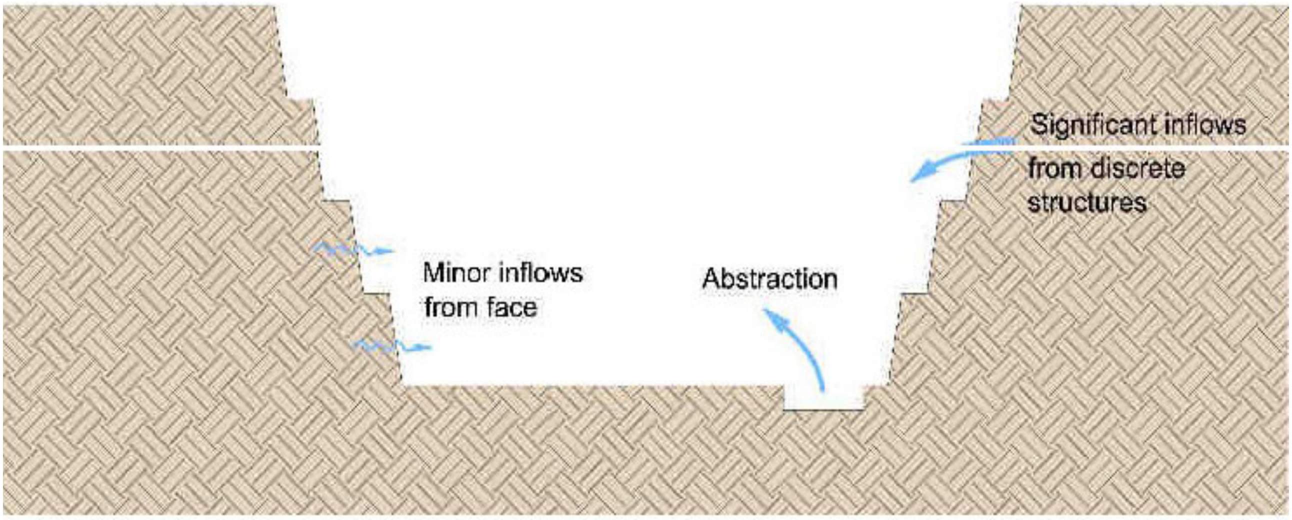


Figure 3.3.1 Conceptualisation of final excavated void (the ultimate form of this final void is subject to approval by the Secretary)

However, to facilitate for the estimate of groundwater inflows, the idealised conceptualisation as shown in Figure 3.3.1 has been adopted.

Given the nature of the variable-permeability hard-rock formations at the Quarry, it can be seen that any significant groundwater inflows are likely to come from a very limited number of discrete, transmissive, geological structures such as major joints, and faults.

The HCM was used to:

- define the area of influence for drawdown impacts (limited by the 0.5 metre drawdown contour);
- identify potential drawdown impacts to other groundwater users in the area of influence;
- predict the likely drawdown impacts; and,
- assess the significance of the net drawdown impacts.

Sensitivity testing of the HCM was conducted (chiefly by varying layer thickness, hydraulic conductivity (K values), and to a lesser extent, storage coefficient, S).

Under groundwater modelling guidelines, the HCM can be categorised as 'Tier 1 (Basic)' that has been tested using simple analytical equations, to arrive at a 'best basic' conceptual model. Common to all such conceptualisations, this HCM is based on an idealised model of the real situation, and thus provides an approximation of the real environment.

For the purpose of the dewatering estimate, whilst the groundwater system is known to be layered with different hydraulic properties, a simplified approach has been used that essentially combines the three (aquifer) layers that would be impacted by quarrying into one layer with averaged properties.

Assumptions in applying the Dupuit–Forchheimer equation are:

- groundwater flows horizontally in an unconfined aquifer
- groundwater discharge is proportional to the saturated aquifer thickness
- the water table is relatively flat
- the groundwater is hydrostatic (equipotential lines are vertical) and
- the vertical component of groundwater flow id negligible.

Table 3.3.1 (on the following page) presents model uncertainty together with note on assumptions made, and confidence levels of those assumptions.

Table 3.3.1 Model uncertainty with respect to using the Dupuit-Forchheimer Assumption to estimate natural dewatering of Blakebrook Quarry

Model uncertainty	System knowledge	Mathematical certainty[14]	Assumptions
Layered	✓✓	✓✓	• Aquifer system is of finite extent. (Not the case as it is bounded by topography) • Aquifer system is anisotropic. (On a regional scale unlikely) • Variations in SWLs are within the monitored range. (Likely over the short term) • Saturated thickness remains constant. (As dewatering progresses especially in the upper unconfined layer this will decrease) • Water table is flat and equipotentials are vertical. (Not at the quarry excavation faces)
Unconfined (pertains to discontinuous top layer only)	✓	✗	
Confined	✓✓	✓✓	
Layers are hydraulically isolated (not leaky)	✓✓	✓	

✓✓= confident.
✓= some uncertainty.
✗= uncertain.

In such exercises 'common sense' must prevail[13] and decisions must be made with the simplest model possible, with refinement of the model required only if a decision cannot be made because the uncertainty is too great. In this vein, it is noted that the drawdown profile in the immediate vicinity of deep excavations, especially in fractured rock (as is the case with Blakebrook Quarry), does not necessarily follow the shape predicted by analytical equations. The slope of the cone of depression is oftentimes steep, with the drawdown being far less than expected at a given radius from the excavation.

Factors that can contribute to these phenomena are as follows:

- Additional hydraulic head losses, as the groundwater flow towards the open excavation becomes turbulent ('non-Darcian flow'), especially when there is a seepage face on the wall of the excavation.
- Groundwater levels being controlled by geological structure, and changing in a series of steps rather than a smooth curve. Depending on where the edge of the excavation is in relation to the structure, there can be sudden jumps in water level away from the excavation.
- Localised increases in the permeability of the rock close to the excavation, either because of the effects of blasting, or because of lithostatic unloading (causing fractures to open up).

Given that groundwater inflow to the void will be non-Darcian, the calculated value of 2.2 L/s is likely an overestimate. This being the case, the 2.2 L/s figure is a conservative value at the time of the final quarry void.

Attempting to draw groundwater level contours around an excavation in fractured rock can be highly misleading, and more attention must be given to geological structure and the presence of features such as seepage faces. Rates of groundwater inflow to an excavation depend on a range of factors such as the excavation's dimensions, the local water balance, and the hydraulic properties of the rock being excavated.

As staged excavations progress, the HCM can be refined based on a dewatering monitoring strategy and confidence in the model can be increased so that uncertainty decreases (and perceived risk reduced to an acceptable level).

Excavated voids can be regarded as extremely large diameter wells. As the excavation schedule

13 Reducing knowledge uncertainty may require extended scientific study; and uncertainty is sometimes impossible to reduce, and must just be recognised.

14 Arising from the limitations of the model selected in accurately representing reality.

is developed a layered, radial flow model is to be developed to supersede the analytical equation application in order to reduce model uncertainty.

3.4 Sensitive groundwater users

Potential impacts to local users of groundwater from any draw down and/or contamination of the local groundwater system have been identified, and are described below.

3.4.1 Groundwater dependent ecosystems

A search of the Australian Government's GDE Atlas[15] was completed to determine the presence of any groundwater dependent ecosystems (GDE) adjacent to the Quarry and its environs. That search indicates the presence of a nearby terrestrial GDE in the land surrounding the Quarry. It is mapped as a terrestrial GDE, of vegetation type Northern Ranges Dry Tallowwood.

It is noted to have a low groundwater dependency likelihood. As such it is unlikely that this GDE would be impacted. Notwithstanding this, more research on this GDE is appropriate (if not already accomplished).

It is also noted that once the quarry excavations deepen, groundwater will inflow into the excavation. It is proposed that this groundwater inflow (along with treated surface runoff) be used to provide landform rehydration in targeted locations. This can be achieved by pumping waters to the head of gullies surrounding the quarry, discharging flows to engineered flow-spreading swales or recharge trenches.

These measures will provide the ability for recharge on the down gradient landform. The form and location of these measures is subject to detailed design and will require consultation with and approval from the relevant statutory authorities.

3.4.2 Groundwater bores

A search of the Australian Government's groundwater bore database[16] was conducted to help determine the presence of any groundwater bores adjacent to the Quarry and its environs. That search indicated the presence of only one bore being beneficially used.[17] This bore, ID 38934 is registered in the database as 'stock and domestic'. It is 14.6 metres deep; hence taps only the 'Shallow aquifer'). It is located some 600 metres northwest of the northern pit (measured from bore, BQPB-1), and, as such is well outside the modelled radius of drawdown influence. Therefore, it is most unlikely that this bore would be impacted.

3.5 Groundwater quality data assessment

An analysis was conducted on the available water quality data from 2016 to 2018[18] in order to set site specific groundwater target concentrations for each of the bores. It is noted that these are interim targets only, as some parameters (e.g. TPH) had a restricted data set.

The interim targets values were established using the following rules:

- Data sets with less than seven sample dates have insufficient information to develop a trigger and interim trigger calculation was postponed until the data set is eight or greater;
- Data sets with more than seven sample dates, and non-detects and/or <LOR less than 25% used the 80th percentile;
- Data sets with analyses 100% <LOR used the maximum LOR of the data set; and
- All other data sets used the maximum value recorded and the coverage at 95% confidence level estimated.[19]

[15] http://www.bom.gov.au/water/groundwater/gde/map.shtml

[16] http://www.bom.gov.au/water/groundwater/explorer/map.shtml

[17] Three other bores within a 1 km radius of the Quarry are very shallow (~ <8m), and appear to be engineering geology bores with no beneficial use.

[18] Data outside of this period exists for some of the bores, given not all bores were constructed at the same time. However, to allow for a comparable analysis the period for which data was available for all bores was used.

[19] USEPA 2009 *Statistical analysis of groundwater monitoring data at RCRA facilities – Unified Guidance* Office of Resource

The summary statistics and interim targets are provided in Appendix 8. It is noted that a target exceedance has a 20% probability per monitoring round (using this approach). As such, results from multiple monitoring events necessarily need to be reviewed as a group against the interim target to determine compliance or otherwise (i.e. one exceedance of the target is not necessary an indication of non-compliance).

Conservation and Recovery, Program Implementation and Information Division. EPA 530-R-09-007 Table 17-4 pg D-25.

4 Conclusions

This report has addressed:

- the requirement for a groundwater assessment (GWA) to be undertaken as prescribed in the 2009 approval and subsequent modified approval in 2017 for Blakebrook Quarry;
- successful completion of a Monitoring Well Implementation Plan (MWIP) (emanating from Part 21, viz. preparation of a Groundwater Monitoring Program) as prescribed by Condition 25 of the PA 2009;
- ongoing monitoring of groundwater levels and quality as prescribed by Condition 25 of the PA 2009;
- a progressive understanding of the groundwater system at the site; and,
- potential impacts to the groundwater system from any vertical excavation of rock below 105 mAHD in the northern pit and 118.35 mAHD in the southern pit (under Condition 17c 2017).

It has done this by:

- the completion of the MWIP (in 2016 and 2017) with the installation of three clusters of monitoring bores; each cluster monitoring three aquifer intervals within the groundwater system at three sites. In detail it;
  - complemented two existing deeper monitoring bores adjacent to the northern pit of the Quarry with the construction of a pair of shallower bore clusters. All these bores are designed to monitor impacts to the local groundwater system from the subsurface to below proposed final pit floor level;
  - described the completion of a single cluster of bores adjacent to the southern pit to monitor impacts to the local groundwater system from the subsurface to below proposed final pit floor level; and,
  - described the construction of a dedicated test pumping bore sited between the two clusters of bores located at the northern pit.
- collation, analysis and interpretation of groundwater data collected in the interval spanning 2016 - 2018, but also dating back to 2013;
- further groundwater sampling, including during the test pumping of a dedicated test bore (September/October 2017);
- conducting test pumping (water-level drawdown and recovery testing) of a dedicated test bore, including drawdown and recovery measurements in all the monitoring bores;
- developing a hydrogeological conceptual model (HCM) that integrates and interprets data collected as part of the drilling and test pumping program;
- undertaking groundwater analytical modelling to demonstrate potential impacts to the groundwater system from quarry excavations;
- estimated groundwater inflows to the extraction pit.
- searching the Australian Government's GDE Atlas to determine the presence of any groundwater dependent ecosystems adjacent to the Quarry and its environs that might be subject to impact from quarrying; and,
- searching the Australian Government's groundwater bore database to determine the presence of any groundwater bores adjacent to the Quarry and its environs that might be subject to impact from quarrying.

The data analysed and interpreted included:

- standing water level (SWL) hydrographs;
- reduced standing water level RSWL (mAHD) time-series data to determine groundwater elevations, and relate this to vertical depths of excavation in the Quarry;
- test pumping drawdown and recovery data, including relating this to vertical depths of excavation in the Quarry;
- obtaining and reporting aquifer hydraulic parameters as part of a groundwater analytical modelling exercise.

This study's findings are:

- The groundwater system has been conceptualised as a layered, multi-aquifer system. Four layers represent the groundwater systems (aquifers) All the aquifers are confined with leakage through separating confining layers (that lay between each aquifer). The confining beds are aquitards, i.e. they allow limited vertical passage/ exchange of water between aquifers. The potentiometric surface of each aquifer lays above the top of its respective aquifer, and the potentiometric gradient is downward (i.e. drainage between the aquifers is in a downwards direction that is there is no upward leakage at the base of the pits.
- The water bearing layers are; shallow (113mAHD to 109mAHD), the intermediate – upper (95mAHD to 87.5mAHD), intermediate – lower (72mAHD to 65mAHD) and deep (28.5mAHD to 22.5mAHD).
- The shallow aquifer is already intersected by the approved extraction in the northern pit to approximately 105mAHD. The intermediate aquifers would be affected by extraction to the ultimate depth of 55mAHD in the northern pit.
- The shallow aquifer will be affected by excavation to the ultimate depth of 105mAHD in the southern pit.
- The potentiometric data of BQS1-S (Intermediate – upper aquifer') indicates that the southern pit is expected to remain dry to a vertical depth of excavation of some 20 m from present ground surface before the potentiometric surface was intercepted.
- The modelled drawdown cone of influence (after 48-hours of pumping at 1.318 L/s (113.9 kL/d)) indicates that the radial limit of drawdown extends only to some 200 m or so (0.25 metre drawdown contour) in Layers 2 and 3, and a little less than 200 m in Layer 4 (0.25 metre drawdown contour). The 0.25 m drawdown contour encroaches upon the BQN1 cluster of monitoring bores and remains some 100 m distant from the BQN2 cluster. The BQS cluster of monitoring bores is unaffected by pumping area of influence.
- After a period of 5-years continuous pumping at a rate of 113.9 kL/d centred on bore BQPB-1, the modelled cone of influence indicates that the radial limit of drawdown extends to approximately 4 km (0.25 metre drawdown contour) in Layer 2 being the most transmissive (apart from the discontinuous Layer-1 uppermost aquifer).
- At the perimeter of the proposed limits of excavation of the quarry the maximum drawdown after 5-years of pumping (dewatering) at a rate of 113.9 kL/d is some 1.5 metres.
- It can be concluded that major drawdown remains locally restricted to a very small area around the pumping centre (within 200 metres of the centre of pumping). Towards the periphery of the cone of influence, dewatered depths are inconsequential.
- Any impact of dewatering (natural or artificial) would be limited to a small area (no greater than several hundred metres, depending on the seepage and/or drainage/pumping rate), and certainly not extend beyond the Quarry site.
- The estimated rate of groundwater inflow to the pit is 2.2L/s. This gives a reasonable order of estimate of predicted groundwater inflow. Given that Layer 1 has more than twice the transmissivity of Layer 2, then early inflows of a slightly higher order (than 2.2 L/s) are likely to occur. However, as the head decreases with an expanding cone of influence, rates of groundwater inflow is expected to lessen over time (even though the three aquifers will be intersected).
- Interim site-specific groundwater targets were developed for each of the bores.
- Further groundwater monitoring is required, following which revised targets must be established.
- A search of the GDE Atlas indicated the presence of terrestrial GDE, it is mapped as having a low likely groundwater dependence. As a result, no impacts to this GDE from the limited modelled groundwater drawdowns from quarry expansion are anticipated.

- A search of the national groundwater bore database (see above) has indicated the presence of one stock bore situated some 600 metres northwest of the site (Bore, BQPB-1). This bore is expected to be unaffected by quarry expansion.

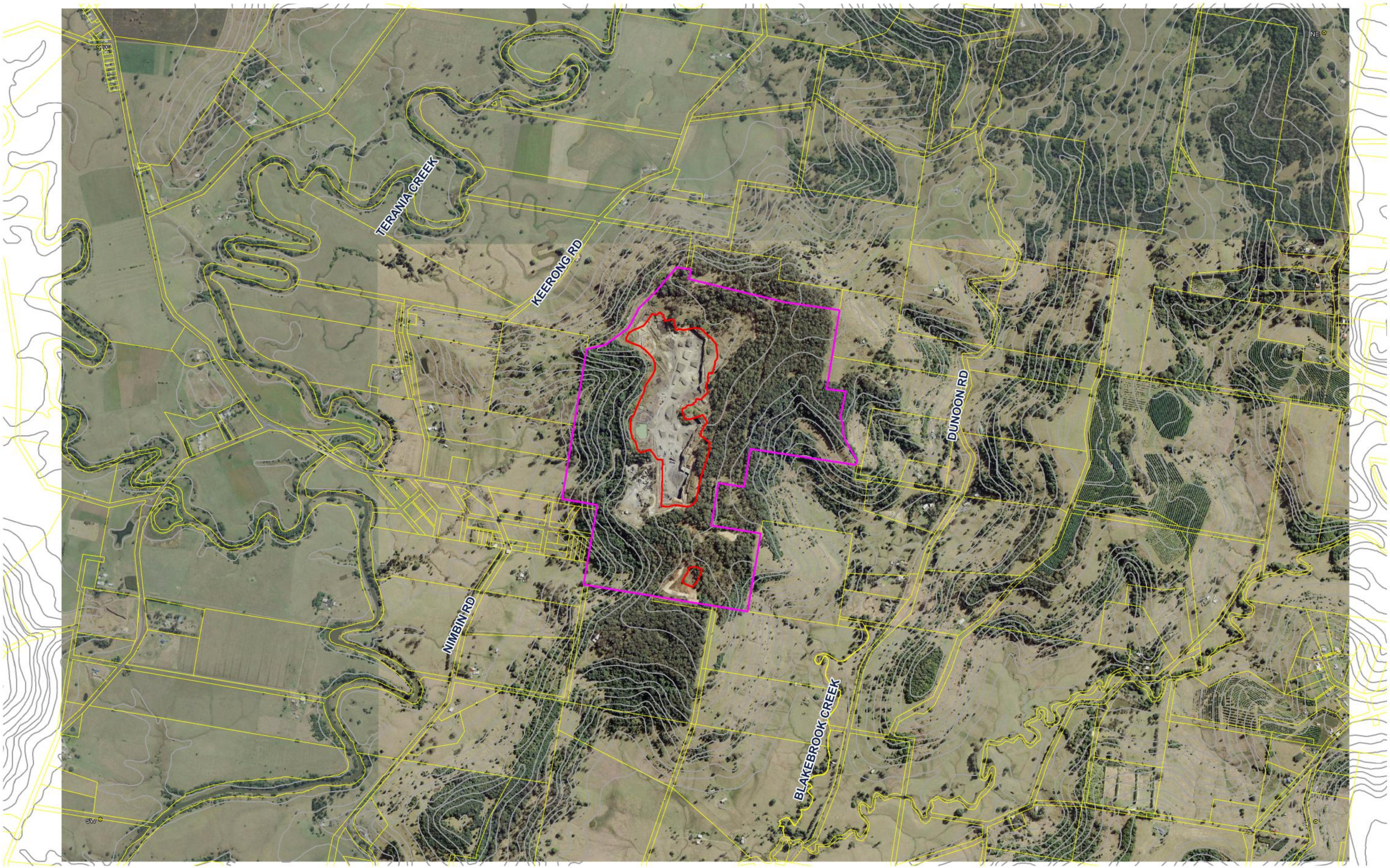
5 Recommendations

This study's recommendations are:

- SWL (groundwater level) measurements must continue.
- The SWL logger must be downloaded on a minimum quarterly basis to ensure that the time period between potential logger malfunctions is minimized.
- Any observed groundwater seepage or inflows to the pit must be recorded in the daily diary.
- Once the northern pit intersects the intermediate aquifers (87.5mAHD) or the southern pit intersects the shallow aquifer (113m AHD) the seepage or groundwater inflow must be proportionally discharged to the various catchments, as proposed in the SWMP (and associated water balance assessment).
- Groundwater inflow (along with treated surface runoff) can be used to provide landform rehydration in targeted locations. This can be achieved by pumping waters to the head of gullies surrounding the quarry, discharging flows to engineered flow-spreading swales or recharge trenchesThis will facilitate recharge into the surrounding landform.
- At this juncture the monitoring bore network is adequate. However, if quarry expansion excludes one or more of the monitoring bores (for example, by destruction) then suitable replacements must be installed as near as possible to the former site(s).
- Water quality monitoring must continue at each of the bores on a quarterly basis. Once 12 rounds of data are available for each bore for each parameter the interim triggers are to be reviewed and updated.
- With respect to the 'low likely groundwater dependence' GDE surrounding the site, field research will assist in quantifying the characteristics of these vegetation communities and identifying potential recharge locations (if required).
- As excavation continues and the geology is further explored it will be possible to refine the hydrogeological conceptual model. This will allow for it to be integrated with a digital elevation model, and represented in a 3-D block diagram format.
- Further, groundwater modelling developed from a refined HCM (see preceding dot-point) can be undertaken as quarry expansion proceeds. Refinements to the existing model can be made, or a groundwater numerical model can be constructed.
- Whilst expanding the Quarry, adherence to the NSW Aquifer Interference Policy (DoI, 2012) is required. This Policy applies to all aquifer interference activities in NSW, especially 'high risk activities' including quarrying (working open cut and/or voids). The proponents must familiarise themselves with this policy.

Where appropriate, the above recommendations have been incorporated into the SWMP and associated water balance assessment.

6 Appendix 1 – Drawings



ORIENTATION

SCALE

150 300 450 600 750 metres

ROBINA
PO Box 4115 Robina QLD4230 07 5578 9944
Email robina@access.gs www.access.gs

LEGEND

- Quarry pit (existing)
- Cadastral boundaries
- Contours (10m interval)
- Site boundary

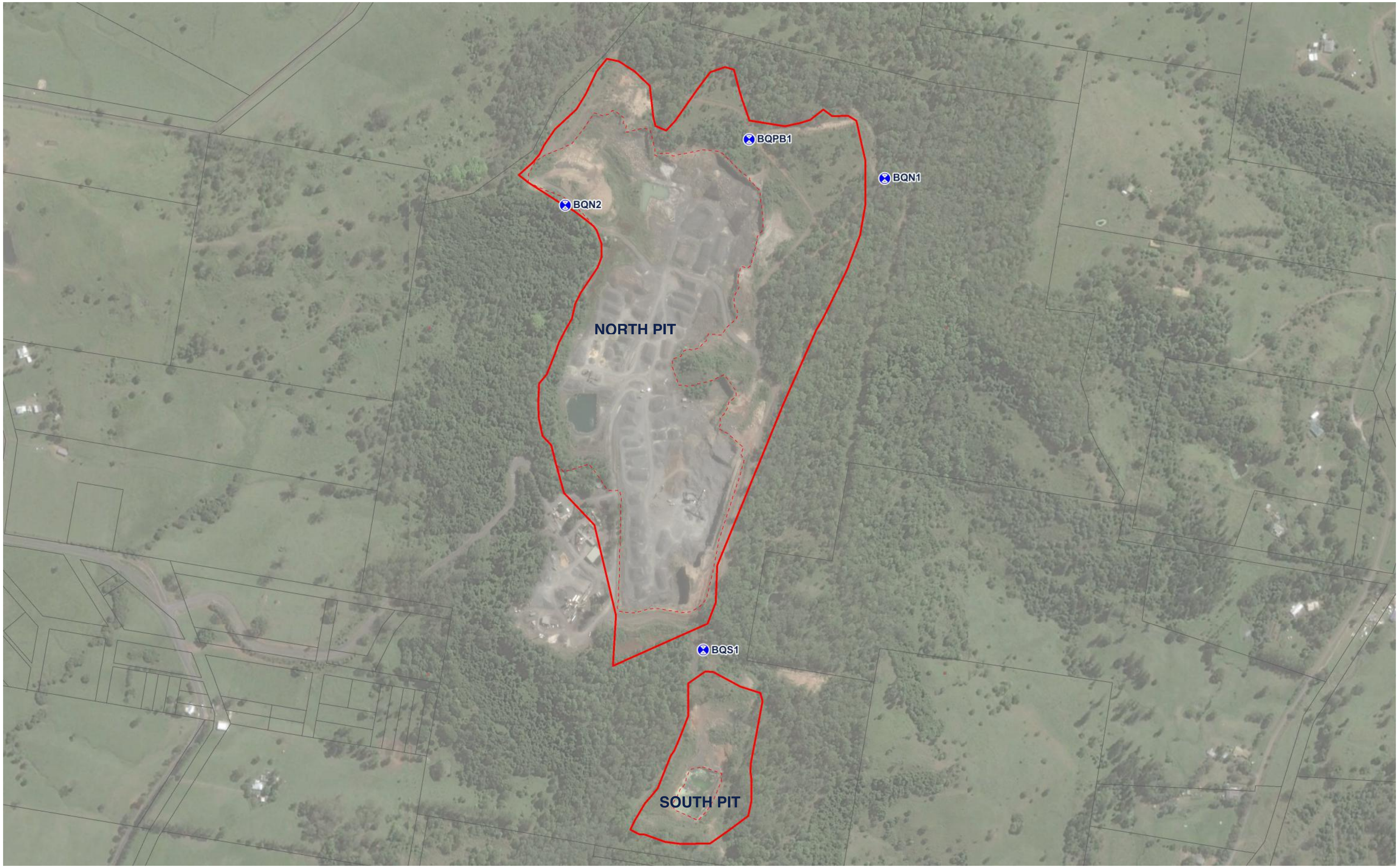
SOURCES

Image source: Google Earth - NSW Globe
Image dates: 4 September 2012

PROJECT	CLIENT	DRAWING
BLAKEBROOK QUARRY	LISMORE CITY COUNCIL	SITE LOCATION

SCALE	DATE	DRAWN	CHECKED	PROJECT	DRAWING	REVISION
1:16,000@A3	14/12/2018	AJF	CMA	11737	001	A

GILBERT SUTHERLAND



ORIENTATION

SCALE

50 100 150 200 250 metres

ROBINA

PO Box 4115 Robina QLD4230 07 5578 9944

Email robina@access.gs www.access.gs

LEGEND

Quarry pit (future)

Quarry pit (existing)

Borehole locations

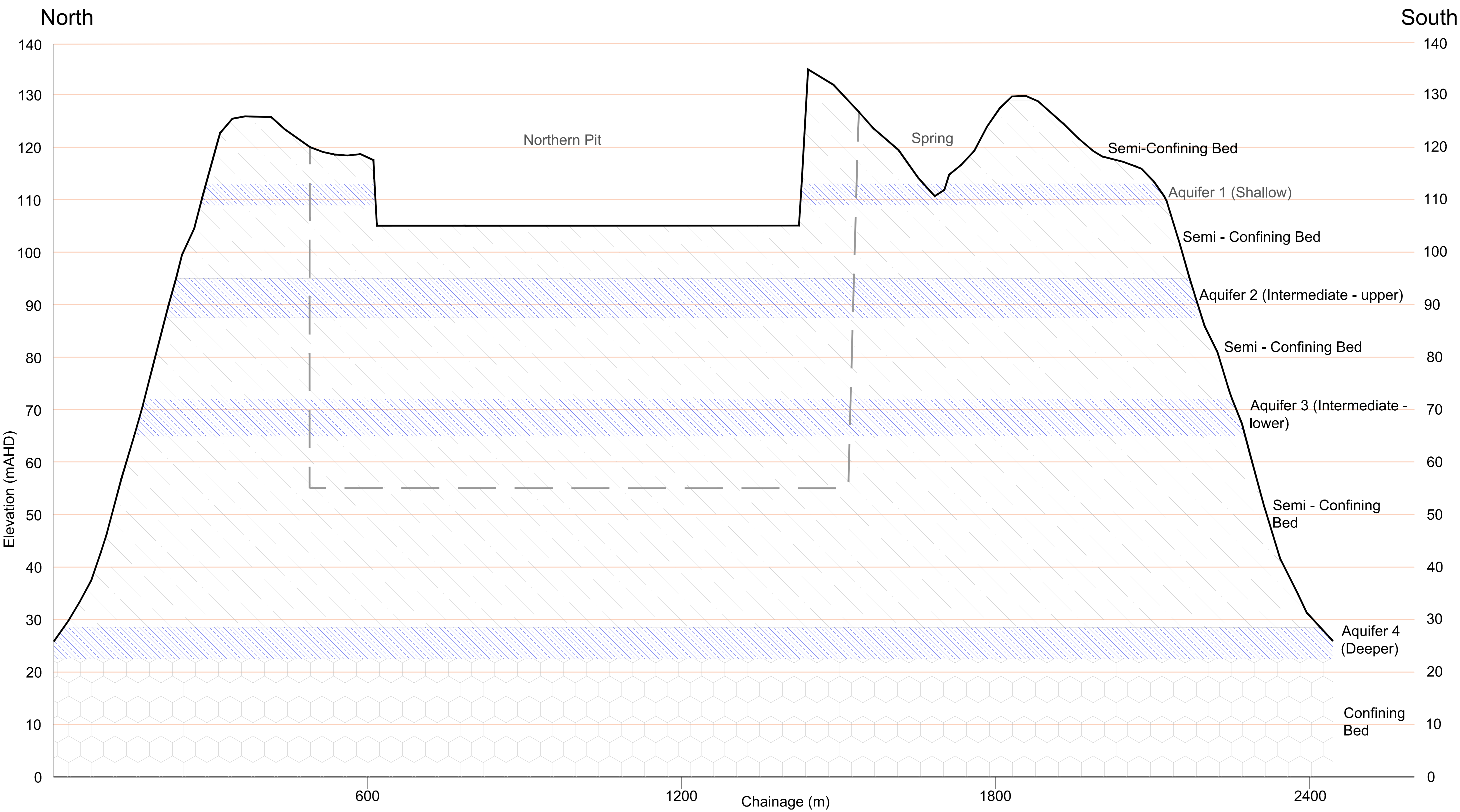
SOURCES

Image source:	Google Earth Pro
Image dates:	17 February 2017

PROJECT	CLIENT	DRAWING
BLAKEBROOK QUARRY	LISMORE CITY COUNCIL	SITE LAYOUT AND BOREHOLE MONITORING LOCATIONS

SCALE	DATE	DRAWN	CHECKED	PROJECT	DRAWING	REVISION
1:6,250@A3	17/12/2018	AJF	CMA	11737	002	-

GILBERT SUTHERLAND



ORIENTATION

SCALE: As shown

ROBINA

PO Box 4115 Robina QLD4230 07 5578 9944
Email robina@access.gs **www.access.gs**

LEGEND

- Topography
- Current Pit
- Proposed Pit
- Confining Bed - Non-aquifer
- Semi Confining Bed - Aquitard
- Aquifer

Water Bearing Zone
Aquifer 1 = 'Shallow
Aquifer 2 = 'Intermediate - upper'
Aquifer 3 = Intermediate - lower'
Aquifer 4 = 'Deeper'

SOURCES

Elevation Information: *Elevation Information System*, Australian Government - Geoscience Australia.

PROJECT	CLIENT	DRAWING
Blakebrook Quarry Proposed Extension	Lismore City Council	Typical Cross Section North-South through Northern Pit

SCALE	DATE	DRAWN	CHECKED	PROJECT	DRAWING	REVISION
As shown	22/01/19	RMB	CMA	11737	101	-

7 Appendix 2 – Borelogs

11737
26/10/17

NSW Office of Water
Work Summary

GW307322 (BQN1A)

Licence: 30BL207063
Licence Status: ACTIVE

Authorised Purpose(s): MONITORING BORE
Intended Purpose(s): MONITORING BORE

Work Type: Bore
Work Status: Equipped
Construct.Method: Rotary Air
Owner Type: Local Govt

Commenced Date:
Completion Date: 26/07/2013
Final Depth: 60.00 m
Drilled Depth: 60.00 m

Contractor Name: GRICKS DRILLING
Driller: Glenn Joseph Gricks
Assistant Driller: Nathan Turner

Property: BLAKEBROOK QUARRY 540 NIMBIN ROAD BLAKEBROOK 2480
GWMA:
GW Zone:
Standing Water Level: 42.500
Salinity:
Yield: 0.500

Site Details

Site Chosen By:

	County	Parish	Cadastre
Form A:	ROUS	ROUS.7	102//817730
Licensed:			

Region: 30 - North Coast
River Basin: 203 - RICHMOND RIVER
Area/District:
CMA Map: 9540-2N
Grid Zone:
Scale:

Elevation: 0.00 m (A.H.D.)
Elevation Source: Unknown
Northing: 6818515.0
Easting: 524420.0
Latitude: 28°45'38.0"S
Longitude: 153°15'00.5"E

GS Map: -
MGA Zone: 0
Coordinate Source: GIS - Geographic Information System

Construction

Negative depths indicate Above Ground Level; C-Cemented; SL-Slot Length; A-Aperture; GS-Grain Size; Q-Quantity; PL-Placement of Gravel Pack; PC-Pressure Cemented; S-Sump; CE-Centralisers

Hole	Pipe	Component	Type	From (m)	To (m)	Outside Diameter (mm)	Inside Diameter (mm)	Interval	Details
1		Hole	Hole	0.00	1.00	200			Rotary Air
1		Hole	Hole	1.00	60.00	165			Down Hole Hammer
1		Annulus	Cement Grout	0.00	44.00	165	60		
1		Annulus	Bentonite	44.00	46.00	165	60		PL:Poured/Shovelled
1		Annulus	Waterworn/Rounded	46.00	60.00	165	60		Graded. PL:Poured/Shovelled
1	1	Casing	Pvc Class 12	-0.50	60.00	60	53		Seated on Bottom. Screwed
1	1	Opening	Slots - Horizontal	48.00	60.00	60		1	Mechanically Slotted. PVC Class 12. Screwed. A: 0.40mm

Water Bearing Zones

From (m)	To (m)	Thickness (m)	WBZ Type	S.W.L. (m)	D.D.L. (m)	Yield (L/s)	Hole Depth (m)	Duration (hr)	Salinity (mg/L)
52.00	60.00	8.00	Unknown	42.50		0.50		01:00:00	

Geologists Log
Drillers Log

From (m)	To (m)	Thickness (m)	Drillers Description	Geological Material	Comments
0.00	1.00	1.00	Soil	Soil	
1.00	4.00	3.00	Basalt; weathered	Basalt	
4.00	13.00	9.00	Basalt; hard	Basalt	
13.00	18.00	5.00	Basalt	Basalt	
18.00	20.00	2.00	Basalt; soft	Basalt	
20.00	24.00	4.00	Basalt; soft. muddy	Basalt	
24.00	30.00	6.00	Basalt; hard	Basalt	
30.00	45.00	15.00	Basalt	Basalt	
45.00	52.00	7.00	Basalt; soft. muddy	Basalt	
52.00	60.00	8.00	Basalt; soft	Basalt	

Remarks

26/07/2013: Form A Remarks:
Nat Carling. 14-Apr-2014; No location was provided. based in the centre of the authorised land. Map sent to owner for true location.
23/06/2014: Nat Carling. 23-June-2014; Updated coordinates. based on the map received from the owner. No site identifier was provided on the map. only location. there coordinates may vary from actual location with other bore site associated with this approval.

*** End of GW307322 ***

NSW Office of Water
Work Summary

GW307323 (BQN1B)

Licence: 30BL207063 **Licence Status:** ACTIVE

Authorised Purpose(s): MONITORING BORE
Intended Purpose(s): MONITORING BORE

Work Type: Bore
Work Status: Equipped
Construct.Method: Rotary Air
Owner Type: Local Govt

Commenced Date:
Completion Date: 25/07/2013

Final Depth: 30.00 m
Drilled Depth: 30.00 m

Contractor Name: GRICKS DRILLING
Driller: Glenn Joseph Gricks
Assistant Driller: N Turner. J Gricks

Property: BLAKEBROOK QUARRY 540 NIMBIN ROAD BLAKEBROOK 2480
GWMA:
GW Zone:

Standing Water Level: 4.500
Salinity:
Yield: 0.800

Site Details

Site Chosen By:

	County	Parish	Cadastre
Form A:	ROUS	ROUS.7	102//817730
Licensed:			

Region: 30 - North Coast
River Basin: 203 - RICHMOND RIVER
Area/District:

CMA Map: 9540-2N
Grid Zone:
Scale:

Elevation: 0.00 m (A.H.D.)
Elevation Source: Unknown

Northing: 6818515.0
Easting: 524420.0

Latitude: 28°45'38.0"S
Longitude: 153°15'00.5"E

GS Map: -
MGA Zone: 0
Coordinate Source: GIS - Geographic Information System

Construction

Negative depths indicate Above Ground Level; C-Cemented; SL-Slot Length; A-Aperture; GS-Grain Size; Q-Quantity; PL-Placement of Gravel Pack; PC-Pressure Cemented; S-Sump; CE-Centralisers

Hole	Pipe	Component	Type	From (m)	To (m)	Outside Diameter (mm)	Inside Diameter (mm)	Interval	Details
1		Hole	Hole	0.00	1.00	200			Rotary Air
1		Hole	Hole	1.00	30.00	165			Down Hole Hammer
1		Annulus	Cement Grout	0.00	8.00	165	60		PL:Poured/Shovelled
1		Annulus	Bentonite	8.00	10.00	165	60		PL:Poured/Shovelled
1		Annulus	Waterworn/Rounded	10.00	30.00	165	60		Graded. PL:Poured/Shovelled
1	1	Casing	Pvc Class 12	-0.50	30.00	60	53		Seated on Bottom. Screwed. S: 21.00-30.00m
1	1	Opening	Slots - Horizontal	12.00	21.00	60		1	Mechanically Slotted. PVC Class 12. Screwed. A: 0.40mm

Water Bearing Zones

From (m)	To (m)	Thickness (m)	WBZ Type	S.W.L. (m)	D.D.L. (m)	Yield (L/s)	Hole Depth (m)	Duration (hr)	Salinity (mg/L)
15.00	19.00	4.00	Unknown	4.50		0.80		01:00:00	

Geologists Log
Drillers Log

From (m)	To (m)	Thickness (m)	Drillers Description	Geological Material	Comments
0.00	1.00	1.00	Soil	Soil	
1.00	4.00	3.00	Basalt Clay; weathered	Basalt	
4.00	5.00	1.00	Basalt; weathered	Basalt	
5.00	15.00	10.00	Basalt; hard	Basalt	
15.00	19.00	4.00	Basalt; fractured	Basalt	
19.00	24.00	5.00	Basalt; soft. muddy	Basalt	
24.00	30.00	6.00	Basalt	Basalt	

Remarks

25/07/2013: Form A Remarks:
Nat Carling. 14-Apr-2014; No location was provided. based in the centre of the authorised land. Map sent to owner for true location.
23/06/2014: Nat Carling. 23-June-2014; Updated coordinates. based on the map received from the owner. No site identifier was provided on the map. only location. there coordinates may vary from actual location with other bore site associated with this approval.

*** End of GW307323 ***

NSW Office of Water
Work Summary

GW307324 (BQN2A)

Licence: 30BL207063 **Licence Status:** ACTIVE

Authorised Purpose(s): MONITORING BORE
Intended Purpose(s): MONITORING BORE

Work Type: Bore
Work Status: Equipped
Construct.Method: Rotary Air
Owner Type: Local Govt

Commenced Date:
Completion Date: 27/07/2013

Final Depth: 60.00 m
Drilled Depth: 60.00 m

Contractor Name: GRICKS DRILLING
Driller: Glenn Joseph Gricks
Assistant Driller: N Turner. J Gricks

Property: BLAKEBROOK QUARRY 540 NIMBIN ROAD BLAKEBROOK 2480
GWMA:
GW Zone:

Standing Water Level: 31.300
Salinity:
Yield: 0.400

Site Details

Site Chosen By:

	County	Parish	Cadastre
Form A:	ROUS	ROUS.7	102//817730
Licensed:			

Region: 30 - North Coast
River Basin: 203 - RICHMOND RIVER
Area/District:

CMA Map: 9540-2N
Grid Zone:
Scale:

Elevation: 0.00 m (A.H.D.)
Elevation Source: Unknown

Northing: 6818835.0
Easting: 524885.0

Latitude: 28°45'27.6"S
Longitude: 153°15'17.6"E

GS Map: -
MGA Zone: 0
Coordinate Source: GIS - Geographic Information System

Construction

Negative depths indicate Above Ground Level; C-Cemented; SL-Slot Length; A-Aperture; GS-Grain Size; Q-Quantity; PL-Placement of Gravel Pack; PC-Pressure Cemented; S-Sump; CE-Centralisers

Hole	Pipe	Component	Type	From (m)	To (m)	Outside Diameter (mm)	Inside Diameter (mm)	Interval	Details
1		Hole	Hole	0.00	1.00	200			Rotary Air
1		Hole	Hole	1.00	60.00	165			Down Hole Hammer
1		Annulus	Cement Grout	0.00	46.00	165	60		PL:Poured/Shovelled
1		Annulus	Bentonite	46.00	48.00	165	60		PL:Poured/Shovelled
1		Annulus	Waterworn/Rounded	48.00	60.00	165	60		Graded. PL:Poured/Shovelled
1	1	Casing	Pvc Class 12	0.00	6.00	60	53		Seated on Bottom. Screwed
1	1	Opening	Slots - Horizontal	51.00	60.00	60		1	Mechanically Slotted. PVC Class 12. Screwed. A: 0.40mm

Water Bearing Zones

From (m)	To (m)	Thickness (m)	WBZ Type	S.W.L. (m)	D.D.L. (m)	Yield (L/s)	Hole Depth (m)	Duration (hr)	Salinity (mg/L)
52.00	60.00	8.00	Unknown	31.30		0.40		01:00:00	

Geologists Log
Drillers Log

From (m)	To (m)	Thickness (m)	Drillers Description	Geological Material	Comments
0.00	1.00	1.00	Soil; red	Soil	
1.00	7.00	6.00	Basalt	Basalt	
7.00	12.00	5.00	Clay	Clay	
12.00	15.00	3.00	Basalt; soft. muddy	Basalt	
15.00	48.00	33.00	Basalt; soft	Basalt	
48.00	60.00	12.00	Basalt	Basalt	

Remarks

27/07/2013: Form A Remarks:
Nat Carling. 14-Apr-2014; No location was provided. based in the centre of the authorised land. Map sent to owner for true location.
23/06/2014: Nat Carling. 23-June-2014; Updated coordinates. based on the map received from the owner. No site identifier was provided on the map. only location. there coordinates may vary from actual location with other bore site associated with this approval.

***** End of GW307324 *****

NSW Office of Water
Work Summary

GW307325 (BQN2B)

Licence: 30BL207063 **Licence Status:** ACTIVE

Authorised Purpose(s): MONITORING BORE
Intended Purpose(s): MONITORING BORE

Work Type: Bore
Work Status: Equipped
Construct.Method: Rotary Air
Owner Type: Local Govt

Commenced Date:
Completion Date: 28/07/2013

Final Depth: 42.00 m
Drilled Depth: 42.00 m

Contractor Name: GRICKS DRILLING
Driller: Glenn Joseph Gricks
Assistant Driller: N Turner. J Gricks

Property: BLAKEBROOK QUARRY 540 NIMBIN ROAD BLAKEBROOK 2480
GWMA:
GW Zone:

Standing Water Level: 28.500
Salinity:
Yield: 0.500

Site Details

Site Chosen By:

	County	Parish	Cadastre
Form A:	ROUS	ROUS.7	102//817730
Licensed:			

Region: 30 - North Coast
River Basin: 203 - RICHMOND RIVER
Area/District:

CMA Map: 9540-2N
Grid Zone:
Scale:

Elevation: 0.00 m (A.H.D.)
Elevation Source: Unknown

Northing: 6818835.0
Easting: 524885.0

Latitude: 28°45'27.6"S
Longitude: 153°15'17.6"E

GS Map: -
MGA Zone: 0
Coordinate Source: GIS - Geographic Information System

Construction

Negative depths indicate Above Ground Level; C-Cemented; SL-Slot Length; A-Aperture; GS-Grain Size; Q-Quantity; PL-Placement of Gravel Pack; PC-Pressure Cemented; S-Sump; CE-Centralisers

Hole	Pipe	Component	Type	From (m)	To (m)	Outside Diameter (mm)	Inside Diameter (mm)	Interval	Details
1		Hole	Hole	0.00	1.00	200			Rotary Air
1		Hole	Hole	1.00	42.00	165			Down Hole Hammer
1		Annulus	Cement Grout	0.00	26.00	165	60		PL:Poured/Shovelled
1		Annulus	Bentonite	26.00	28.00	165	60		PL:Poured/Shovelled
1		Annulus	Waterworn/Rounded	28.00	42.00	165	60		Graded. PL:Poured/Shovelled
1	1	Casing	Pvc Class 12	0.00	42.00	60	53		Seated on Bottom. Screwed
1	1	Opening	Slots - Horizontal	30.00	42.00	60		1	Mechanically Slotted. PVC Class 12. Screwed. A: 0.40mm

Water Bearing Zones

From (m)	To (m)	Thickness (m)	WBZ Type	S.W.L. (m)	D.D.L. (m)	Yield (L/s)	Hole Depth (m)	Duration (hr)	Salinity (mg/L)
28.00	38.00	10.00	Unknown	28.50		0.50		01:00:00	

Geologists Log
Drillers Log

From (m)	To (m)	Thickness (m)	Drillers Description	Geological Material	Comments
0.00	2.00	2.00	Soil; red	Soil	
2.00	7.00	5.00	Basalt	Basalt	
7.00	13.00	6.00	Clay/Basalt	Clay	
13.00	23.00	10.00	Basalt	Basalt	
23.00	30.00	7.00	Basalt; soft. muddy	Basalt	
30.00	42.00	12.00	Basalt	Basalt	

Remarks

28/07/2013: Form A Remarks:
Nat Carling. 14-Apr-2014; No location was provided. based in the centre of the authorised land. Map sent to owner for true location.
23/06/2014: Nat Carling. 23-June-2014; Updated coordinates. based on the map received from the owner. No site identifier was provided on the map. only location. there coordinates may vary from actual location with other bore site associated with this approval.

*** End of GW307325 ***

BQN2D

Department of Primary Industries
Water

Form A Particulars of completed work

1

Driller's Licence No:	DL 2266
Class of Licence:	class 4
Driller's Name:	steven baker
Assistant Driller:	darryl hunt
Contractor:	Gilbert & Sutherland Pty Ltd
New bore	X
Deepened	
Reconditioned	
Replacement bore	
Enlarged	
Other (specify)	
Final Depth	133 m

2

Work Licence No:	30BL207399
Name of Licensee:	Lismore City Council
Intended Use:	Monitoring bore
Completion Date:	29/08/16

DRILLING DETAILS 3

From (m)	To (m)	Hole Diameter (mm)	Drilling Method (See Code 3)
0	5	177	9
5	133	120	9

WATER BEARING ZONES 4

From (m)	To (m)	Thickness (m)	S W L (m)	Estimated Yield (L/s) Individual Aquifer	Cumulative	Test method (See Code 4)		D D L at end of test (m)	Duration Hrs	min	Salinity (Conductivity or TDS) Cond (µS/cm)	TDS (mg/L)
19	24	5		0.015	0.015	1	G			0.25		
44	46.5	2.5		0.385	0.04	1	G			0.25		
112	117	5		0.133	0.173	1	G			0.5		

CASING / LINER DETAILS 5

Material (Code 5)	OD (mm)	Wall Thickness (mm)	From (m)	To (m)	Method Fixing (Code 5)
5	140	5.5	0	5	1
8	60.2	4.6	0	109	5
8	60.2	4.6	121	133	5

Casing support method	See Code 5	2					
Type of casing bottom	See Code 5	1					
Centralisers installed (Yes/No)	No	(indicate on sketch)					
Sump installed (Yes/No)	Yes	From	121	m	To	133	m
Pressure cemented (Yes/No)	Yes	From	0	m	To	85	m
Casing Protector cemented in place							

WATER ENTRY DESIGN 6

Material (Code 5)	OD (mm)	Wall Thickness (mm)	From (m)	To (m)	Opening type (See Code 6)	Fixing (See Code 5)	Screen Aperture (mm)	Slot Details Length (mm)	Width (mm)	Alignment (See Code 6)
8	60.2	4.6	109	121	5	5	0.5			H

GRAVEL PACK 7

Type		Grade		Grain size (mm) From	To	Depth (m) From	To	Quantity Litres	m³
Rounded	X	Graded	X	1	3	90	133	364	0.36
Crushed		Ungraded							
Bentonite/Grout seal (Yes/No)		Yes				0	90	761.85	0.76
Method of placement of Gravel Pack		See Code 7		1					

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Department of Primary Industries
Water

Form A Particulars of completed work

Work Licence No: 30BL207399

BORE DEVELOPMENT 8

Chemical used for breaking down drilling mud	(Yes/No)	No	Name:									
Method	Bailing/Surging		Jetting		Airlifting	X	Backwashing		Pumping		Other:	
Duration		hrs		hrs	0.5	hrs		hrs		hrs		hrs

DISINFECTION ON COMPLETION 9

Chemical(s) used	Quantity applied (Litres)	Method of application

PUMPING TESTS ON COMPLETION 10

Test type		Date	Pump intake depth (m)	Initial Water Level (SWL) (m)	Pumping rate (L/s)	Water Level at end of pumping (DDL) (m)	Duration of Test (hrs)	Recovery Water level (m)	Recovery Time taken (hrs)	Recovery Time taken (mins)
Multi stage (stepped drawdown)	Stage 1									
	Stage 2									
	Stage 3									
	Stage 4									
Single stage (constant rate)										

Height of measuring point above ground level ____ m   Test Method ____ See Code 4

WORK PARTLY BACKFILLED OR ABANDONED 11

Original depth of work: ____ m   Is work partly backfilled: (Yes/No) ____

Is work abandoned: (Yes/No) ____   Method of abandonment: Backfilled ☐ Plugged ☐ Capped ☐

Has any casing been left in the work (Yes/No) ____   From ____ m To ____ m

Sealing / fill type (See Code 11)	From depth (m)	To depth (m)	Sealing / fill type (See Code 11)	From depth (m)	To depth (m)

12

Site chosen by: Hydrogeologist ☐ Geologist ☐ Driller ☐ Diviner ☐ Client ☒ Other ____

13

Lot No 102   DP No 817730

Work Location Co ordinates   Easting 153°15.027'   Northing 28°45.578'   Zone 54

GPS: (Yes/No) Yes   >>   AMG/AGD ☒ or MGA/GDA ☐   (See explanation)

Longitude ____   Latitude ____

Please mark the work site with "X" on the CLID provided map.
Indicate also the distances in metres from two (2) adjacent boundaries, and attach the map to this Form A package.

Signatures:

Driller: [signature]   **Licensee:** ____

Date: 10/09/16   **Date:** ____

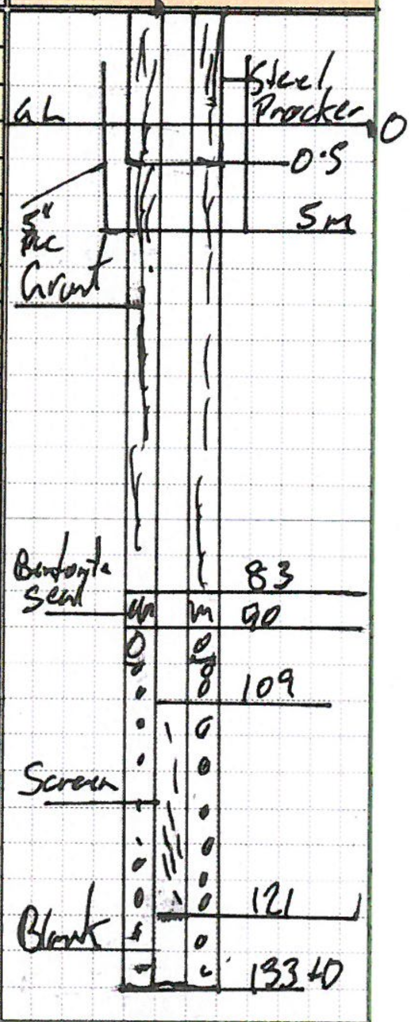
Please submit forms to water.gds@dpi.nsw.gov.au or to the local NSW Office of Water agency

Work Licence No: 30BL207399

DRILLER'S ROCK/STRATA DESCRIPTION (LITHOLOGY) 15

Depth From (m)	Depth To (m)	Description (See Code 15)
0	2	FILL
2	3	SOIL RED
3	7	BASALT HARD
7	12	BASALT BROKEN WITH CLAY YELLOW
12	28	BASALT HARD
28	30	HONEYCOMB BASALT RED BROWN
30	44	BASALT HARD
44	46.5	HONEYCOMB BASALT RED BROWN
46.5	80	BASALT HARD
80	83	HONEYCOMB BASALT RED BROWN
83	112	BASALT HARD
112	117	BASALT HARD BROKEN WATER .133 L/C
117	127	BASALT HARD
127	128	CLAY WHITE
128	133	SANDSTONE WHITE FG

WORK CONSTRUCTION SKETCH



WORK NOT CONSTRUCTED BY DRILLING RIG 16

Method of excavation: Hand dug ☐ Back hoe ☐ Dragline ☐ Dozer ☐ Other -

Depth (m)	Length (m)	Width (m)	Diameter (m)	Lining material	Dimentions of liner (m)	From Depth (m)	To Depth (m)

Please attach copies of the following if available 17

Geologist log	(Yes/No) No	Laboratory analysis of water Sample	(Yes/No) No	Pumping test(s)	(Yes/No) No
Geophysical log	(Yes/No) No	Sieve analysis of aquifer material	(Yes/No) No	Installed Pump details	(Yes/No) No

BQ N1D

Department of Primary Industries Water

NSW GOVERNMENT

Form A Particulars of completed work

		1
Driller's Licence No:	DL 2266	
Class of Licence:	class 4	
Driller's Name:	steven baker	
Assistant Driller:	darryl hunt	
Contractor:	Gilbert & Sutherland Pty Ltd	
New bore	X	Replacement bore:
Deepened		Enlarged:
Reconditioned		Other (specify):
Final Depth	115 m	

		2
Work Licence No:	30BL207399	
Name of Licensee:	Lismore City Council	
Intended Use:	Monitoring bore	
Completion Date:	29/08/16	

DRILLING DETAILS 3

From (m)	To (m)	Hole Diameter (mm)	Drilling Method See Code 3
0	72	177	9
72	115	120	9

WATER BEARING ZONES 4

From (m)	To (m)	Thickness (m)	S W L (m)	Estimated Yield (L/s) Individual Aquifer	Cumulative	Test method See Code 4		D D L at end of test (m)	Duration Hrs	min	Salinity (Conductivity or TDS) Cond (µS/cm)	TDS (mg/L)
56	63	7		3	3	1	G			30		
99	109	10	tba	0.093	0.093	1	G			30		

CASING / LINER DETAILS 5

Material Code 5	OD (mm)	Wall Thickness (mm)	From (m)	To (m)	Method Fixing Code 5
6	140	7.2	0	72	1
8	60.2	4.6	0	97	5
8	60.2	4.6	109	115	5

Casing support method (See Code 5): 2

Type of casing bottom (See Code 5): 1

	(Yes/No)						
Centralisers installed	No	(indicate on sketch)					
Sump installed	Yes	From	109	m	To	115	m
Pressure cemented	Yes	From	0	m	To	90	m
Casing Protector cemented in place							

WATER ENTRY DESIGN 6

Material Code 5	OD (mm)	Wall Thickness (mm)	From (m)	To (m)	Opening type See Code 6	Fixing See Code 5	Screen Aperture (mm)	Slot Length (mm)	Slot Width (mm)	Alignment See Code 6
8	60.2	4.6	97	109	5	5	0.5			H

GRAVEL PACK 7

Type		Grade		Grain size (mm) From	To	Depth (m) From	To	Quantity Litres	m³
Rounded		Graded	X	1	3	92	115	194.7	0.19
Crushed	X	Ungraded							
Bentonite/Grout seal (Yes/No)			Yes			0	92	778	0.78

Method of placement of Gravel Pack (See Code 7): 1

For Departmental use only: GW

Department of Primary Industries Water

NSW GOVERNMENT

Form A Particulars of completed work

Work Licence No: 30BL207399

BORE DEVELOPMENT (8)

Chemical used for breaking down drilling mud (Yes/No) ___ Name: ___

Method	Bailing/Surging	Jetting	Airlifting	Backwashing	Pumping	Other:
			X			
Duration	hrs	hrs	0.5 hrs	hrs	hrs	hrs

DISINFECTION ON COMPLETION (9)

Chemical(s) used	Quantity applied (Litres)	Method of application

PUMPING TESTS ON COMPLETION (10)

Test type		Date	Pump intake depth (m)	Initial Water Level (SWL) (m)	Pumping rate (L/s)	Water Level at end of pumping (DDL) (m)	Duration of Test (hrs)	Recovery Water level (m)	Recovery Time taken (hrs)	Recovery Time taken (mins)
Multi stage (stepped drawdown)	Stage 1									
	Stage 2									
	Stage 3									
	Stage 4									
Single stage (constant rate)										

Height of measuring point above ground level ___ m Test Method ___ See Code 4

WORK PARTLY BACKFILLED OR ABANDONED (11)

Original depth of work: ___ m Is work partly backfilled: (Yes/No) ___

Is work abandoned: (Yes/No) ___ Method of abandonment: Backfilled [ ] Plugged [ ] Capped [ ]

Has any casing been left in the work (Yes/No) ___ From ___ m To ___ m

Sealing / fill type (See Code 11)	From depth (m)	To depth (m)	Sealing / fill type (See Code 11)	From depth (m)	To depth (m)

(12)

Site chosen by: Hydrogeologist [ ] Geologist [ ] Driller [ ] Diviner [ ] Client [X] Other ___

(13)

Lot No 102 DP No 817730

Work Location Co ordinates Easting E153°15.360' Northing S 28°45.560' Zone 54

GPS: (Yes/No) Yes >> AMG/AGD [ ] or MGA/GDA [ ] (See explanation)

Longitude ___ Latitude ___

Please mark the work site with "X" on the CLID provided map.
Indicate also the distances in metres from two (2) adjacent boundaries, and attach the map to this Form A package.

Signatures:

Driller: [signature] **Licensee:** ______

Date: 10/09/16 **Date:** ______

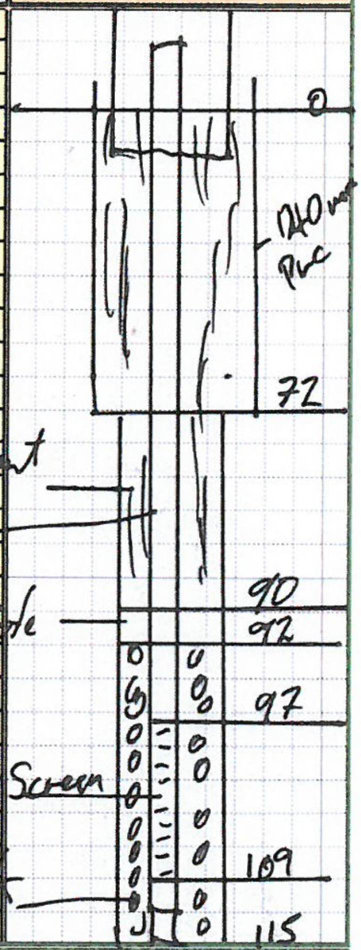
Please submit forms to water.gds@dpi.nsw.gov.au or to the local NSW Office of Water agency

Work Licence No: 30BL207399

DRILLER'S ROCK/STRATA DESCRIPTION (LITHOLOGY)

Depth From (m)	Depth To (m)	Description (See Code 15)
0	1	top soil and clay
1	3	basalt weathered
3	56	basalt hard
56	63	basalt hard and broken with water
63	99	basalt hard
99	109	basalt red honeycomb
109	115	basalt hard

WORK CONSTRUCTION SKETCH (15)



WORK NOT CONSTRUCTED BY DRILLING RIG (16)

Method of excavation: Hand dug ☐ Back hoe ☐ Dragline ☐ Dozer ☐ Other

Depth (m)	Length (m)	Width (m)	Diameter (m)	Lining material	Dimentions of liner (m)	From Depth (m)	To Depth (m)

Please attach copies of the following if available (17)

Geologist log (Yes/No)	No	Laboratory analysis of water Sample (Yes/No)	No	Pumping test(s) (Yes/No)	No
Geophysical log (Yes/No)	No	Sieve analysis of aquifer material (Yes/No)	No	Installed Pump details (Yes/No)	No

BQS1S

Department of Primary Industries Water — NSW Government

Form A Particulars of completed work

Driller's Licence No:	DL2364	1
Class of Licence:	4	
Driller's Name:	Cameron Sharp	
Assistant Driller:	Darrly Hunt	
Contractor:	Gilbert and Sutherland	
New bore	X	Replacement bore
Deepened		Enlarged
Reconditioned		Other (specify)
Final Depth	55	m

Work Licence No:	30BL207399	2
Name of Licensee:	Lismore City Council	
Intended Use:	Monitoring	
Completion Date:	25/8/16	

DRILLING DETAILS 3

From (m)	To (m)	Hole Diameter (mm)	Drilling Method See Code 3
0	55	120	9

WATER BEARING ZONES 4

From (m)	To (m)	Thickness (m)	S W L (m)	Estimated Yield (L/s) Individual Aquifer	Cumulative	Test method See Code 4		D D L at end of test (m)	Duration Hrs	min	Salinity (Conductivity or TDS) Cond (µS/cm)	TDS (mg/L)
38	43	5	30	0.195	0.195	1	H	30		15	300	

CASING / LINER DETAILS 5

Material Code 5	OD (mm)	Wall Thickness (mm)	From (m)	To (m)	Method Fixing Code 5
13	50		0	55	5

Casing support method (See Code 5): 2

Type of casing bottom (See Code 5): 1

Centralisers installed (Yes/No)	No	(indicate on sketch)					
Sump installed (Yes/No)	Yes	From	52	m	To	55	m
Pressure cemented (Yes/No)	No	From		m	To		m
Casing Protector cemented in place							

WATER ENTRY DESIGN 6

Material Code 5	OD (mm)	Wall Thickness (mm)	From (m)	To (m)	Opening type See Code 6	Fixing See Code 5	Screen Aperture (mm)	Slot Details Length (mm)	Width (mm)	Alignment See Code 6
8	50		40	52	5	5			0.5	H

GRAVEL PACK 7

Type		Grade		Grain size (mm) From	To	Depth (m) From	To	Quantity Litres	m^3
Rounded	X	Graded	X	2	3	35	55	190	0.19
Crushed		Ungraded							
Bentonite/Grout seal (Yes/No)			Yes			29	35	60	0.01

Method of placement of Gravel Pack (See Code 7): 1

For Departmental use only: G W

NSW GOVERNMENT | Department of Primary Industries Water

Form A Particulars of completed work

Work Licence No: 30BL207399

BORE DEVELOPMENT (8)

Chemical used for breaking down drilling mud (Yes/No)	No	Name:					
Method	Bailing/Surging	Jetting	Airlifting	Backwashing	Pumping	Other:	
Duration	hrs	hrs	1 hrs	hrs	hrs	hrs	

DISINFECTION ON COMPLETION (9)

Chemical(s) used	Quantity applied (Litres)	Method of application

PUMPING TESTS ON COMPLETION (10)

Test type		Date	Pump intake depth (m)	Initial Water Level (SWL) (m)	Pumping rate (L/s)	Water Level at end of pumping (DDL) (m)	Duration of Test (hrs)	Recovery Water level (m)	Recovery Time taken (hrs)	Recovery Time taken (mins)
Multi stage (stepped drawdown)	Stage 1									
	Stage 2									
	Stage 3									
	Stage 4									
Single stage (constant rate)										

Height of measuring point above ground level ____ m Test Method ____ See Code 4

WORK PARTLY BACKFILLED OR ABANDONED (11)

Original depth of work: ____ m Is work partly backfilled: (Yes/No) ____

Is work abandoned: (Yes/No) ____ Method of abandonment: Backfilled ☐ Plugged ☐ Capped ☐

Has any casing been left in the work (Yes/No) ____ From ____ m To ____ m

Sealing / fill type (See Code 11)	From depth (m)	To depth (m)	Sealing / fill type (See Code 11)	From depth (m)	To depth (m)
1	0	35			

(12)

Site chosen by: Hydrogeologist ☐ Geologist ☒ Driller ☐ Diviner ☐ Client ☒ Other ____

(13)

Lot No ____ DP No ____

Work Location Co ordinates Easting 524670 Northing 6817819 Zone 54

GPS: (Yes/No) Yes >> AMG/AGD ☐ or MGA/GDA ☒ (See explanation)

Longitude ____ Latitude ____

Please mark the work site with "X" on the CLID provided map.
Indicate also the distances in metres from two (2) adjacent boundaries, and attach the map to this Form A package.

Signatures:

Driler: [signature] **Licensee:** ____

Date: 4/9/16 **Date:** ____

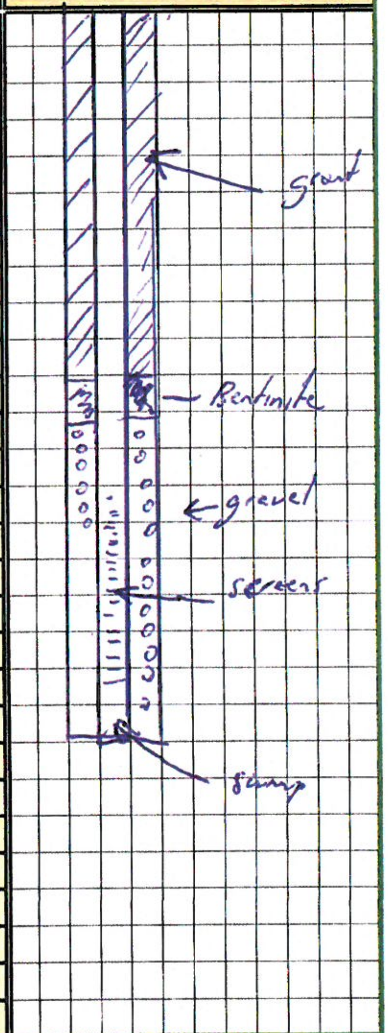
Please submit forms to water.gds@dpi.nsw.gov.au or to the local NSW Office of Water agency

Work Licence No: 30BL207399

DRILLER'S ROCK/STRATA DESCRIPTION (LITHOLOGY)

Depth From (m)	Depth To (m)	Description (See Code 15)
0	5	clay red
5	8	clay firm brown
8	55	bassalt firm blue

15 WORK CONSTRUCTION SKETCH



16 WORK NOT CONSTRUCTED BY DRILLING RIG

Method of excavation: Hand dug ☐ Back hoe ☐ Dragline ☐ Dozer ☐ Other ☐

Depth (m)	Length (m)	Width (m)	Diameter (m)	Lining material	Dimentions of liner (m)	From Depth (m)	To Depth (m)

17 Please attach copies of the following if available

Geologist log (Yes/No)		Laboratory analysis of water Sample (Yes/No)	Yes	Pumping test(s) (Yes/No)	
Geophysical log (Yes/No)		Sieve analysis of aquifer material (Yes/No)		Installed Pump details (Yes/No)	

BQS1I

NSW GOVERNMENT | Department of Primary Industries Water

Form A Particulars of completed work

Driller's Licence No:	DL2364	1
Class of Licence:		4
Driller's Name:	Cameron Sharp	
Assistant Driller:	Darrly Hunt	
Contractor:	Gilbert and Sutherland	
New bore	X	Replacement bore
Deepened		Enlarged
Reconditioned		Other (specify)
Final Depth	73	m

Work Licence No:	30BL207399	2
Name of Licensee:	Lismore City Council	
Intended Use:	Monitoring	
Completion Date:	24/8/16	

DRILLING DETAILS (3)

From (m)	To (m)	Hole Diameter (mm)	Drilling Method (See Code 3)
0	73	120	9

WATER BEARING ZONES (4)

From (m)	To (m)	Thickness (m)	S W L (m)	Estimated Yield (L/s) Individual Aquifer	Estimated Yield (L/s) Cumulative	Test method (See Code 4)		D D L at end of test (m)	Duration Hrs	Duration min	Salinity Cond (µS/cm)	Salinity TDS (mg/L)
34	39	5	30	0.195	0.195	1	H	30		15	300	
64	70	8	30	0.29	0.485	1	H	30		15	300	

CASING / LINER DETAILS (5)

Material Code 5	OD (mm)	Wall Thickness (mm)	From (m)	To (m)	Method Fixing Code 5
13	50		0	73	5

Casing support method	See Code 5	2						
Type of casing bottom	See Code 5	1						
Centralisers installed (Yes/No)	No	(indicate on sketch)						
Sump installed (Yes/No)	Yes	From	70	m	To	73	m	
Pressure cemented (Yes/No)	No	From		m	To		m	
Casing Protector cemented in place								

WATER ENTRY DESIGN (6)

Material Code 5	OD (mm)	Wall Thickness (mm)	From (m)	To (m)	Opening type See Code 6	Fixing See Code 5	Screen Aperture (mm)	Slot Length (mm)	Slot Width (mm)	Slot Alignment See Code 6
8	50		58	70	5	5			0.5	H

GRAVEL PACK (7)

Type		Grade		Grain size From (mm)	Grain size To (mm)	Depth From (m)	Depth To (m)	Quantity Litres	Quantity m^3
Rounded	X	Graded	X	2	3	53	73	190	0.19
Crushed		Ungraded							
Bentonite/Grout seal (Yes/No)			Yes			47	53	60	0.01
Method of placement of Gravel Pack				See Code 7	1				

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NSW GOVERNMENT | Department of Primary Industries Water

Form A Particulars of completed work

Work Licence No: 30BL207399

BORE DEVELOPMENT (8)

Chemical used for breaking down drilling mud (Yes/No) No Name:

Method	Bailing/Surging	Jetting	Airlifting	Backwashing	Pumping	Other:
Duration	hrs	hrs	1 hrs	hrs	hrs	hrs

DISINFECTION ON COMPLETION (9)

Chemical(s) used	Quantity applied (Litres)	Method of application

PUMPING TESTS ON COMPLETION (10)

Test type		Date	Pump intake depth (m)	Initial Water Level (SWL) (m)	Pumping rate (L/s)	Water Level at end of pumping (DDL) (m)	Duration of Test (hrs)	Recovery Water level (m)	Recovery Time taken (hrs)	Recovery Time taken (mins)
Multi stage (stepped drawdown)	Stage 1									
	Stage 2									
	Stage 3									
	Stage 4									
Single stage (constant rate)										

Height of measuring point above ground level m Test Method See Code 4

WORK PARTLY BACKFILLED OR ABANDONED (11)

Original depth of work: m Is work partly backfilled: (Yes/No)

Is work abandoned: (Yes/No) Method of abandonment: Backfilled ☐ Plugged ☐ Capped ☐

Has any casing been left in the work (Yes/No) From m To m

Sealing / fill type (See Code 11)	From depth (m)	To depth (m)	Sealing / fill type (See Code 11)	From depth (m)	To depth (m)
1	0	47			

(12)

Site chosen by: Hydrogeologist ☐ Geologist ☒ Driller ☐ Diviner ☐ Client ☒ Other

(13)

Lot No DP No

Work Location Co ordinates Easting 524670 Northing 6817819 Zone 54

GPS: (Yes/No) Yes >> AMG/AGD ☐ or MGA/GDA ☒ (See explanation)

Longitude Latitude

Please mark the work site with "X" on the CLID provided map.
Indicate also the distances in metres from two (2) adjacent boundaries, and attach the map to this Form A package.

Signatures:

Driller: ------------------------------ **Licensee:** ------------------------------

Date: ------------------------------ **Date:** ------------------------------

Please submit forms to water.gds@dpi.nsw.gov.au or to the local NSW Office of Water agency

Work Licence No: 30BL207399

DRILLER'S ROCK/STRATA DESCRIPTION (LITHOLOGY) — 15

Depth From (m)	Depth To (m)	Description (See Code 15)
0	5	clay red
5	8	clay firm brown
8	66	bassalt firm blue
66	67.5	bassalt/clay broken
67.5	73	bassalt firm blue

WORK CONSTRUCTION SKETCH

WORK NOT CONSTRUCTED BY DRILLING RIG — 16

Method of excavation: Hand dug ☐ Back hoe ☐ Dragline ☐ Dozer ☐ Other ☐

Depth (m)	Length (m)	Width (m)	Diameter (m)	Lining material	Dimentions of liner (m)	From Depth (m)	To Depth (m)

Please attach copies of the following if available — 17

Geologist log (Yes/No)		Laboratory analysis of water Sample (Yes/No)	Yes	Pumping test(s) (Yes/No)	
Geophysical log (Yes/No)		Sieve analysis of aquifer material (Yes/No)		Installed Pump details (Yes/No)	

BQS1D

Department of Primary Industries Water

Form A Particulars of completed work

Driller's Licence No:	DL2364		1
Class of Licence:			4
Driller's Name:	Cameron Sharp		
Assistant Driller:	Darrly Hunt		
Contractor:	Gilbert and Sutherland		
New bore	X	Replacement bore	
Deepened		Enlarged	
Reconditioned		Other (specify)	
Final Depth	102.7 m		

Work Licence No:	30BL207399	2
Name of Licensee:	Lismore City Council	
Intended Use:	Monitoring	
Completion Date:	23/8/16	

DRILLING DETAILS 3

From (m)	To (m)	Hole Diameter (mm)	Drilling Method See Code 3
0	102.7	120	9

WATER BEARING ZONES 4

From (m)	To (m)	Thickness (m)	S W L (m)	Estimated Yield (L/s) Individual Aquifer	Estimated Yield (L/s) Cumulative	Test method See Code 4		D D L at end of test (m)	Duration Hrs	Duration min	Salinity Cond (μS/cm)	Salinity TDS (mg/L)
34	39	5	30	0.195	0.195	1	H	30		15	300	
64	72	8	30	0.29	0.485	1	H	30		15	300	
95	99	4	30	0.73	1.215	1	H	30		15	300	

CASING / LINER DETAILS 5

Material Code 5	OD (mm)	Wall Thickness (mm)	From (m)	To (m)	Method Fixing Code 5
13	50		0	102.7	5

Casing support method See Code 5: 2

Type of casing bottom See Code 5: 1

Centralisers installed (Yes/No)	No	(indicate on sketch)			
Sump installed (Yes/No)	Yes	From	99 m	To	103 m
Pressure cemented (Yes/No)	No	From	m	To	m
Casing Protector cemented in place					

WATER ENTRY DESIGN 6

Material Code 5	OD (mm)	Wall Thickness (mm)	From (m)	To (m)	Opening type See Code 6	Fixing See Code 5	Screen Aperture (mm)	Slot Length (mm)	Slot Width (mm)	Alignment See Code 6
8	50		87.7	99.7	5	5			0.5	H

GRAVEL PACK 7

Type		Grade		Grain size From (mm)	Grain size To (mm)	Depth From (m)	Depth To (m)	Quantity Litres	Quantity m^3
Rounded	X	Graded	X	2	3	82.7	102.7	190	0.19
Crushed		Ungraded							
Bentonite/Grout seal (Yes/No)			Yes			76.7	82.7	60	0.01
Method of placement of Gravel Pack				See Code 7	1				

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Work Licence No: 30BL207399

BORE DEVELOPMENT (8)

Chemical used for breaking down drilling mud (Yes/No)	No	Name:									
Method	Bailing/Surging		Jetting		Airlifting		Backwashing		Pumping		Other:
Duration		hrs		hrs	1	hrs		hrs		hrs	hrs

DISINFECTION ON COMPLETION (9)

Chemical(s) used	Quantity applied (Litres)	Method of application

PUMPING TESTS ON COMPLETION (10)

Test type		Date	Pump intake depth (m)	Initial Water Level (SWL) (m)	Pumping rate (L/s)	Water Level at end of pumping (DDL) (m)	Duration of Test (hrs)	Recovery Water level (m)	Recovery Time taken (hrs)	Recovery Time taken (mins)
Multi stage (stepped drawdown)	Stage 1									
	Stage 2									
	Stage 3									
	Stage 4									
Single stage (constant rate)										

Height of measuring point above ground level [ ] m Test Method [ ] See Code 4

WORK PARTLY BACKFILLED OR ABANDONED (11)

Original depth of work: [ ] m Is work partly backfilled: (Yes/No) [ ]

Is work abandoned: (Yes/No) [ ] Method of abandonment: Backfilled [ ] Plugged [ ] Capped [ ]

Has any casing been left in the work (Yes/No) [ ] From [ ] m To [ ] m

Sealing / fill type See Code 11	From depth (m)	To depth (m)	Sealing / fill type See Code 11	From depth (m)	To depth (m)
1	0	76.7			

(12)

Site chosen by: Hydrogeologist [ ] Geologist [X] Driller [ ] Diviner [ ] Client [X] Other [ ]

(13)

Lot No [ ] DP No [ ]

Work Location Co ordinates Easting [524670] Northing [6817819] Zone [54]

GPS: (Yes/No) [Yes] >> AMG/AGD [ ] or MGA/GDA [X] (See explanation)

Longitude [ ] Latitude [ ]

Please mark the work site with "X" on the CLID provided map.
Indicate also the distances in metres from two (2) adjacent boundaries, and attach the map to this Form A package.

Signatures:

Driller: ------------------------------ **Licensee:** ------------------------------

Date: ------------------------------ **Date:** ------------------------------

Please submit forms to water.gds@dpi.nsw.gov.au or to the local NSW Office of Water agency

Work Licence No: 30BL207399

DRILLER'S ROCK/STRATA DESCRIPTION (LITHOLOGY) — 15

Depth From (m)	Depth To (m)	Description (See Code 15)
0	5	clay red
5	8	clay firm brown
8	66	bassalt firm blue
66	67.5	bassalt/clay broken
67.5	102.7	bassalt firm blue

WORK CONSTRUCTION SKETCH

WORK NOT CONSTRUCTED BY DRILLING RIG — 16

Method of excavation: Hand dug ☐ Back hoe ☐ Dragline ☐ Dozer ☐ Other ☐

Depth (m)	Length (m)	Width (m)	Diameter (m)	Lining material	Dimentions of liner (m)	From Depth (m)	To Depth (m)

Please attach copies of the following if available — 17

Geologist log (Yes/No)		Laboratory analysis of water Sample (Yes/No)	Yes	Pumping test(s) (Yes/No)	
Geophysical log (Yes/No)		Sieve analysis of aquifer material (Yes/No)		Installed Pump details (Yes/No)	

BQPB1

Easting: 524757
Northing: 6818728

Construction details:

Hole size - 178mm
125mm class 12 PVC - 0-127m
Slotted PVC - 97-127m
C-Bridge @ 30m
Cement grout - 0-30m

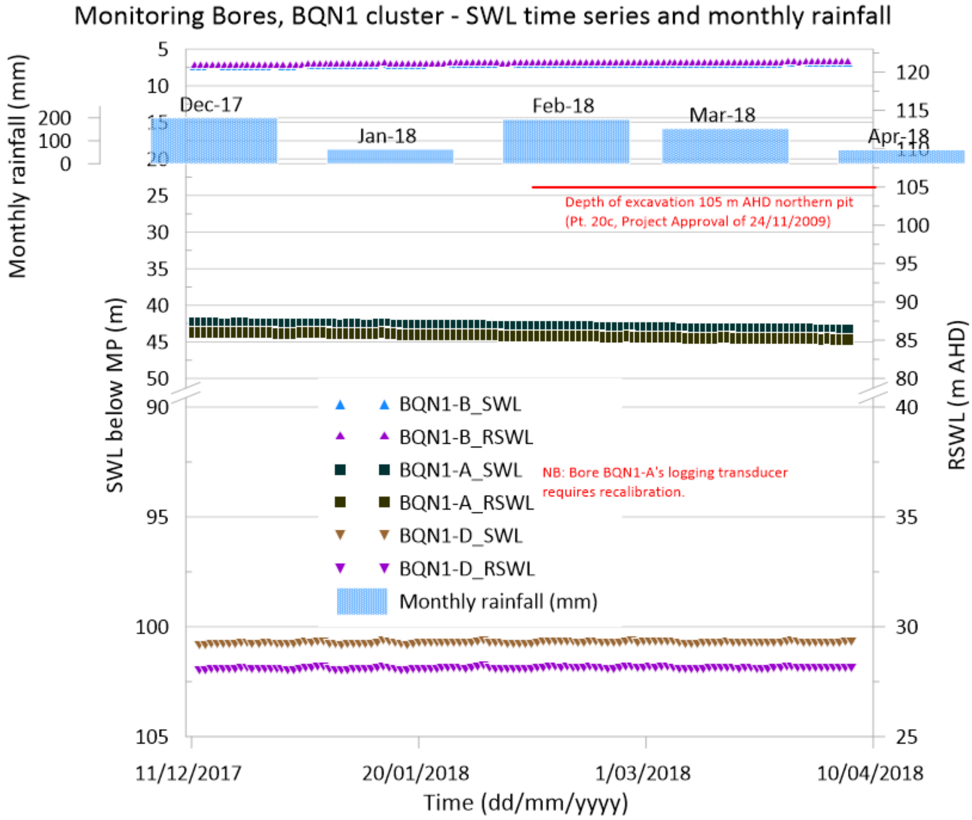
Bore log:

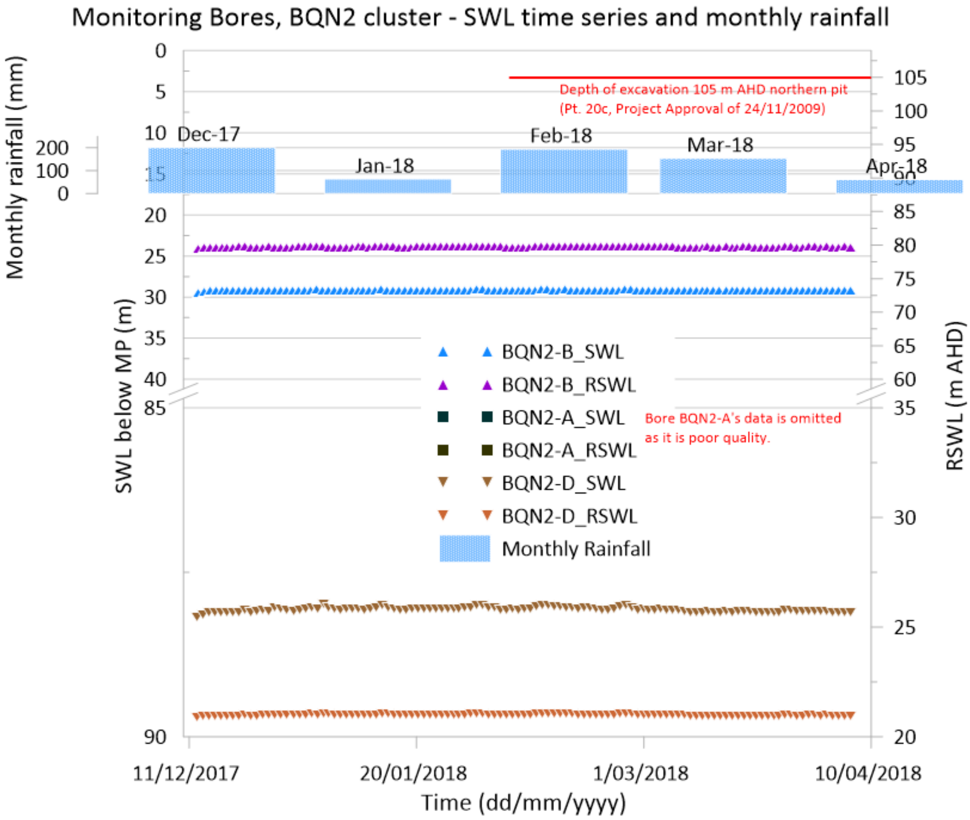
0-1m RED Clay Loam
1-3m Yellow/White Clay
3-19m Blue/Grey Basalt
19-24m Light Grey weathered Basalt
24-56m Blue/Grey Basalt
56-64m Black with Red Mottled zones weathered Honeycomb Basalt
64-95m Blue/Grey Basalt
95-102m Black with Red Mottled zones weathered Honeycomb Basalt
102-127m Blue/Grey Basalt

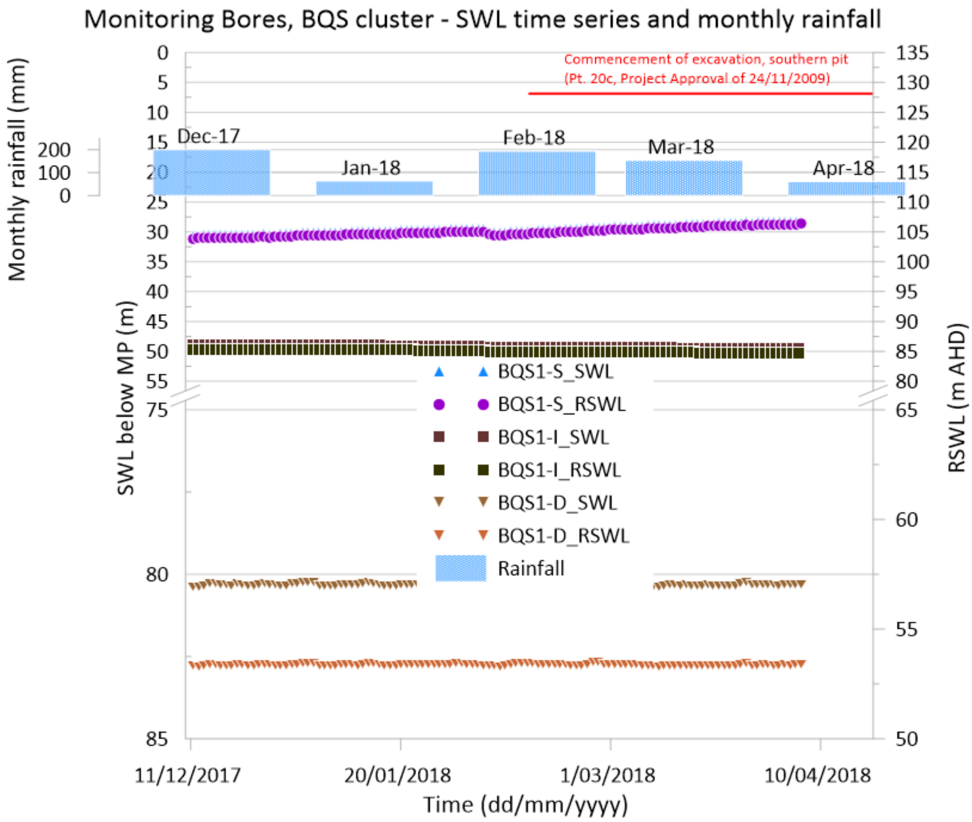
Water Bearing zones:
@ 3m - 0.15L/s
56-127m - 4 L/s

Airlifting:
SWL - 37m
@ 66m - 1.2L/s for 1 Hour
@69m - 1.75L/s for 1 Hour.

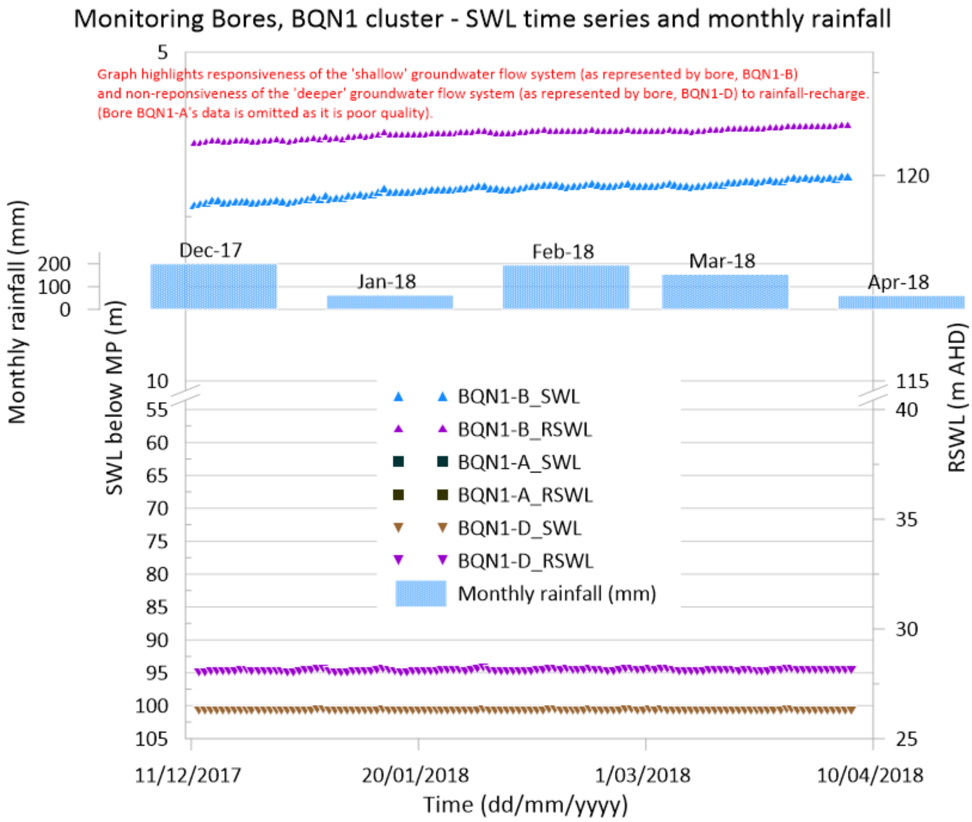
8 Appendix 3 – Monitoring bore SWL hydrographs


Monitoring Bores, BQN1 cluster - SWL time series and monthly rainfall
Monthly rainfall (mm)
SWL below MP (m)
RSWL (m AHD)
Dec-17
Jan-18
Feb-18
Mar-18
Apr-18
Depth of excavation 105 m AHD northern pit
(Pt. 20c, Project Approval of 24/11/2009)
BQN1-B_SWL
BQN1-B_RSWL
BQN1-A_SWL
BQN1-A_RSWL
BQN1-D_SWL
BQN1-D_RSWL
Monthly rainfall (mm)
NB: Bore BQN1-A's logging transducer requires recalibration.
11/12/2017
20/01/2018
1/03/2018
10/04/2018
Time (dd/mm/yyyy)

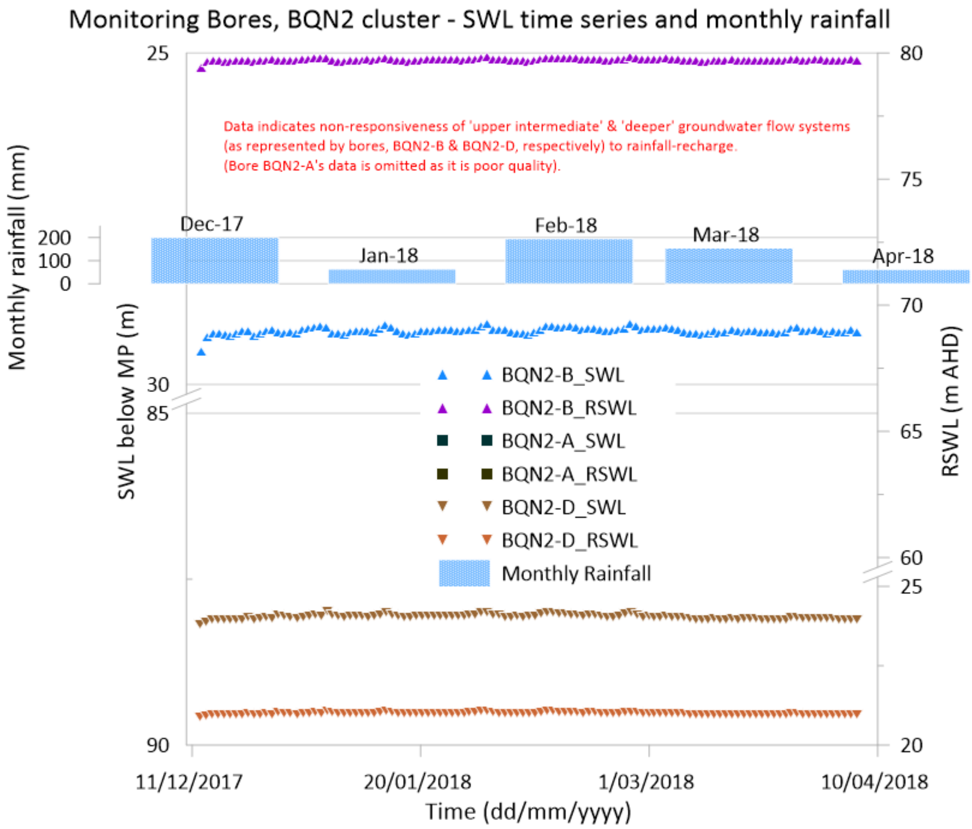

Monitoring Bores, BQN2 cluster - SWL time series and monthly rainfall
Monthly rainfall (mm)
SWL below MP (m)
RSWL (m AHD)
Dec-17
Jan-18
Feb-18
Mar-18
Apr-18
Depth of excavation 105 m AHD northern pit
(Pt. 20c, Project Approval of 24/11/2009)
BQN2-B_SWL
BQN2-B_RSWL
BQN2-A_SWL
BQN2-A_RSWL
BQN2-D_SWL
BQN2-D_RSWL
Monthly Rainfall
Bore BQN2-A's data is omitted as it is poor quality.
11/12/2017
20/01/2018
1/03/2018
10/04/2018
Time (dd/mm/yyyy)

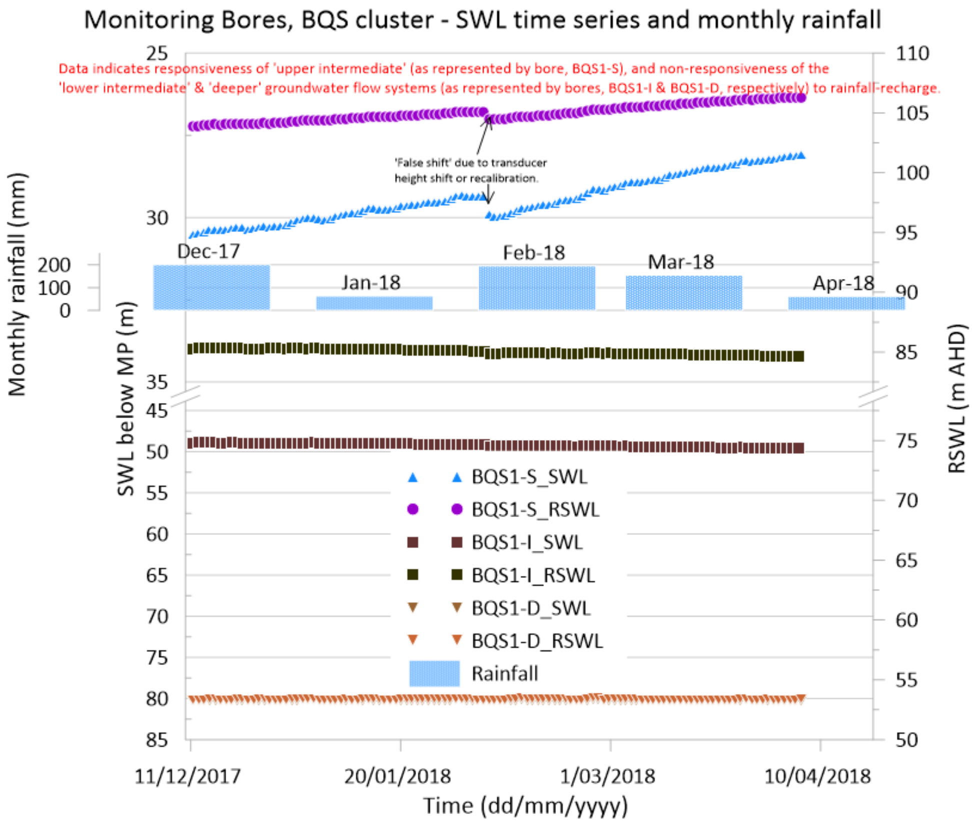


Monitoring Bores, BQS cluster - SWL time series and monthly rainfall
Commencement of excavation, southern pit
(Pt. 20c, Project Approval of 24/11/2009)
Monthly rainfall (mm)
SWL below MP (m)
RSWL (m AHD)
Dec-17
Jan-18
Feb-18
Mar-18
Apr-18
BQS1-S_SWL
BQS1-S_RSWL
BQS1-I_SWL
BQS1-I_RSWL
BQS1-D_SWL
BQS1-D_RSWL
Rainfall
11/12/2017
20/01/2018
1/03/2018
10/04/2018
Time (dd/mm/yyyy)



Monitoring Bores, BQN1 cluster - SWL time series and monthly rainfall
Graph highlights responsiveness of the 'shallow' groundwater flow system (as represented by bore, BQN1-B)
and non-reponsiveness of the 'deeper' groundwater flow system (as represented by bore, BQN1-D) to rainfall-recharge.
(Bore BQN1-A's data is omitted as it is poor quality).
Monthly rainfall (mm)
SWL below MP (m)
RSWL (m AHD)
Dec-17
Jan-18
Feb-18
Mar-18
Apr-18
BQN1-B_SWL
BQN1-B_RSWL
BQN1-A_SWL
BQN1-A_RSWL
BQN1-D_SWL
BQN1-D_RSWL
Monthly rainfall (mm)
11/12/2017
20/01/2018
1/03/2018
10/04/2018
Time (dd/mm/yyyy)


Monitoring Bores, BQN2 cluster - SWL time series and monthly rainfall
Data indicates non-responsiveness of 'upper intermediate' & 'deeper' groundwater flow systems (as represented by bores, BQN2-B & BQN2-D, respectively) to rainfall-recharge. (Bore BQN2-A's data is omitted as it is poor quality).
Dec-17
Jan-18
Feb-18
Mar-18
Apr-18
Monthly rainfall (mm)
SWL below MP (m)
RSWL (m AHD)
BQN2-B_SWL
BQN2-B_RSWL
BQN2-A_SWL
BQN2-A_RSWL
BQN2-D_SWL
BQN2-D_RSWL
Monthly Rainfall
11/12/2017
20/01/2018
1/03/2018
10/04/2018
Time (dd/mm/yyyy)


Monitoring Bores, BQS cluster - SWL time series and monthly rainfall
Data indicates responsiveness of 'upper intermediate' (as represented by bore, BQS1-S), and non-responsiveness of the 'lower intermediate' & 'deeper' groundwater flow systems (as represented by bores, BQS1-I & BQS1-D, respectively) to rainfall-recharge.
'False shift' due to transducer height shift or recalibration.
Dec-17
Jan-18
Feb-18
Mar-18
Apr-18
Monthly rainfall (mm)
SWL below MP (m)
RSWL (m AHD)
BQS1-S_SWL
BQS1-S_RSWL
BQS1-I_SWL
BQS1-I_RSWL
BQS1-D_SWL
BQS1-D_RSWL
Rainfall
11/12/2017
20/01/2018
1/03/2018
10/04/2018
Time (dd/mm/yyyy)

9 Appendix 4 – Detailed modelling results

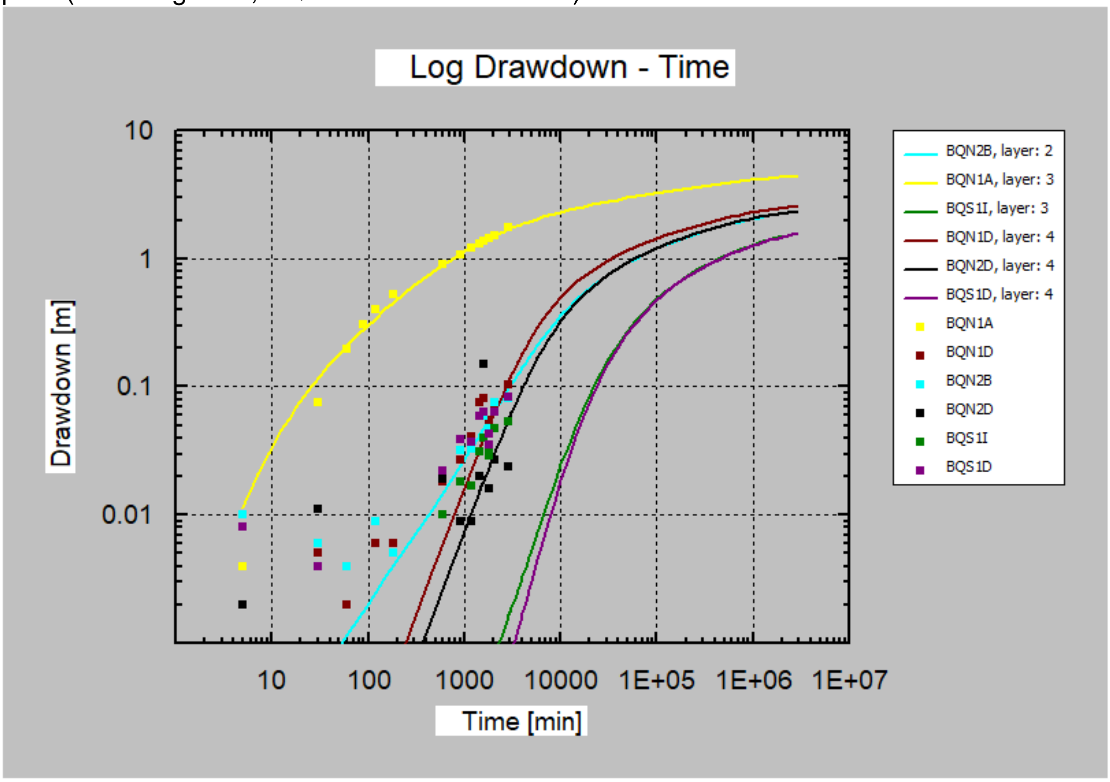
Blakebrook Quarry – MLU Model Run 1

Table of parameters used to simulate test pumping drawdowns and recoveries

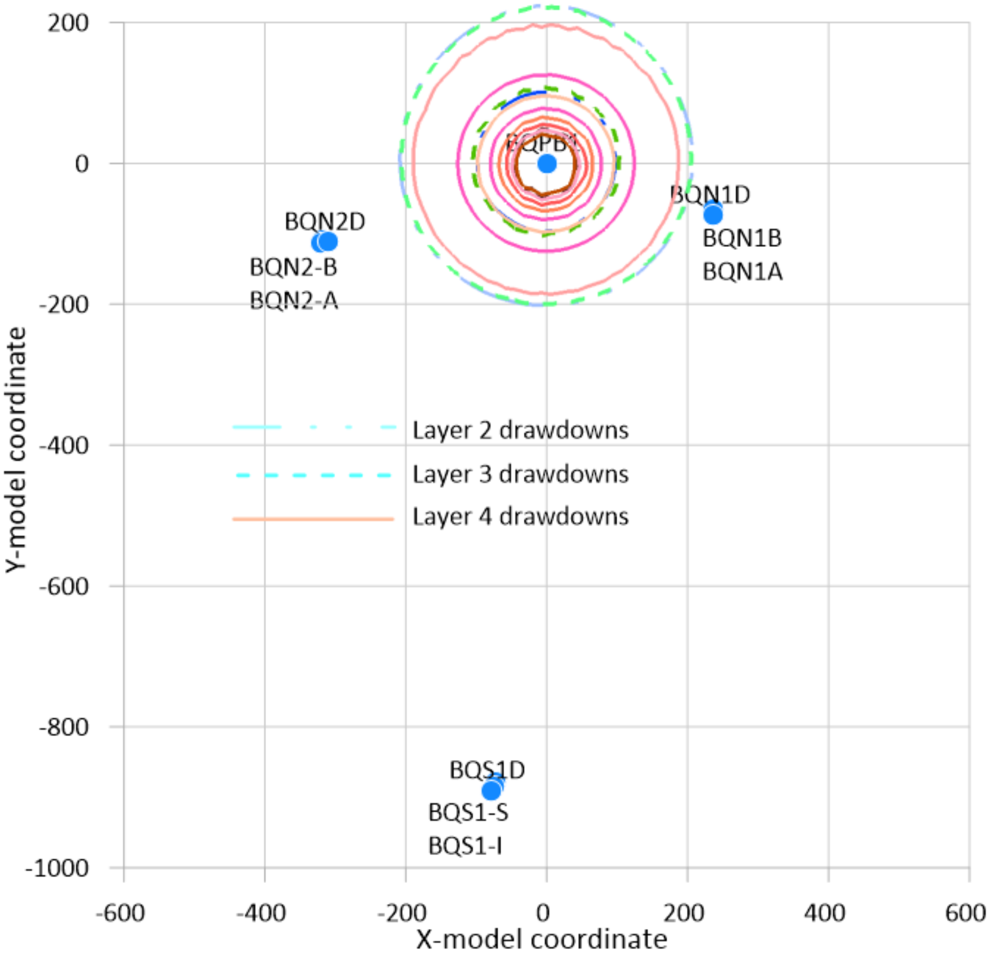
Aquifer	Base [m]	Thickness [m]	Kh [m/min]	Code	T [m²/min]	#	Code	S [-]	#	Name
	108.5	15	5.59019E-09	c1	2.683272E+09		S'1	0		
1	104.5	4	0.006679	T1	0.026716		S1	0.000999	B	Shallow aquifer
	90.5	14	5.21751E-09	c2	2.683272E+09		S'2	0		
2	83	7.5	0.001413	T2	0.010598		S2	7.708272E-08	D	Intermediate aq. (upper)
	67.5	15.5	0.000169	c3	91611.7		S'3	1E-06		
3	60.5	7	0.000412	T3	0.002881		S3	6.238266E-08	F	Intermediate aq. (lower)
	24	36.5	0.000042	c4	8.676291E+05		S'4	1E-06		
4	18	6	0.000338	T4	0.002025		S4	0.001604	H	Deeper aquifer
	12	6	1E-06	c5	6E+06		S'5	1E-06		

Aquifer	Base [m]	Thickness [m]	Kv [m/min]	Code	c [min]	#	Code	S' [-]	#	Name
	108.5	15	5.59019E-09	c1	2.683272E+09		S'1	0		
1	104.5	4	0.006679	T1	0.026716		S1	0.000999	B	Shallow aquifer
	90.5	14	5.21751E-09	c2	2.683272E+09		S'2	0		
2	83	7.5	0.001413	T2	0.010598		S2	7.707844E-08	D	Intermediate aq. (upper)
	67.5	15.5	0.000169	c3	91611.7		S'3	1E-06		
3	60.5	7	0.000412	T3	0.002881		S3	6.237919E-08	F	Intermediate aq. (lower)
	24	36.5	0.000042	c4	8.676291E+05		S'4	1E-06		
4	18	6	0.000338	T4	0.002025		S4	0.001604	H	Deeper aquifer
	12	6	1E-06	c5	6E+06		S'5	1E-06		

Test pumping (30 Sep–2 Oct 2017) simulation – log drawdown vs. log time measured data versus 'best fit' plots (excluding Bore, BQN1-B's drawdown data)

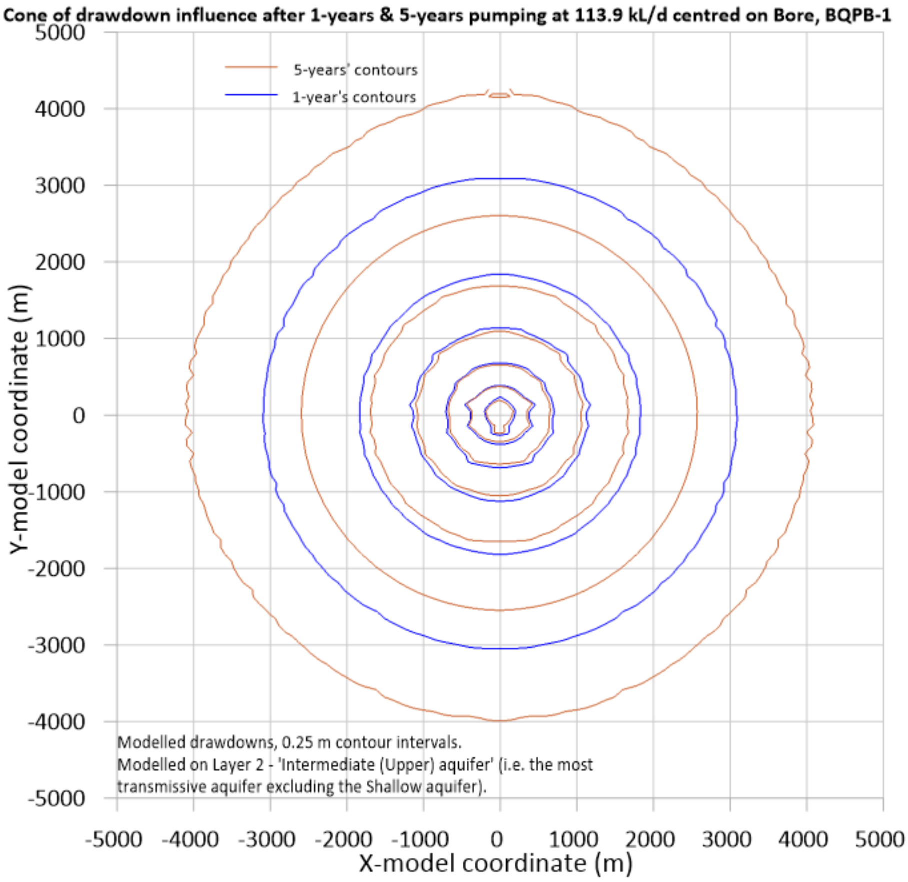


Test pumping (30 Sep–2 Oct 2017) simulation – simulated 48 hours drawdown contours (excluding Bore, BQN1-B's drawdown data)



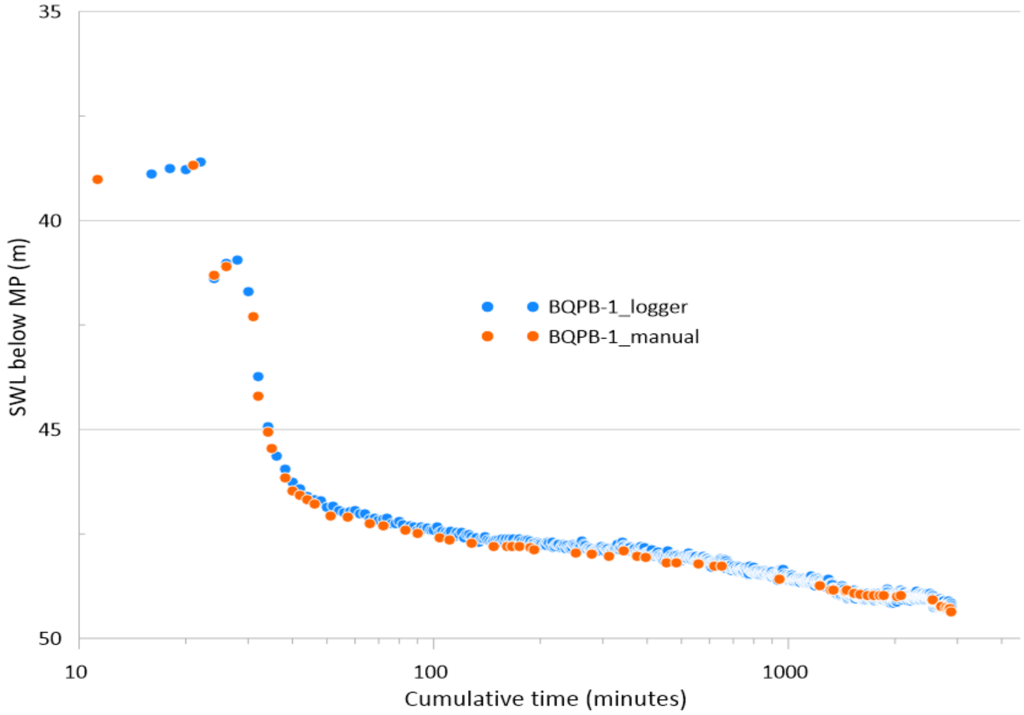
Modelled drawdowns (0.25 m contour intervals).
'Intermediate - upper & lower aquifes' & 'Deeper aquifer'.

Blakebrook Quarry – MLU Model Run 2 and 3 – continuous pumping periods of 1-year and 5-years

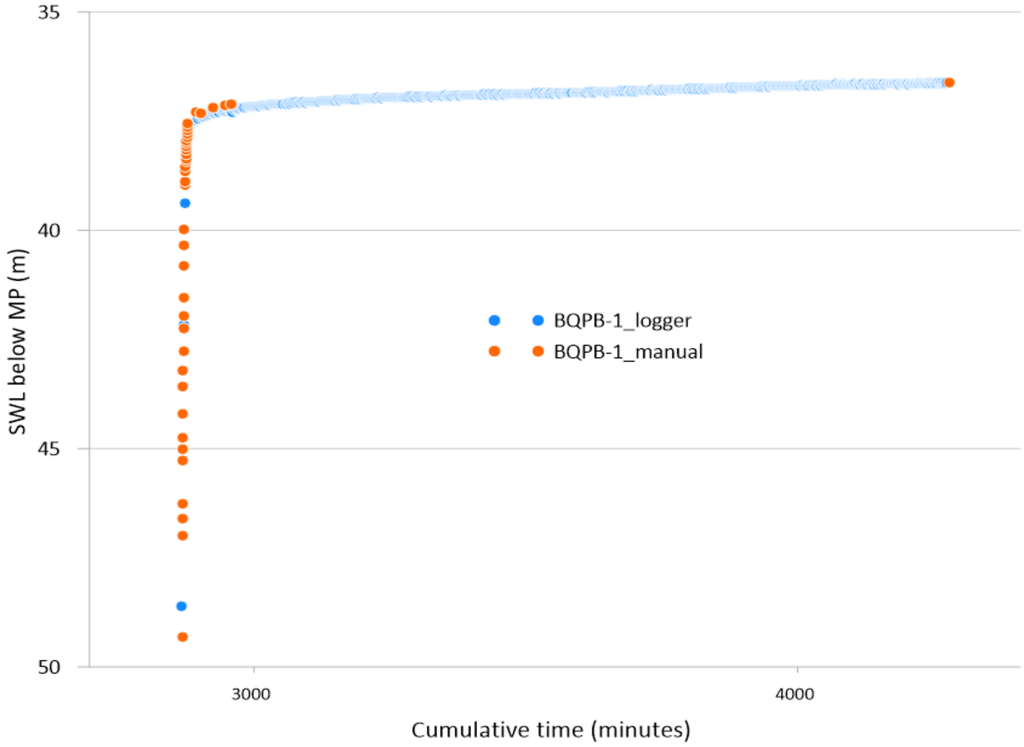


10 Appendix 5 – Pump test results

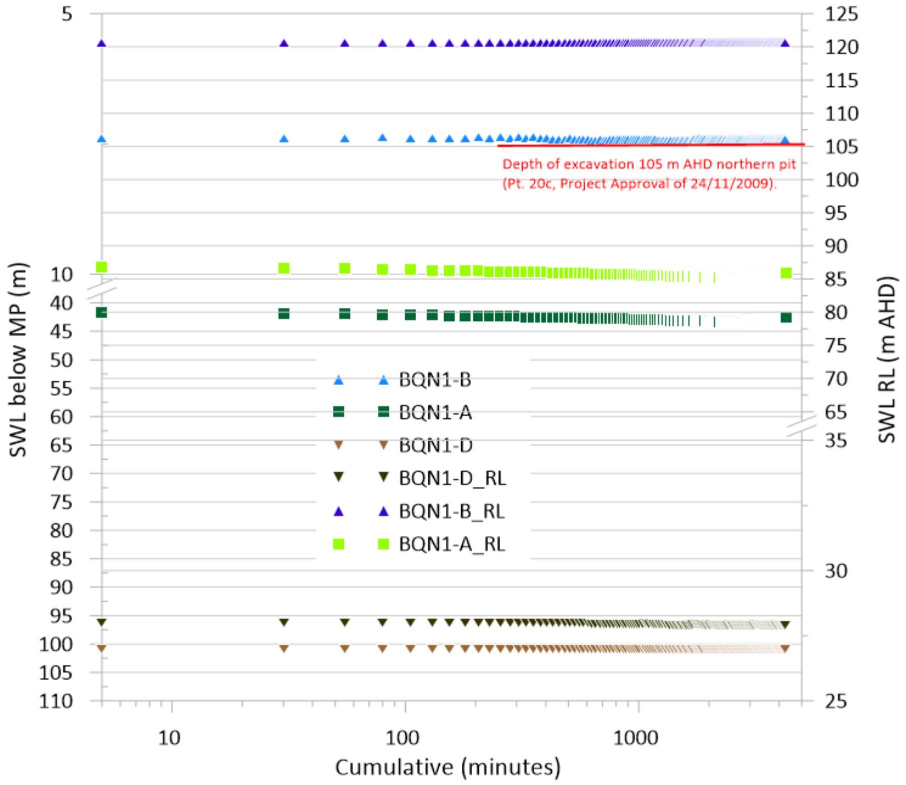
BQPB-1 Pumped Bore - Drawdown vs. Log time
Date of test: 30/9 to 2/10/2017.
Discharge rate approx. 1.32 L/s for 48 hours.



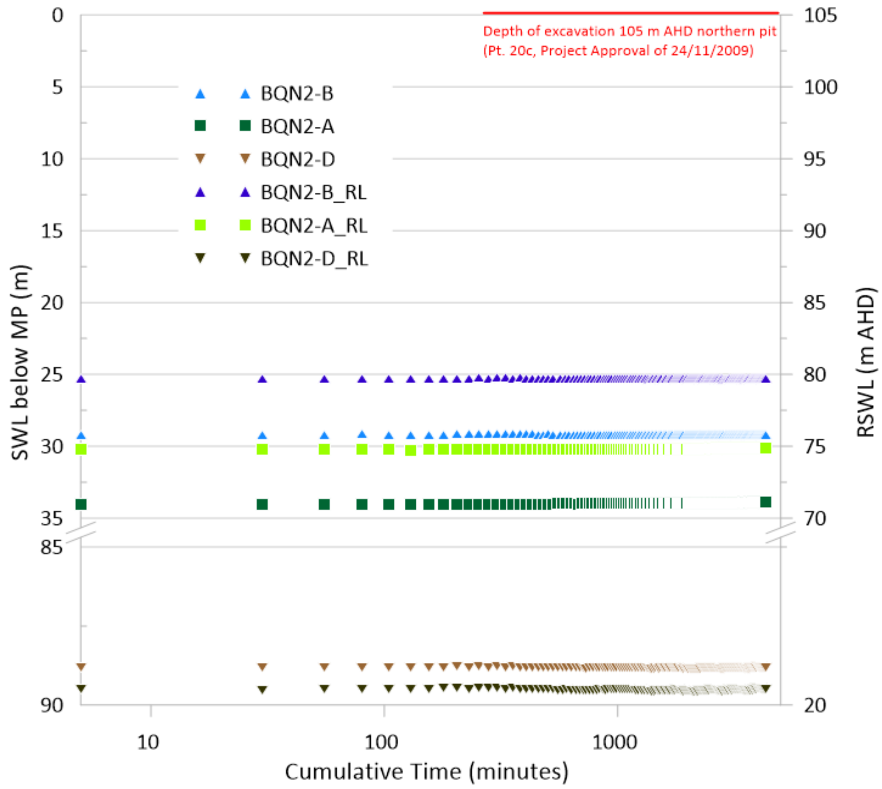
BQPB-1 Pumped Bore - Recovery vs. Log time
Date of test: 30/9 to 2/10/2017
Recovery period: 24 hours

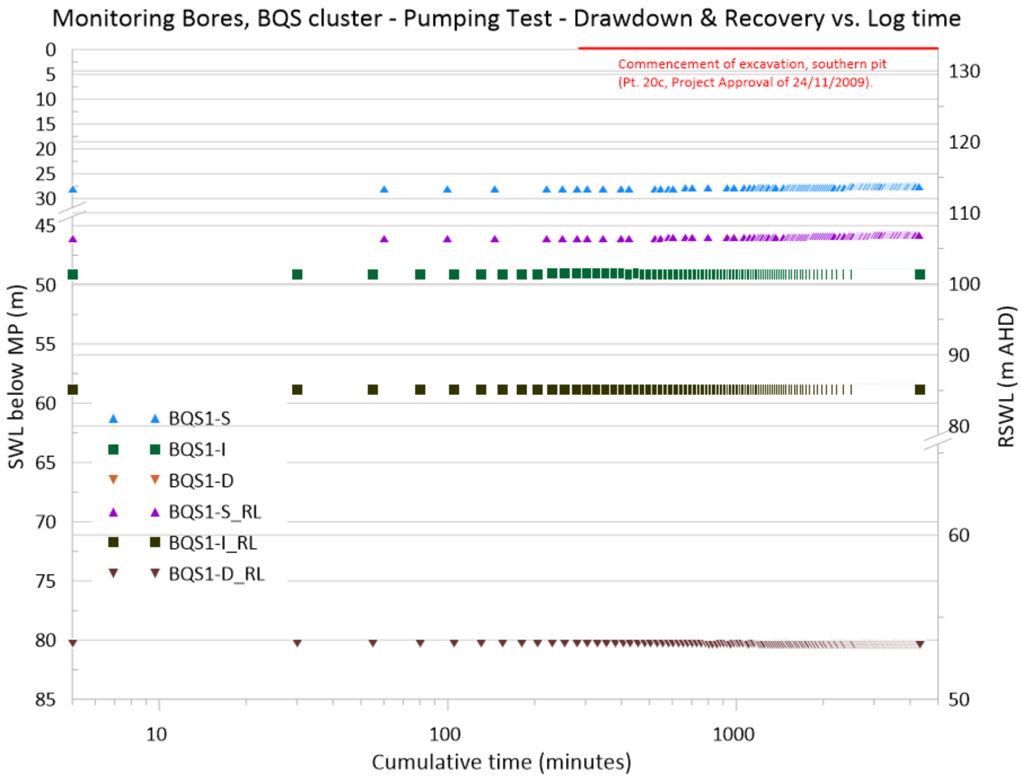


Monitoring Bores, BQN1 cluster - Pumping Test - Drawdown & Recovery vs. Log time



Monitoring Bores, BQN2 cluster - Pumping Test - Drawdown & Recovery vs. Log time





Monitoring Bores, BQS cluster - Pumping Test - Drawdown & Recovery vs. Log time
Commencement of excavation, southern pit
(Pt. 20c, Project Approval of 24/11/2009).
SWL below MP (m)
RSWL (m AHD)
Cumulative time (minutes)
BQS1-S
BQS1-I
BQS1-D
BQS1-S_RL
BQS1-I_RL
BQS1-D_RL

11 Appendix 6 – Estimation of groundwater inflow to pit

The estimation of the groundwater inflow to the Blakebrook Quarry final pit void (55mAHD) was calculated as follows:

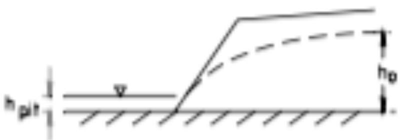
Approximating the pit geometry expressed as a circular void, the area of the final void will be approximately 417,000 m^2.

$$rpit = \sqrt{\frac{\text{area of base of pit}}{\pi}}$$

… then, r_{pit} = 365 m

Using the Dupuit-Forchheimer equation to determine the discharge rate:

Q = $\frac{\pi K\,(ho^2 - hpit^2)}{\ln\left(\frac{r0}{rpit}\right)}$ where $r0 = \sqrt{\frac{2.25\text{Kh0t}}{\text{Sy}}}$



for a fully dewatered pit, h_{pit} = 0, and,

Q = $\frac{\pi K\,(ho^2)}{\ln\left(\frac{r0}{rpit}\right)}$

If the pit is of large diameter before dewatering commences (as it reaches the water table), r_0 is replaced by $r_{pit} + \Delta r$

where $\Delta r = \sqrt{\frac{3\text{Kh0t}}{\text{Sy}}}$ and time starts with dewatering, not with excavation of pit.

… then drawdown at radius r (Δr) = $h0 - \sqrt{h0^2 \frac{\ln(r/rpit)}{\ln(\text{r0/rpit})}}$

In fractured rock, K_R varies with orientation, but the discharge is not direction dependent, then,
$K_R = \sqrt{\text{Kmax} - \text{Kmin}}$ the effective K, can be used to estimate Q.

Applying to the Blakebrook Quarry final void:

where K_{hm} = $\sqrt{\frac{n(K)}{\frac{1}{K1}+\frac{1}{K2}+\frac{1}{K3}}} \cdot \sqrt{\frac{n(b)}{\frac{1}{b1}+\frac{1}{b2}+\frac{1}{b3}}}$

and, given that K_1 = 9.6m2/d – Layer A1, K_2 = 2m2/d – Layer A2, and, K_3 = 0.6m2/d – Layer A3. (Note that Layer A4 lies below the final excavated pit floor), and,
b_1 = 4m – thickness of Layer 1, b_2 = 7.5m – Layer 2, and, b_3 = 7m – Layer 3[20].

then K_{hm}= 4.1 m/day

[20] Refer *Table 6 Analytical Model of the Groundwater System underlying Blakebrook Quarry*.

Assuming Sy (specific yield) = 0.1 and, given that, h_0 = SWL (Layer 1) 122m RL – 60.5 m RL (the RL of Layer 3) = 61.5 m.
Assuming that inflows (by natural groundwater discharge) to the pit occur 1 year after commencement of first excavation, then,

$r0\ (rpit\ + \Delta\ r)$ = 2,025 m

… and, Q = 190 kL/day (2.2 L/s)

To summarise, the predicted rate of **groundwater inflow is 2.2 L/s** after the first year of excavation to final void of 55m RL.

Assumptions
The Dupuit–Forchheimer equation assumes that groundwater flows horizontally in an unconfined aquifer and that the groundwater discharge is proportional to the saturated aquifer thickness.

Given that it is predicted that three separate aquifers will be intersected during the course of excavation, the rate of groundwater inflow will vary according to when these aquifers are intersected. However, the above result gives a first and reasonable order of estimate of predicted groundwater inflow. Given that Layer 1 has more than twice the transmissivity of Layer 2, then early inflows of a slightly higher order (than 2.2 L/s) are likely to occur. However, as the head decreases with an expanding cone of influence, rates of groundwater inflow are expected to lessen over time (even though the three aquifers will be intersected).

The timing / schedule of excavation is unknown, but the calculation assumes that the depth of excavation to final pit depth (RL 55m) will take between 1 and 5 years.

Note that this estimation neither accounts for rainfall-recharge to the aquifers, nor direct input to the pit by rainfall.

Reference source: *Figure 20: Open Cut Mines and Equivalent Circular Pi*t cited in *Australian Groundwater School (undated). Volume 1. ISBN 0 643 06069 3 Volume 2. ISBN 0 643 06070 7 Volume 3. ISBN 0 643 06071 5. Centre for Groundwater Studies.*

12 Appendix 7 – Secretary’s endorsement for G&S to prepare Groundwater Assessment

NSW GOVERNMENT | Planning & Environment

Planning Services
Resource Assessments
Contact: Jack Murphy
Phone: (02) 8217 2016
Email: jack.murphy@planning.nsw.gov.au

Ms Eleisha Went
Commercial Services Compliance Coordinator
Lismore City Council
PO Box 23A
Lismore NSW 2480

Email: eleisha.went@lismore.nsw.gov.au

Dear Ms Went,

Blakebrook Quarry Modification 1 (MP 07_0020)
Appointment of a Suitably Qualified and Experienced Person

I refer to your email dated 24 January 2019, requesting the Secretary's endorsement of suitably qualified and experienced experts to prepare the Groundwater Assessment Report for Blakebrook Quarry (MP 07_0020).

The Department has reviewed the credentials of Mr Eric Richard Rooke and Mr Christopher Mark Anderson of Gilbert and Sutherland Pty Ltd and agrees that they are suitably qualified experts. In accordance with condition 17(a) of Schedule 3 of MP 07_0020, the Secretary endorses Lismore City Council's proposed team to prepare the above document.

Should you have any enquiries in relation to this matter, please contact Jack Murphy.

Yours sincerely,

Howard Reed

Howard Reed 25. 1. 19
Director
Resource Assessments
as nominee of the Secretary

13 Appendix 8 – Summary statistics and interim groundwater targets

Summary statistics for groundwater bores data set 2016 to June 2018

BQS1-S	Count	LOR	N	%LOR	Minimum	20th Percentile	Median	80th Percentile	Maximum	Mean	STD
pH	10	0	10	0%	6.22	6.78	6.87	7.12	7.59	6.91	0.36
Conductivity (EC) (dS/m)	6	0	6	0%	0.354	0.399	0.443	0.512	1.444	0.599	0.418
Total Dissolved Salts (mg/L)	6	0	6	0%	241	271	301	348	982	407	284
Total Suspended Solids (mg/L)	10	0	10	0%	25	27	164	472	2630	430	794
Total Oils and Grease (mg/L)	9	1	10	10%	2.0	3.6	4.3	10.8	17.0	7.2	5.4
Nitrate (mg/L N)	9	1	10	10%	0.016	0.025	0.036	0.054	0.236	0.058	0.068
Silver (mg/L)	0	8	8	100%	0.00				0.00		
Aluminium (mg/L)	10	0	10	0%	0.020	0.181	0.214	0.623	0.954	0.351	0.289
Arsenic (mg/L)	3	6	9	67%	0.001	0.001	0.002	0.007	0.011	0.005	0.006
Cadmium (mg/L)	0	9	9	100%	0.00				0.00		
Chromium (mg/L)	7	2	9	22%	0.001	0.001	0.001	0.002	0.002	0.001	0.001
Copper (mg/L)	9	0	9	0%	0.001	0.001	0.003	0.004	0.005	0.003	0.001
Iron (mg/L)	9	0	9	0%	0.036	0.692	1.031	1.829	2.730	1.242	0.903
Manganese (mg/L)	9	0	9	0%	0.051	0.110	0.142	0.163	0.175	0.133	0.039
Nickel (mg/L)	8	1	9	11%	0.006	0.006	0.008	0.009	0.010	0.008	0.001
Lead (mg/L)	6	2	8	25%	0.001	0.001	0.001	0.001	0.004	0.002	0.001
Selenium (mg/L)	0	9	9	100%	0.000				0.000		
Zinc (mg/L)	10	0	10	0%	0.001	0.024	0.027	0.055	2.000	0.230	0.622
Mercury (mg/L)	1	8	9	89%	0.001	0.001	0.001	0.001	0.001	0.001	

BQS1-I	Count	LOR	N	%LOR	Minimum	20th Percentile	Median	80th Percentile	Maximum	Mean	STD
pH	10	0	10	0%	7.12	7.86	8.08	8.10	8.12	7.92	0.32
Conductivity (EC) (dS/m)	6	0	6	0%	1.522	1.559	1.580	1.581	1.624	1.574	0.033
Total Dissolved Salts (mg/L)	6	0	6	0%	1035	1060	1075	1075	1104	1071	23
Total Suspended Solids (mg/L)	10	0	10	0%	1	36	491	663	2550	572	746
Total Oils and Grease (mg/L)	9	1	10	10%	2	3	4	8	21	6	6
Nitrate (mg/L N)	10	0	10	0%	0.009	0.012	0.019	0.043	0.079	0.028	0.022
Silver (mg/L)	0	10	10	100%	0.000				0.000		
Aluminium (mg/L)	10	0	10	0%	0.003	0.153	0.283	1.038	1.084	0.528	0.460
Arsenic (mg/L)	9	1	10	10%	0.001	0.001	0.001	0.001	0.001	0.001	0.000
Cadmium (mg/L)	0	10	10	100%	0.000				0.000		
Chromium (mg/L)	6	4	10	40%	0.001	0.001	0.001	0.002	0.006	0.002	0.002
Copper (mg/L)	9	1	10	10%	0.001	0.002	0.003	0.004	0.006	0.003	0.002
Iron (mg/L)	10	0	10	0%	0.012	0.321	0.635	4.977	5.811	2.171	2.452
Manganese (mg/L)	10	0	10	0%	0.067	0.076	0.135	0.180	0.671	0.177	0.179
Nickel (mg/L)	9	1	10	10%	0.002	0.004	0.006	0.011	0.017	0.007	0.005
Lead (mg/L)	8	2	10	20%	0.001	0.001	0.003	0.005	0.007	0.003	0.002
Selenium (mg/L)	0	10	10	100%	0.000				0.000		
Zinc (mg/L)	10	0	10	0%	0.003	0.021	0.049	0.140	0.143	0.070	0.056
Mercury (mg/L)	0	10	10	100%	0.000				0.000		

BQS1-D	Count	LOR	N	%LOR	Minimum	20th Percentile	Median	80th Percentile	Maximum	Mean	STD
pH	10	0	10	0%	7.02	8.16	8.26	8.30	8.43	8.13	0.40
Conductivity (EC) (dS/m)	6	0	6	0%	1.790	1.805	1.815	1.829	1.978	1.839	0.070
Total Dissolved Salts (mg/L)	6	0	6	0%	1217	1227	1233	1244	1345	1250	48
Total Suspended Solids (mg/L)	10	0	10	0%	2	63	207	486	975	305	319
Total Oils and Grease (mg/L)	9	1	10	10%	2.8	4.2	7.0	14.2	30.0	10.1	8.9
Nitrate (mg/L N)	10	0	10	0%	0.011	0.015	0.043	0.054	0.077	0.039	0.025
Silver (mg/L)	0	10	10	100%	0.000				0.000		
Aluminium (mg/L)	9	1	10	10%	0.142	0.497	0.895	1.002	1.210	0.752	0.354
Arsenic (mg/L)	9	1	10	10%	0.001	0.001	0.001	0.002	0.002	0.001	0.001
Cadmium (mg/L)	0	10	10	100%	0.000				0.000		
Chromium (mg/L)	8	2	10	20%	0.002	0.002	0.002	0.003	0.003	0.002	0.000
Copper (mg/L)	8	2	10	20%	0.002	0.003	0.003	0.005	0.015	0.005	0.004
Iron (mg/L)	10	0	10	0%	0.006	0.867	2.649	6.580	8.861	3.489	3.016
Manganese (mg/L)	10	0	10	0%	0.027	0.053	0.069	0.145	0.184	0.092	0.053
Nickel (mg/L)	10	0	10	0%	0.001	0.006	0.009	0.011	0.021	0.009	0.006
Lead (mg/L)	9	1	10	10%	0.001	0.003	0.004	0.009	0.016	0.006	0.005
Selenium (mg/L)	0	10	10	100%	0.000				0.000		
Zinc (mg/L)	10	0	10	0%	0.005	0.042	0.090	0.171	0.228	0.105	0.075
Mercury (mg/L)	0	10	10	100%	0.000				0.000		

BQN1-S	Count	LOR	N	%LOR	Minimum	20th Percentile	Median	80th Percentile	Maximum	Mean	STD
pH	13	0	13	0%	6.77	6.98	7.03	7.18	7.61	7.09	0.20
Conductivity (EC) (dS/m)	6	0	6	0%	1.14	1.14	1.15	1.17	3.64	1.57	1.01
Total Dissolved Salts (mg/L)	6	0	6	0%	778	778	785	796	2474	1066	690
Total Suspended Solids (mg/L)	12	0	12	0%	2	3	4	6	1150	101	330
Total Oils and Grease (mg/L)	10	3	13	23%	2	3	4	4	5	4	1
Nitrate (mg/L N)	4	9	13	69%	0.002	0.003	0.005	0.008	0.010	0.005	0.004
Silver (mg/L)	0	13	13	100%	0.000				0.000		
Aluminium (mg/L)	10	3	13	23%	0.001	0.002	0.003	0.004	0.293	0.032	0.092
Arsenic (mg/L)	13	0	13	0%	0.002	0.002	0.003	0.003	0.003	0.003	0.000
Cadmium (mg/L)	0	13	13	100%	0.000				0.000		
Chromium (mg/L)	2	11	13	85%	0.000	0.000	0.001	0.001	0.001	0.001	0.001
Copper (mg/L)	9	4	13	31%	0.001	0.001	0.001	0.002	0.004	0.002	0.001
Iron (mg/L)	13	0	13	0%	0.008	1.730	1.891	2.162	2.496	1.832	0.603
Manganese (mg/L)	13	0	13	0%	0.143	0.150	0.158	0.163	0.355	0.171	0.056
Nickel (mg/L)	2	11	13	85%	0.002	0.002	0.002	0.002	0.002	0.002	0.000
Lead (mg/L)	0	13	13	100%	0.000				0.000		
Selenium (mg/L)	0	13	13	100%	0.000				0.000		
Zinc (mg/L)	12	1	13	8%	0.001	0.001	0.007	0.011	0.154	0.018	0.043
Mercury (mg/L)	0	13	13	100%	0.000				0.000		

BQN1-I	Count	LOR	N	%LOR	Minimum	20th Percentile	Median	80th Percentile	Maximum	Mean	STD
pH	13	0	13	0%	6.94	9.03	10.29	11.34	11.53	10.07	1.37
Conductivity (EC) (dS/m)	6	0	6	0%	1.825	1.950	2.070	2.082	2.302	2.050	0.159
Total Dissolved Salts (mg/L)	6	0	6	0%	1241	1326	1408	1416	1565	1394	108
Total Suspended Solids (mg/L)	13	0	13	0%	38	62	125	172	578	171	163
Total Oils and Grease (mg/L)	6	7	13	54%	1.7	2.0	2.8	9.0	22.0	6.7	8.0
Nitrate (mg/L N)	13	0	13	0%	0.007	0.077	0.132	0.234	0.356	0.163	0.110
Silver (mg/L)	2	11	13	85%	0.001	0.001	0.001	0.001	0.001	0.001	0.000
Aluminium (mg/L)	12	1	13	8%	0.072	0.144	0.694	1.891	11.400	1.686	3.139
Arsenic (mg/L)	10	3	13	23%	0.001	0.001	0.001	0.002	0.005	0.002	0.001
Cadmium (mg/L)	0	13	13	100%	0.000				0.000		
Chromium (mg/L)	11	2	13	15%	0.001	0.003	0.004	0.008	0.012	0.005	0.003
Copper (mg/L)	11	2	13	15%	0.002	0.003	0.005	0.019	0.044	0.011	0.013
Iron (mg/L)	13	0	13	0%	0.008	0.126	0.500	1.972	10.010	1.488	2.674
Manganese (mg/L)	13	0	13	0%	0.005	0.014	0.049	0.113	2.030	0.237	0.554
Nickel (mg/L)	13	0	13	0%	0.001	0.003	0.003	0.022	0.037	0.011	0.014
Lead (mg/L)	8	5	13	38%	0.001	0.001	0.002	0.002	0.018	0.004	0.006
Selenium (mg/L)	1	12	13	92%	0.002	0.002	0.002	0.002	0.002	0.002	
Zinc (mg/L)	13	0	13	0%	0.002	0.007	0.011	0.035	0.124	0.024	0.033
Mercury (mg/L)	0	13	13	100%	0.000				0.000		

BQN1-D	Count	LOR	N	%LOR	Minimum	20th Percentile	Median	80th Percentile	Maximum	Mean	STD
pH	9	0	9	0%	8.61	8.72	9.01	9.10	9.17	8.93	0.21
Conductivity (EC) (dS/m)	6	0	6	0%	1.238	1.379	1.399	1.440	1.440	1.382	0.076
Total Dissolved Salts (mg/L)	6	0	6	0%	842	938	951	979	979	940	51
Total Suspended Solids (mg/L)	9	0	9	0%	14	21	36	1320	3410	755	1420
Total Oils and Grease (mg/L)	9	0	9	0%	2.0	3.0	3.4	4.4	10.0	4.1	2.4
Nitrate (mg/L N)	9	0	9	0%	0.005	0.011	0.036	0.060	0.068	0.035	0.025
Silver (mg/L)	0	9	9	100%	0.000				0.000		
Aluminium (mg/L)	9	0	9	0%	0.016	0.405	0.476	24.774	97.400	17.331	33.354
Arsenic (mg/L)	8	1	9	11%	0.003	0.003	0.003	0.009	0.055	0.011	0.018
Cadmium (mg/L)	2	7	9	78%	0.001	0.001	0.001	0.001	0.001	0.001	0.000
Chromium (mg/L)	8	1	9	11%	0.003	0.003	0.005	0.074	0.166	0.040	0.061
Copper (mg/L)	9	0	9	0%	0.003	0.029	0.072	0.165	0.796	0.158	0.251
Iron (mg/L)	9	0	9	0%	0.026	1.424	1.749	97.645	403.000	69.684	135.546
Manganese (mg/L)	9	0	9	0%	0.002	0.029	0.033	1.286	7.736	1.165	2.524
Nickel (mg/L)	9	0	9	0%	0.004	0.005	0.009	0.208	0.756	0.138	0.253
Lead (mg/L)	3	6	9	67%	0.005	0.006	0.007	0.008	0.008	0.007	0.002
Selenium (mg/L)	1	8	9	89%	0.004	0.004	0.004	0.004	0.004	0.004	
Zinc (mg/L)	9	0	9	0%	0.002	0.032	0.040	1.136	3.630	0.680	1.208
Mercury (mg/L)	0	9	9	100%	0.000				0.000		

BSN2-S	Count	LOR	N	%LOR	Minimum	20th Percentile	Median	80th Percentile	Maximum	Mean	STD
pH	12	0	12	0%	7.39	9.50	10.43	11.07	11.22	10.15	1.19
Conductivity (EC) (dS/m)	5	0	5	0%	1.107	1.109	1.110	1.138	1.150	1.122	0.019
Total Dissolved Salts (mg/L)	5	0	5	0%	753	753	755	774	782	763	13
Total Suspended Solids (mg/L)	12	0	12	0%	65	90	106	156	244	130	58
Total Oils and Grease (mg/L)	9	3	12	25%	1.500	2.360	3.000	3.640	5.000	3.011	1.045
Nitrate (mg/L N)	12	0	12	0%	0.015	0.151	0.263	0.332	0.635	0.270	0.168
Silver (mg/L)	0	12	12	100%	0.000				0.000		
Aluminium (mg/L)	12	0	12	0%	0.081	0.215	0.385	0.885	1.022	0.493	0.332
Arsenic (mg/L)	11	1	12	8%	0.002	0.003	0.003	0.004	0.004	0.003	0.001
Cadmium (mg/L)	0	12	12	100%	0.000				0.000		
Chromium (mg/L)	11	1	12	8%	0.001	0.001	0.001	0.002	0.002	0.001	0.001
Copper (mg/L)	12	0	12	0%	0.001	0.002	0.006	0.015	0.026	0.009	0.008
Iron (mg/L)	12	0	12	0%	0.073	0.114	0.435	0.579	1.365	0.468	0.405
Manganese (mg/L)	12	0	12	0%	0.004	0.007	0.023	0.056	0.123	0.033	0.037
Nickel (mg/L)	12	0	12	0%	0.001	0.002	0.004	0.005	0.006	0.004	0.002
Lead (mg/L)	7	5	12	42%	0.001	0.001	0.001	0.003	0.004	0.002	0.001
Selenium (mg/L)	1	11	12	92%	0.001	0.001	0.001	0.001	0.001	0.001	
Zinc (mg/L)	12	0	12	0%	0.003	0.006	0.013	0.022	0.045	0.017	0.014
Mercury (mg/L)	0	12	12	100%	0.000				0.000		

BQN2-I	Count	LOR	N	%LOR	Minimum	20th Percentile	Median	80th Percentile	Maximum	Mean	STD
pH	12	0	12	0%	7.63	8.07	8.20	8.67	8.99	8.28	0.40
Conductivity (EC) (dS/m)	5	0	5	0%	0.808	0.875	0.894	1.200	1.202	0.999	0.187
Total Dissolved Salts (mg/L)	5	0	5	0%	549	595	608	817	817	680	128
Total Suspended Solids (mg/L)	12	0	12	0%	10	13	19	45	315	65	104
Total Oils and Grease (mg/L)	7	4	11	36%	1.6	2.6	3.0	6.9	8.0	4.2	2.5
Nitrate (mg/L N)	12	0	12	0%	0.019	0.068	0.083	0.306	0.566	0.167	0.171
Silver (mg/L)	0	12	12	100%	0.000				0.000		
Aluminium (mg/L)	12	0	12	0%	0.055	0.090	0.124	0.189	0.620	0.179	0.158
Arsenic (mg/L)	12	0	12	0%	0.002	0.002	0.003	0.003	0.004	0.003	0.001
Cadmium (mg/L)	0	12	12	100%	0.000				0.000		
Chromium (mg/L)	9	3	12	25%	0.001	0.001	0.002	0.003	0.003	0.002	0.001
Copper (mg/L)	12	0	12	0%	0.008	0.009	0.016	0.028	0.048	0.019	0.012
Iron (mg/L)	12	0	12	0%	0.050	0.159	0.213	0.301	1.200	0.311	0.312
Manganese (mg/L)	12	0	12	0%	0.012	0.028	0.038	0.041	0.110	0.041	0.026
Nickel (mg/L)	12	0	12	0%	0.006	0.011	0.014	0.017	0.023	0.014	0.005
Lead (mg/L)	8	4	12	33%	0.001	0.001	0.001	0.002	0.002	0.001	0.001
Selenium (mg/L)	0	12	12	100%	0.000				0.000		
Zinc (mg/L)	12	0	12	0%	0.004	0.010	0.018	0.027	0.033	0.018	0.010
Mercury (mg/L)	0	12	12	100%	0.000				0.000		

BQN2-D	Count	LOR	N	%LOR	Minimum	20th Percentile	Median	80th Percentile	Maximum	Mean	STD
pH	9	0	9	0%	6.99	8.11	8.81	8.85	8.94	8.42	0.65
Conductivity (EC) (dS/m)	5	0	5	0%	0.962	0.996	1.007	1.014	1.030	1.003	0.025
Total Dissolved Salts (mg/L)	5	0	5	0%	654	677	685	688	700	681	17
Total Suspended Solids (mg/L)	9	0	9	0%	15	21	282	773	878	369	371
Total Oils and Grease (mg/L)	8	1	9	11%	1.5	2.7	4.0	4.0	13.0	4.5	3.6
Nitrate (mg/L N)	9	0	9	0%	0.012	0.052	0.070	0.073	0.099	0.063	0.024
Silver (mg/L)	0	9	9	100%	0.000				0.000		
Aluminium (mg/L)	9	0	9	0%	0.077	0.155	0.399	0.499	0.559	0.344	0.188
Arsenic (mg/L)	9	0	9	0%	0.002	0.002	0.002	0.003	0.005	0.003	0.001
Cadmium (mg/L)	0	9	9	100%	0.000				0.000		
Chromium (mg/L)	6	3	9	33%	0.001	0.001	0.001	0.001	0.004	0.001	0.001
Copper (mg/L)	9	0	9	0%	0.002	0.003	0.008	0.012	0.013	0.007	0.004
Iron (mg/L)	9	0	9	0%	0.120	0.142	1.116	3.904	4.528	1.859	1.868
Manganese (mg/L)	9	0	9	0%	0.007	0.013	0.041	0.065	0.072	0.040	0.025
Nickel (mg/L)	8	1	9	11%	0.001	0.004	0.009	0.013	0.038	0.012	0.012
Lead (mg/L)	5	4	9	44%	0.002	0.004	0.004	0.005	0.005	0.004	0.001
Selenium (mg/L)	0	9	9	100%	0.000				0.000		
Zinc (mg/L)	9	0	9	0%	0.010	0.019	0.092	0.145	0.169	0.090	0.063
Mercury (mg/L)	0	9	9	100%	0.000				0.000		

Interim Triggers data set 2016 to June 2018

	BQS1-S	BQS1-I	BQS1-D	BQN1-S	BQN1-I	BQN1-D	BQN2-S	BQN2-I	BQN2-D
pH	7.12	8.12	8.30	7.18	11.34	9.10	11.07	8.67	8.85
Conductivity (EC) (dS/m)	0.512	1.624	1.829	1.171	2.082	1.440	1.138	1.200	1.014
Total Dissolved Salts (mg/L)	348	1104	1244	796	1416	979	774	817	688
Total Suspended Solids (mg/L)	472.2	2550	486	6	172.4	1319.8	156.2	45	773
Total Oils and Grease (mg/L)	10.8	21.0	14.2	4.1	9.0	4.4	3.6	6.9	4.0
Nitrate (mg/L N)	0.054	0.079	0.054	0.008	0.234	0.060	0.332	0.306	0.073
Silver (mg/L) [1]	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Aluminium (mg/L)	0.623	1.038	1.002	0.004	1.891	24.774	0.885	0.189	0.499
Arsenic (mg/L)	0.007	0.001	0.002	0.003	0.002	0.009	0.004	0.003	0.003
Cadmium (mg/L) [1]	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Chromium (mg/L)	0.002	**0.006** [2]	0.003	**0.001** [3]	0.008	0.074	0.002	0.003	**0.004** [2]
Copper (mg/L)	0.004	0.004	0.005	**0.004** [3]	0.019	0.165	0.015	0.028	0.012
Iron (mg/L)	1.829	4.977	6.580	2.162	1.972	97.645	0.579	0.301	3.904
Manganese (mg/L)	0.163	0.180	0.145	0.163	0.113	1.286	0.056	0.041	0.065
Nickel (mg/L)	0.009	0.011	0.011	**0.002** [3]	0.022	0.208	0.005	0.017	0.013
Lead (mg/L)	0.001	0.005	0.009	**0.001** [1]	**0.018** [3]	**0.008** [4]	**0.004** [5]	**0.002** [5]	**0.005** [2]
Selenium (mg/L) [1]	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005
Zinc (mg/L)	0.055	0.140	0.171	0.011	0.035	1.136	0.022	0.027	0.145
Mercury (mg/L) [1]	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005

Notes
1 – trigger based on maximum LOR
2 – Non-parametric maximum – 74.1% coverage at 95% confidence level
3 – Non-parametric maximum – 79.4% coverage at 95 % confidence level
4 - Non-parametric maximum – 71.7% coverage at 95% confidence level
5 - Non-parametric maximum – 77.9% coverage at 95% confidence level

Planning Services
Resource Assessments
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Ms Eleisha Went
Commercial Services Compliance Coordinator
Lismore City Council
PO Box 23A
Lismore NSW 2480

Email: eleisha.went@lismore.nsw.gov.au

Dear Ms Went,

Blakebrook Quarry (MP 07_0020)
Groundwater Assessment Report

I refer to your email dated 5 June 2019, submitting the revised Groundwater Assessment Report for approval.

The Department has reviewed this document and considers that it meets condition 17 of Schedule 3 of MP 07_0020. Consequently, the Secretary has approved this plan.

Please ensure a finalised copy of this document is made available on Council's website.

The Department also notes that the Department of Industry – Lands and Water has instructed Council to obtain the necessary Water Access Licences (WALs) for extraction of groundwater up to the predicted maximum annual take of 70 ML per annum, from the North Coast Volcanics Groundwater Source and, the North Coast Fractured and Porous Rock Groundwater Sources.

The Department requests this process commence no later than **9 July 2019**, and to be notified once the required WALs have been obtained.

Should you have any enquiries in relation to this matter, please contact Jack Murphy.

Yours sincerely,

Howard Reed 25.6.19

Howard Reed
Director
Resource Assessments
as nominee of the Secretary