Proposed cemetery site, Old Cooma Road, Googong: Hydrogeological Assessment

Queanbeyan-Palerang Regional Council

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This document has been prepared by Eco Logical Australia Pty Ltd

Template 2.8.1

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Abbreviations, initialisms and acronyms

Abbreviation	Description
AEP	Annual Exceedance Probability (approximately the inverse of the ARI, in percent)
AHD	Australian Height Datum
ARI	Annual Recurrence Interval (approximately the inverse of the AEP, in years)
BoM	Bureau of Meteorology
CDMDR	Cumulative Deviation from Mean Daily Rainfall
DEM	Digital Elevation Model
DPIE	NSW Department of Planning, Industry and Environment
ELA	Eco Logical Australia Pty Ltd
GDE	Groundwater Dependent Ecosystems
IFD	Intensity-Frequency-Duration
LEP	Local Environment Plan
MDB	Murray Darling Basin
NRAR	NSW Natural Resources Access Regulator
QPRC	Queanbeyan-Palerang Regional Council

Executive Summary

Previous water studies (Eco Logical Australia, 2018) were submitted to NSW Natural Resources Access Regulator (NRAR) for consideration and NRAR provided comment on 22 October, 2018 (Appendix A) on the proposed development and has outlined specific requirements pertaining to groundwater conditions at the site and recommendations that need to be fulfilled prior to commencement of burials. This report responds to those recommendations and provides data and interpretation in support of amendment to the Queanbeyan Local Environmental Plan (LEP) 2012 to add the term 'cemetery' to Schedule 1 of the LEP to make this use permissible with consent within Lot 2 DP 112382 and Lot 126 DP754881.

NRAR provided several specific recommendations that are required to be addressed prior to finalising the proposed amendment to the LEP.

NRAR Recommendation #1

"Further investigation of the baseline groundwater levels and groundwater quality for a minimum 12 month period is undertaken prior to any further action to ensure there is sufficient depth to the water table."

Response

A network of five new monitoring bores (at three locations) have been installed across the Site, with nested sites in the east and west and a shallow bore to the south. Continuous logger monitoring of water levels has been undertaken over the past 15 months and manual spot readings have confirmed the accuracy of the loggers.

NRAR Recommendation #2

"Assessment of the cover-type material and depth to bedrock across the entire site to ensure that natural formations offer protection."

Response

Compilation of all geotechnical reports has provided a comprehensive picture of shallow ground materials allowing a distinction between shallow and deep unconsolidated profiles and demarking a zone with insufficient depth for gravesite development.

NRAR Recommendation #3

"Conduct a hydrogeological assessment of present and future risks should groundwater levels be less than 3 m below the ground surface … and:

a) Establish recommendations concerning appropriate management and treatment of leachates

b) Establish recommendations in order to prevent migration of decomposition products into the substrate and groundwater."

Response

Comparison of water levels with recent rainfall records allows an assessment of response to future events. Water levels respond to definable rainfall events and can be related to past rainfall trends. Rapid response to external stimuli (either addition through indirect rainfall recharge, or extraction through pumping) affords an opportunity to maintain deeper water levels, particularly in the western part of the Site where the current water level is close to 3 m below ground level.

The most appropriate course of management is to prevent water levels rising to depths less than 3 m below ground level through the use of monitoring and pumping as necessary.

a) Maintenance of the existing clay aquitard between the shallow and deep aquifers will restrict migration of any potential contaminants. No gravesites should be dug that penetrate this layer.

b) Groundwater from the shallow aquifer naturally uses the existing surficial drainage network and this system should be monitored and bunding and sedimentation ponds could be considered. The existing flow is currently impeded by the road to the west (Eco Logical Australia, 2018) and a suitable containment structure could be established at this location.

NRAR Recommendation #4

"Allowance for climatic effects should be considered."

Response

Current climate predictions for this region suggest a continued drying, punctuated by more severe storm events. Whilst the drying will maintain low water levels, it is likely that extreme events (>100 mm) could induce water level rise in excess of 0.5 m, based on current records. Mitigation actions, such as pumping can effectively reduce this potential and should be coupled with on-going monitoring to continue to build a full understanding of the dynamics of the aquifer systems.

Consolidated response to NRAR generic recommendations

NRAR also noted five relevant (hydrogeological) general recommendations for any new cemetery site (Section 1.2). Based on the studies undertaken to date, the proposed development can satisfy these recommendations through an on-going program of groundwater monitoring and continued awareness of rainfall patterns and the corresponding potential impacts on the water levels. Judicial use of local groundwater pumping can help lower water levels as required, with a natural watercourse providing a suitable discharge pathway. Water quality in the groundwaters is good and would not pose any environmental stress to the surface system.

Groundwater could therefore be maintained at greater than 3 m below the ground surface (general recommendation 1) and gravesites can be excavated a minimum of 1.5 m above the water table for a large portion of the Site as dictated by the depth to competent rock (general recommendation 5).

Depth to unaltered or unweathered bedrock is in excess of 6 m for much of the Site. Areas where bedrock is within 3 m of the land surface have been identified and can be avoided (general recommendation 6).

The floodplain adjacent to the creek lines has been determined through examination of digital elevation models and through flood modelling (Eco Logical Australia, 2018) and these zones should be avoided as gravesites (General recommendation 7).

Zonation of the Site allows distinction of areas where there is a high risk of impact from gravesites. Gravesites would be excluded from zones where water levels are consistently shallow; zones which are adjacent to the creek and where the shallow substrate is very permeable (general recommendation 8).

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1. Introduction

Eco Logical Australia (ELA) has been engaged by the Queanbeyan-Palerang Regional Council (QPRC) to undertake a hydrogeological and hydrological review and constraints assessment for the proposed development and use of a cemetery site located within Lot 2 (DP112382) and Lot 126 (DP754881) situated at 1241 Old Cooma Road, Googong (the Site – Figure 1-1).

The assessment was undertaken to identify any potential hydrological and hydrogeological impacts and impacted areas to assess the suitability of the site for the proposed activity.

1.1 Project Background

The Queanbeyan Lanyon Drive Cemetery currently services the Queanbeyan region and is expected to reach capacity during the next five years, based on a forecasted population growth of approximately 36% by 2031 (QPRC, 2017). The Queanbeyan region includes the main growth centres of Googong, Tralee/South Jerrabomberra and infill units in Queanbeyan (QPRC, 2017).

To meet the future cemeterial needs of the region, the Queanbeyan-Palerang Regional Council (QPRC) has been engaged in a process of strategic planning to identify a new cemetery site, as well as undertaking works to prolong the serviceability of the existing Lanyon Drive Cemetery. As part of the planning proposal for the new cemetery site, QPRC is required by the New South Wales Department of Planning, Industry and Environment (DPIE) to undertake background studies to characterise the existing environment at the site and identify potential areas that may impact upon the proposed development.

Previous background studies included a hydrological assessment (Eco Logical Australia, 2018) which included a preliminary hydrogeological assessment based on available literature from previous studies as well as data from State databases. Specifically, the following data sources were interrogated during that assessment:

- Previous studies:
  - Groundwater Report on Beatty Hill, Old Cooma Road Development Application, 2001, Hyrdroilex Geological Consultants
  - Geotechnical Investigation Report, 1241 Old Cooma Road, Googong, NSW, ACT Geotechnical Engineers, 2017, Geotechnical Engineers Pty Ltd
  - Flood analysis and concept culvert design, Rural Residential Subdivision, Burra Road, Mount Pleasant, 2015, CIC Australia P/L.
- NSW Office of Water (*now DPIE*) PINNEENA Groundwater database.
- Bureau of Meteorology (BoM) Groundwater Explorer database.
- BoM GDE Atlas.
- Local contour maps.

1.2 Recommendations from the Natural Resources Access Regulator (NRAR)

The NSW Natural Resources Access Regulator (NRAR) is the independent, transparent and effective regulator with total carriage of the compliance and enforcement of water management legislation in NSW. NRAR undertakes these functions that previously were split between the Department of Industry

and WaterNSW. NRAR is thus responsible for water access licensing and approvals that are sought by government agencies (amongst others) that may impact on water resources.

Previous water studies (Eco Logical Australia, 2018) were submitted to NRAR for consideration and NRAR provided comment on 22 October, 2018 (Appendix A) on the proposed development and has outlined specific requirements pertaining to groundwater conditions at the site and recommendations that need to be fulfilled prior to commencement of burials.

Specifically, NRAR recommended:

1. Further investigation of the baseline groundwater levels and groundwater quality for a minimum 12 month period is undertaken prior to any further action to ensure there is sufficient depth to the water level.
2. Assessment of the cover-type material and depth to bedrock across the entire site to ensure that natural formations offer protection.
3. Conduct a hydrogeological assessment of present and future risks should groundwater levels be less than 3 m below the ground surface … and:
    a. Establish recommendations concerning appropriate management and treatment of leachates
    b. Establish recommendations in order to prevent migration of decomposition products into the substrate and groundwater.
4. Allowance for climatic effects should be considered.

NRAR also noted the following relevant (hydrogeological) general recommendations for any new cemetery site:

1. The site should not have groundwater closer than 3m below ground level.
2. *… (not groundwater related)*
3. *… (not groundwater related)*
4. *… (not groundwater related)*
5. Burials should at least 1.5 metre clearance between the base of the grave and the top of the maximum groundwater level — burial sites should not have any standing water in them when dug.
6. Burial sites should not be dug in unaltered or unweathered bedrock (i.e. bedrock areas are recommended to be excluded from all burials)
7. Burial sites should not be dug in areas susceptible to groundwater flooding (e.g. decomposed — weathered bedrock zones may be noteworthy groundwater sources, buried alluvial sand - gravel deposits along watercourse lines are highly susceptible to groundwater flooding).
8. Cemeteries are not recommended to be located in areas where:
    a. The groundwater level is shallow
    b. Seasonal or ephemeral floods occur
    c. The substrate is very permeable (e.g., sands and gravels, fractured rocks, karst structures)

1.3 Objective of this assessment

The objective of this assessment is to address the recommendations specified by NRAR (above) and provide evidence on the hydrogeological conditions prevailing across the site.

This report has been prepared to provide documented evidence of studies undertaken to address the specific recommendations of NRAR for the Site and provide context for the next phase of proposed development as a cemetery and crematorium.

1.4 Works undertaken

ELA commissioned Coffey Services Australia Pty Ltd (Coffey) to install groundwater monitoring bores at three locations on the Site, collect representative groundwater samples, provide lithological logs at the locations of the bores and undertake continuous water level monitoring for a period of at least 12 months. Two sites were chosen to have both a shallow and deep monitoring bore, with the shallow bore sampling waters in the alluvium or colluvium and the deep bores tapping the underlying fractured bedrock aquifer.

In addition to water quality for groundwater at each location, loggers were installed at the three shallow bores to provide continuous water level monitoring. Approximately monthly manual water level readings have been taken since February 2019, coinciding with download of the logger data at the three shallow bores.

Data has been compiled and evaluated and used to produce a reasonable understanding of the groundwater conditions at the Site and an appreciation of the expected groundwater response to changing climatic conditions.

1.5 Study Area

The study area is approximately 36.4 hectares and is located approximately 11 kilometres south-west of Queanbeyan, and approximately 5 km west of the Queanbeyan River (Figure 1-1). The Site is triangular in shape and bounded by Old Cooma Road to the west and Burra Road to the east. The Burra Road – Old Cooma Road intersection is located at the northern point of the site.

The Site is currently used for grazing and agricultural purposes and has been farmed since the 1800's (QPRC, 2017). An existing dwelling is located near the centre of the site. Outside the Site, the surrounding area comprises land that is zoned for environmental living purposes with the Mount Campbell community title development located to the west of the site, containing dwellings on smaller rural lots (QPRC, 2017).

Figure 1-1: Study Area (the line across the top shows two lots associated with this site)

2. Existing environment

2.1 Site characterisation

The Site slopes gradually from north-east to south-west, developing a floodplain to the south of Church Creek, which is a third order watercourse within the Site, marked on the LEP Riparian and Watercourses Map, that crosses the site from the south to the west (Figure 2-1). The creek receives discharge from several smaller tributaries, with the regional flow direction to the north-west. There are several other smaller non-defined overland flow paths that cross the Site that were created via culverts under the roads that border the Site.

Two other unnamed first and second order water courses have also been mapped from the local contour maps as feeding into Church Creek (shown in Figure 2-1). It is unclear, however, whether these watercourses would meet the definition of a river under the Water Management Act (2000). Flood modelling undertaken previously (Eco Logical Australia, 2018) confirmed the likelihood that these water courses could flow under extreme rainfall conditions (Figure 2-2), though most flow remained concentrated in the main channel of Church Creek.

A review of the NSW DPIE surface water database identified no registered stream flow monitoring gauges near the site, with the closest stream gauge (# 410770) located on the Queanbeyan River at the ACT border (approximately 12.5 km north of the Site).

Groundwater flow dynamics in the study area were not delineated previously as no active monitoring bores could be identified in or around the study area to allow for monitoring of groundwater levels. An old bore located on the site may have been used as a water source in the past. Groundwater was assumed to flow from north-east to south-west, from higher to lower ground, with the creek acting as a drain for shallow groundwater. From the single bore (GW0209031), a water level of 2.04 m below ground level (mbgl) was recorded on 7 July 2018. The shallow water table at this location prompted further investigations and recommendations from NRAR, particularly as previous shallow bores (to 3.5 mbgl) did not intercept groundwater anywhere across the Site.

2.1.1 Climate

Rainfall and temperature data was obtained from the Bureau of Meteorology (BoM) online climate database for the Tuggeranong (Isabella Plains) AWS (BoM site 070339) located approximately 10.2 km west of the study area. The regional climate is categorised as cool temperate, with year-round rainfall (average annual rainfall 631.3 mm) with a seasonal distribution showing greater rainfall in the summer months (Figure 2-3). Mean maximum temperatures range from 11.8 °C in July to 29 °C in January.

Monthly and daily rainfall data for the last 23 years was retrieved from the BoM Weather Station Directory (http://www.bom.gov.au/climate/data/stations/). From the daily data a cumulative deviation from the mean daily rainfall (CDMDR) provides an overview on climactic changes, highlighting wetter periods as increasing trends and dry periods as decreasing trends (Figure 2-4). This gives a good indicator as to whether the area is suffering the effects of drought or if the current precipitation level is on/above average for the region. Of note, the strong downward trend due to the Millennium Drought is clearly seen as a prolonged deficit in the CDMDR in Figure 2-4.

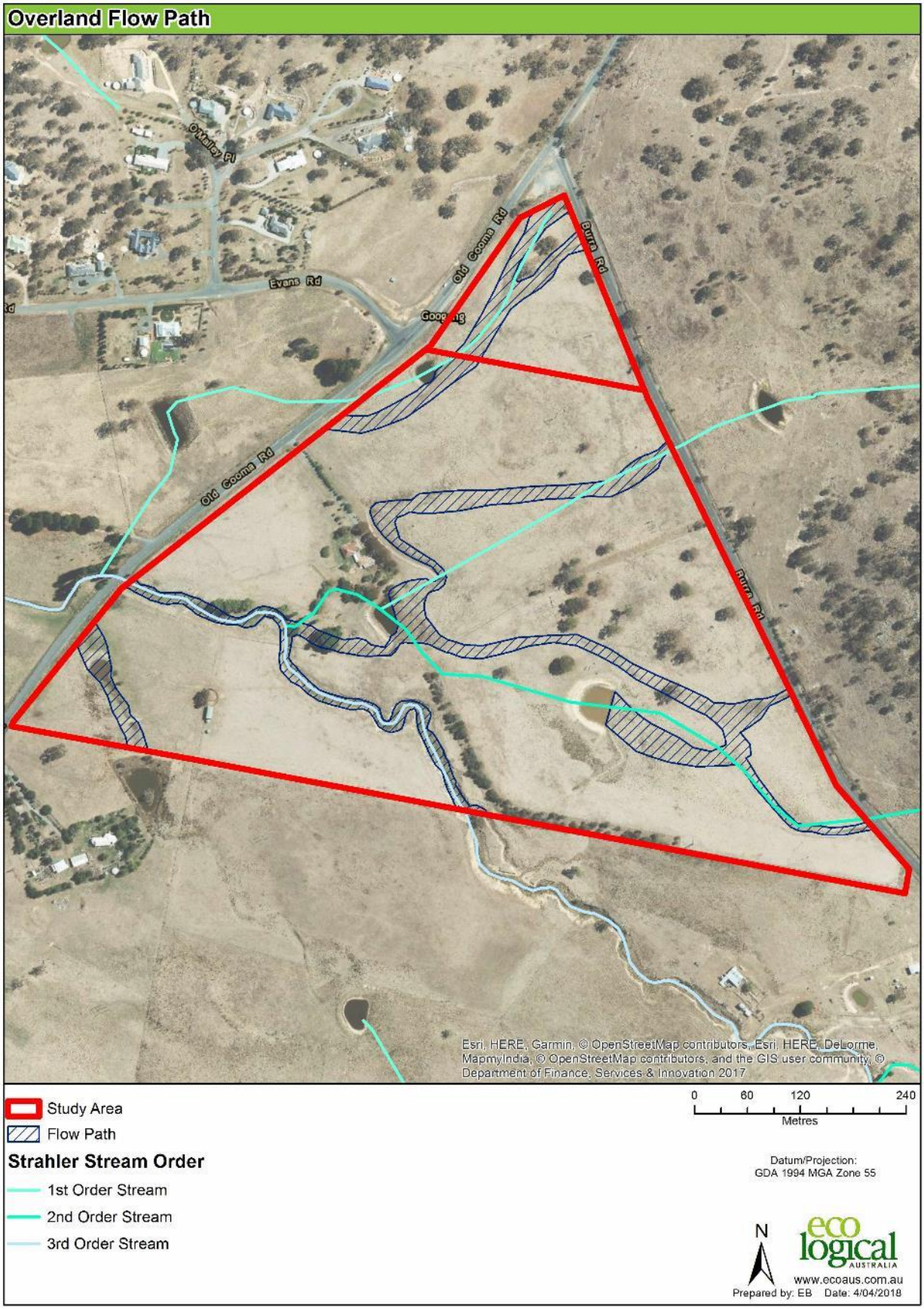

Figure 2-1: Overland flow paths across the Site. Church Creek runs from the central south boundary across to exit the Site to the west. Flow paths indicate expected flow based on the DEM. Strahler stream orders indicated for cadastral watercourses

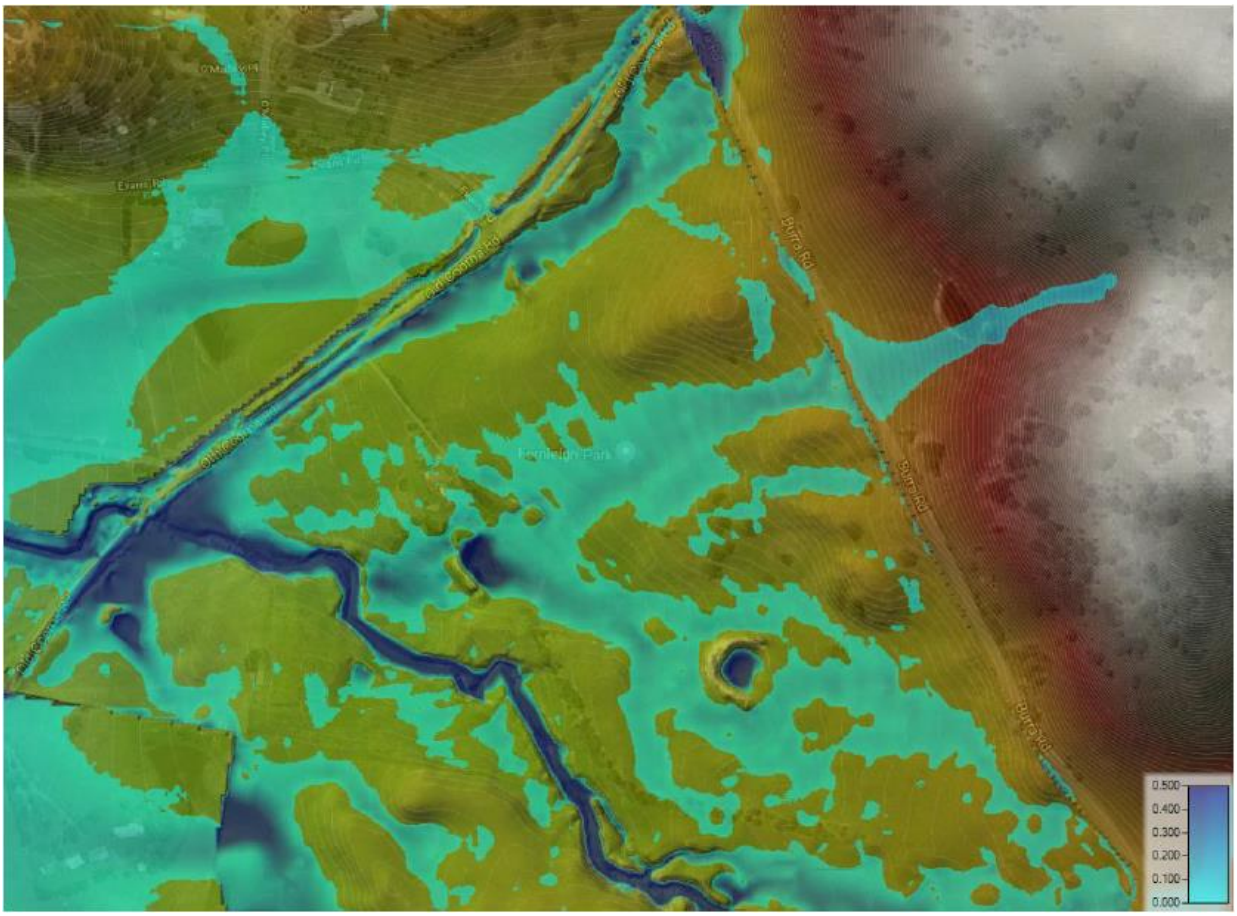

Figure 2-2: Modelled flood extents across the Site under the 1% AEP (1 in 100 year ARI conditions)(Eco Logical Australia, 2018)

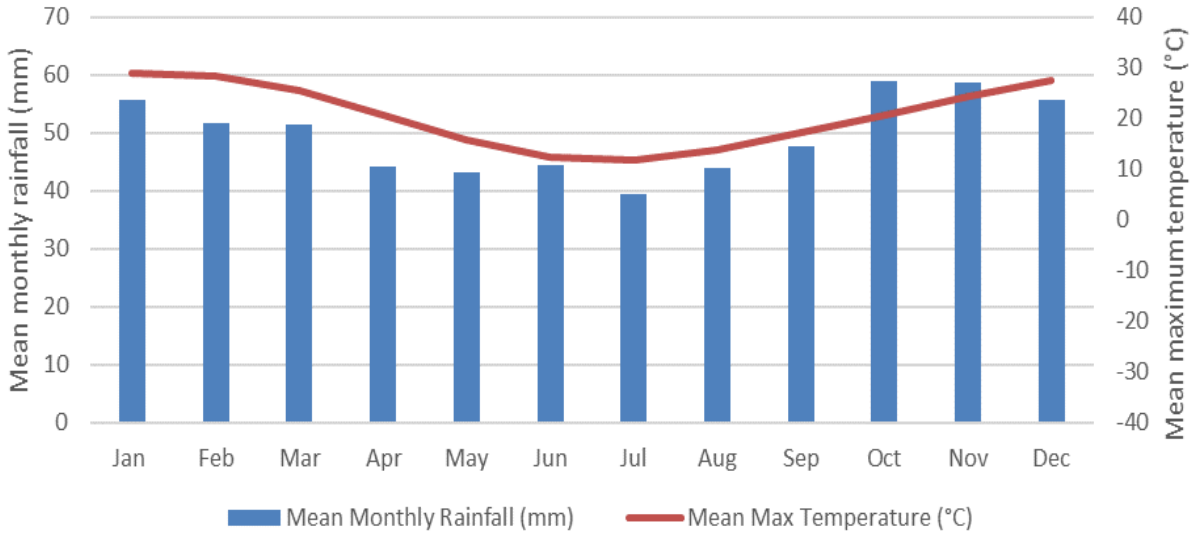

Figure 2-3: Monthly average rainfall and evaporation recorded at Tuggeranong (BoM 70339), 10.2 km west of the Site

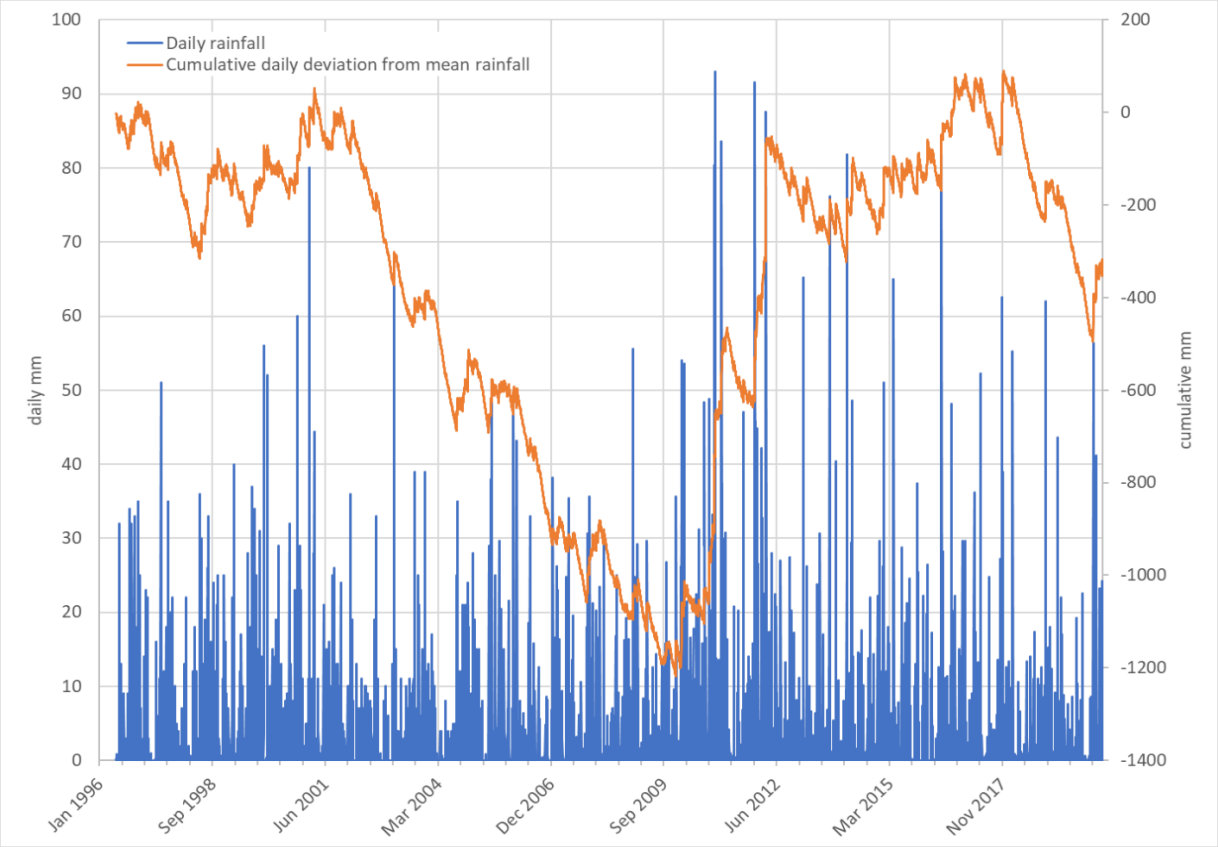

Figure 2-4: Rainfall recorded at Tuggeranong (Isabella Plains) Automated Weather Station (BoM 70339) and equivalent cumulative deviation from the mean daily rainfall

Based on rainfall data from last 23 years, the region has recovered from the Millennium Drought, recovering to pre-drought conditions between 2010 and 2012, then exhibiting long-term average conditions (flat trend in the CDMDR) through to 2018. The last two years have been drier than average, though significant rainfall fell in February and March of this year (Figure 2-5).

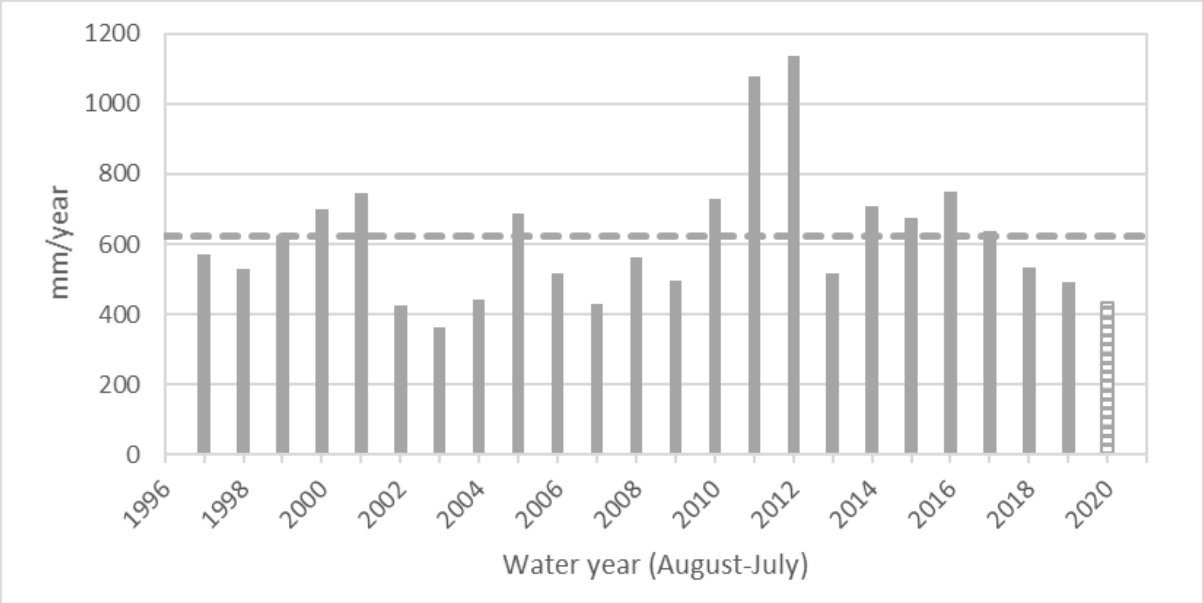

Figure 2-5: Annual rainfall for water years (August to July) at Tuggeranong (Isabella Plains) Automated Weather Station (BoM 70339). Mean rainfall for the period 1996 to 2020 of 624 mm also shown. (2020 only though to April)

2.1.2 Regional geology

The regional geological setting of the property is shown in Figure 2-6. The study area is located within a complex structural corridor within rock sequences of Silurian age, regionally described as the Canberra Graben. This structural feature is bounded to the west by the Murrumbidgee Batholith, comprised of granodioritic intrusives, and to the east by the Cullarin Horst, a complex geological province represented by deformed Ordovician-aged sediments intruded by granites (HGC, 2001).

The 1:100,000 Canberra Geology map indicates that the site is located mostly on the Colinton Volcanics bedrock, with a small part south of the study area located on the Williamsdale Volcanics. Two faults separate the Colinton Volcanics from the Deakins Volcanics approximately 3.5 km west and from Cappanana Formation approximately 4 km east of the study area.

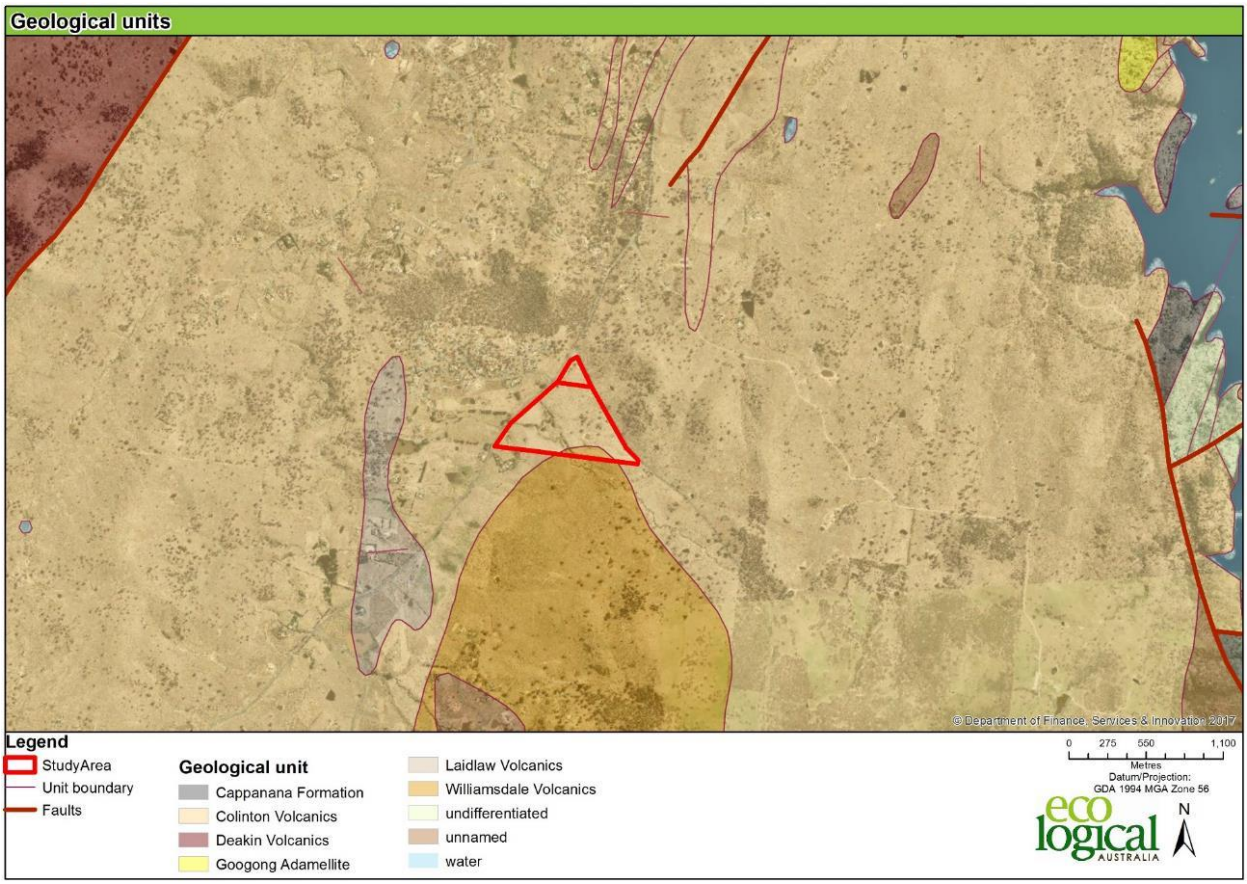

Figure 2-6: Surface Geological units across the region

2.1.3 Subsurface soil profile

The subsurface conditions near the Site was investigated in 2017 via ten auger holes (ACT Geotechnical Engineers, 2017) and is summarized in **Table 2-1**, below.

Table 2-1: Generalised soil and sub-soil conditions at the site (ACT Geotechnical Engineers, 2017)

Geological profile	Typical Depth Interval	Description
Topsoil	0 m to between 0.1m and 0.2m	SILTY SAND; fine to coarse sand, low plasticity silt, brown, some grass roots, dry to moist, loose.
Slope wash	Between 0.1m and 0.2m to between 0.4m and 0.6m	SILTY SAND; fine to medium sand, low plasticity silt, pale grey-brown, dry to moist, medium dense.
Alluvial/ Residual Soil	Between 0.1mto 0.6 m to between 0.3m and >3.5m	SILTY SANDY CLAY, SILTY CLAYEY SAND, & SANDY CLAY; fine to coarse sand, low to medium and some medium to high plasticity clay, red-brown, orange-brown, brown, grey, dry to moist and moist, stiff to very stiff and dense.
Bedrock	Typically, from 0.2 to 1 m and below	DACITE; fine to coarse grained, orange brown, grey, highly weathered (HW) and weak rock grading to moderately weathered (MW) and medium strong rock.

During bore development for this project, Coffey recorded ground conditions across the Site (Table 2-2 and Appendix B) in January 2019. Conditions confirmed those recorded by ACT Geotechnical Engineers (2017), namely the high clay content of the floodplain deposits. Of note, geotechnical bores on the slopes recorded thin soils with higher sand and silt content.

Table 2-2: Summary of ground conditions encountered during monitoring bore drilling, January, 2019

Material	Description	Depth to top of unit (m)	Range of thickness of unit (m)
Topsoil	Silty CLAY, low plasticity, brown, with rootlets and organic fines	0	0.05 to 0.2
Alluvium	Silty CLAY to clayey SAND, low to medium plasticity clay, brown to pale brown, fine to coarse-grained sand with traces of fine to medium-grained gravel	0.05 to 0.2	1.0 to 4.0
Residual soil	Clayey SAND, fine to medium-grained, pale brown, medium plasticity clay, very dense	1.0 to 4.0	0.75 to 1.5
Dacite bedrock	Extremely and highly weathered, very low to low strength	3.1 to 7.6	0.2 to 2.3
	Moderately to slightly weathered, generally low to medium strength	6.9 to 7.6	unproven

2.1.4 Registered and previously reported bores

Interrogation of the DPIE online groundwater database and the BoM Groundwater Explorer database identified 38 registered groundwater bores within approximately 2 km of the Site, with only two of the 38 bores located within or in close proximity to the Site as shown in **Figure 2-7**. No water level/quality data for these bores were available in the PINNEENA database. The five registered bores within (or

within 200m of) the Site boundary were all drilled in the 1950s and are unlikely to be functioning today. All other bores were drilled since 1986 for stock and domestic use (29 for household use; two for stock use and two of unknown use). As such, there is no requirement for these bores to monitor or report level or quality information, though property owners may have this information.

A summary of registration details for these bores is provided in Appendix C. Thirty-four of the 38 bores were drilled to about 20 m or deeper, giving good evidence that local groundwaters are deep and in the fractured rock aquifers. The lithology of two of the shallow bores is not provided and these likely represent perched lenses in the weathered regolith as the other two shallow bores are reportedly completed in clay.

Groundwater in the area is expected to be associated with fractures within bedrock and contained within joints, fractures, faults and fissures in the rock mass (HGC, 2001). The closest major fault mapped is approximately 1.5 km north of the study area (Figure 2-6).

The geotechnical investigation for the Site (ACT Geotechnical Engineers, 2017) completed ten auger holes to a maximum depth of 3.5 m within the Site area. No groundwater was encountered in any of the augered holes, with the soils mostly dry to moist. Temporary, perched seepages might be expected following rainfall within the more pervious soils in the southern area, with shallow hard rock encountered in the north .

Of six bores reported in the immediate vicinity of the Site (Figure 2-9), only one (GW0209031.1) could be accessed during a site visit in July 2018 to measure a water level(Coffey, 2019, reproduced at Appendix B). The depth to water was recorded as 2.04 mbgl. If this measured water level is to be taken as representative of the Site water table, insufficient free-board would be available to justify a cemetery at this location.

2.1.5 Water chemistry

No salinity data was recorded from the 38 registered bores located within 2 km distance of the Site. A previous study at Old Cooma Road (HGC, 2001), located approximately 3 km south-west of the Site, reported that the likely total salinity is expected to be in the range of 500-800 mg/L, with elevated bicarbonate and total hardness in the range of 300-500 mg/L. The significant number of local stock and domestic bores suggests that deeper, fractured rock, aquifers provide water of reasonable quality.

2.1.6 Groundwater Dependent Ecosystems (GDEs)

As reported previously, no potentially significant GDEs could be identified within a 2 km buffer around the Site based on a high level, desk-top assessment of available data (Eco Logical Australia, 2018).

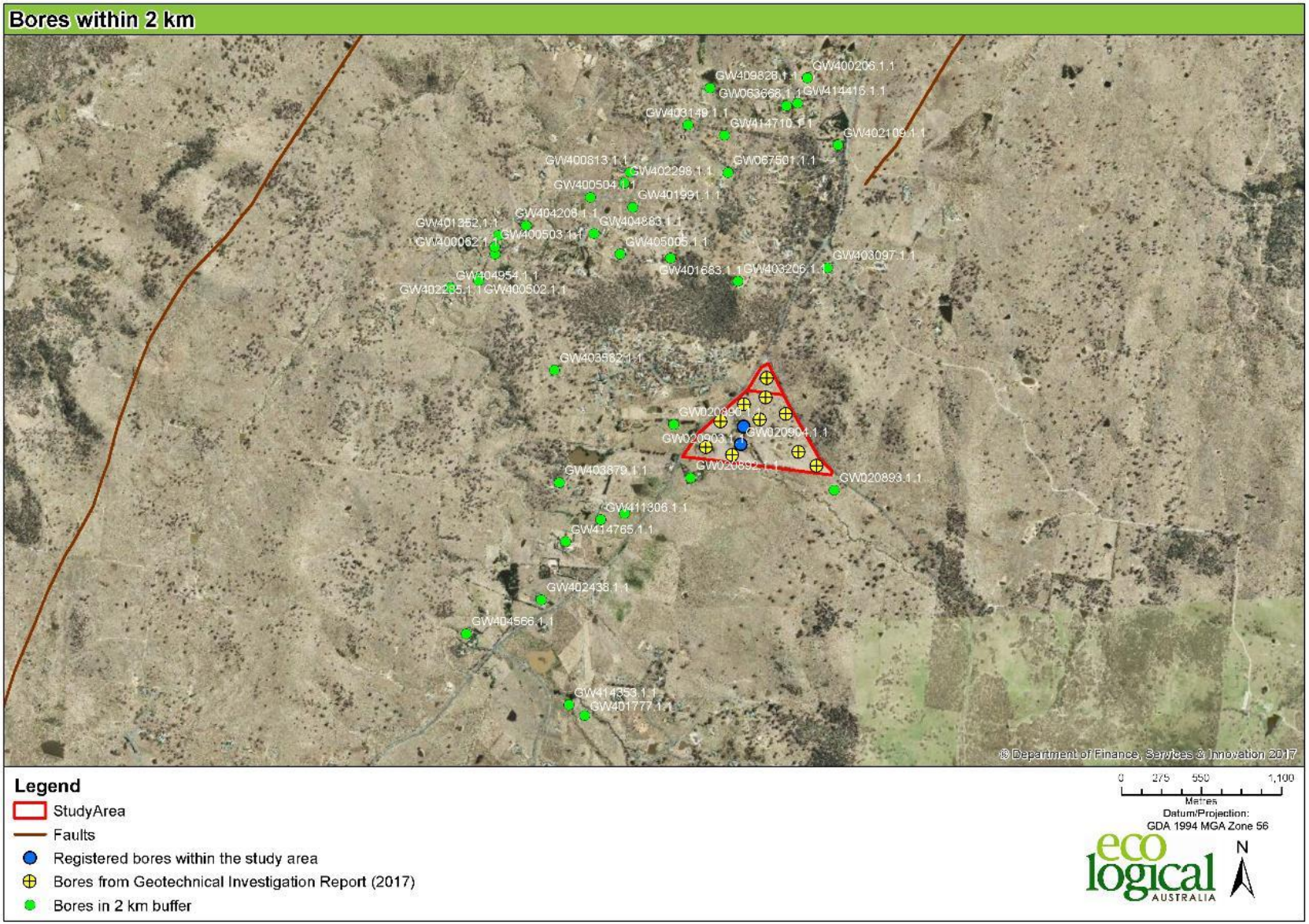

Figure 2-7: Registered and reported groundwater bores around the study area

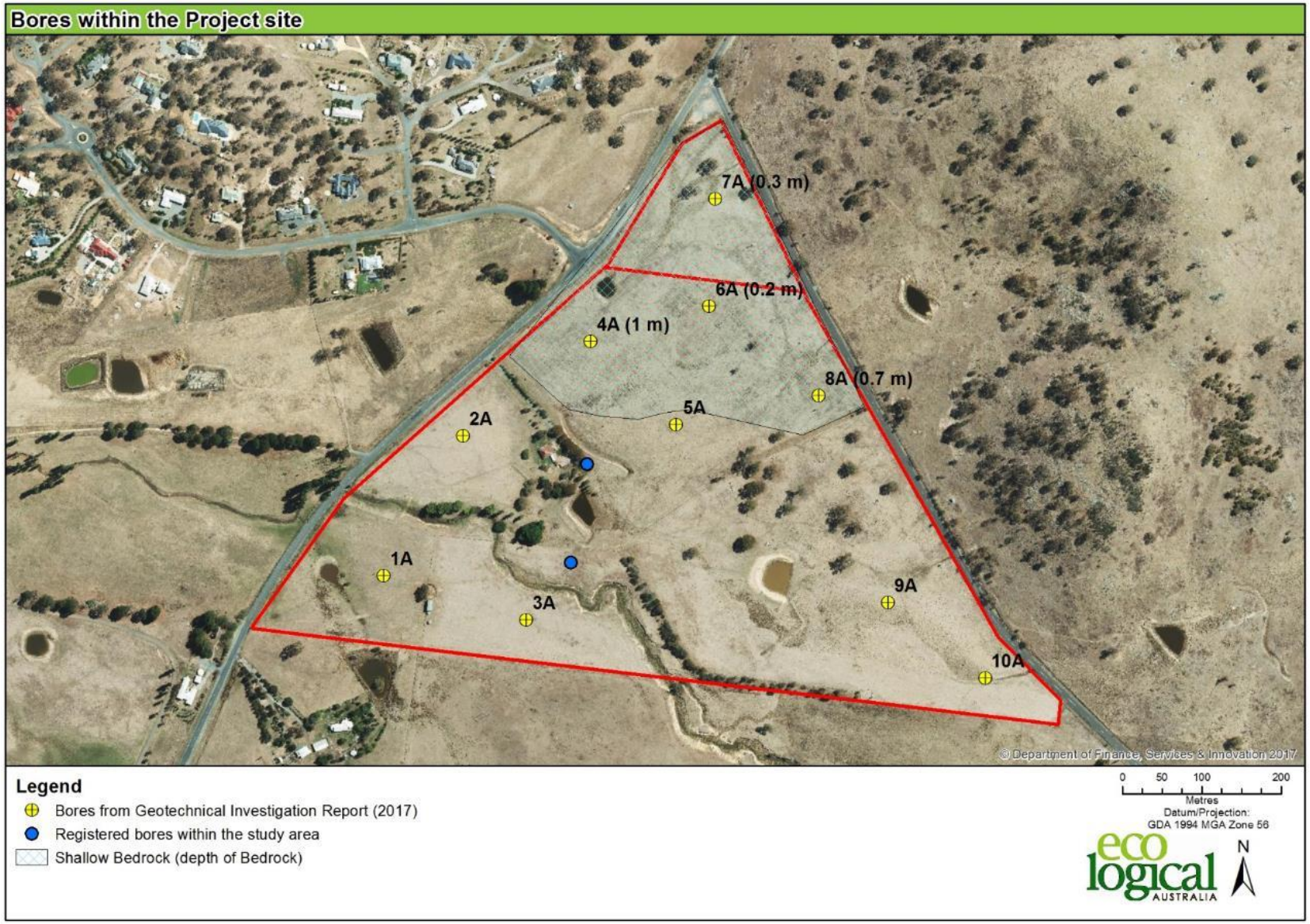

Figure 2-8: Reported bores within the project area prior to this study.

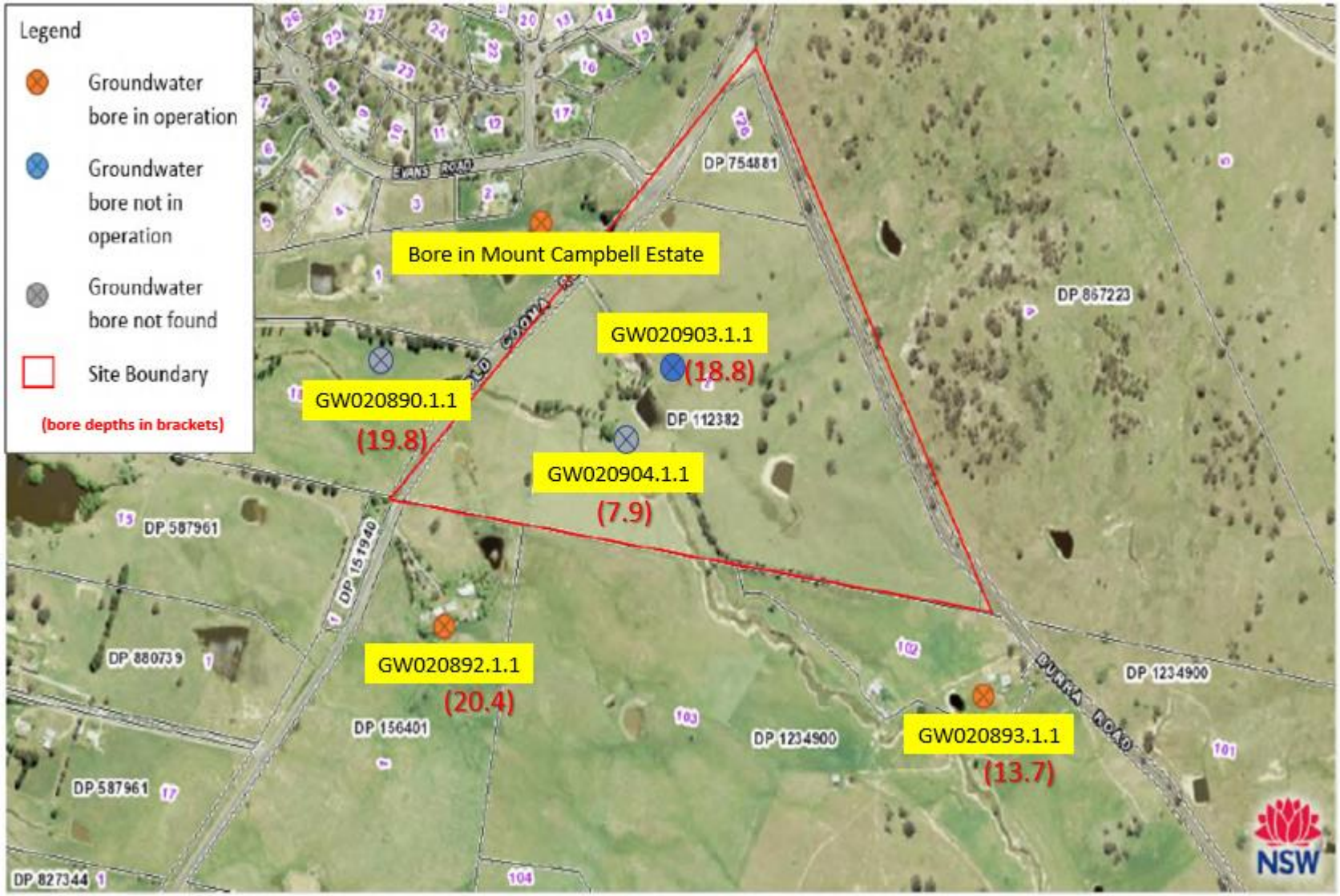

Figure 2-9: Registered groundwater bores around the Site. Construction depth indicated in brackets.

Table 2-3: Summary information for geotechnical holes within the Site area (*after* ACT Geotechnical Engineers, 2017)

Bore ID	Logging Date	Soil Type	Moisture status	Excavation depth (m)	Water encountered	Geological profile (at 3.5 m)
1A	6/04/2017	Silty sand/silty sandy clay/ clayey sand	dry to moist at 2 m depth below ground, moist at 3 m below ground	3.5	No	Alluvium
2A	6/04/2017	Silty sand/silty sandy clay/ silty clayey sand	dry to moist at 1 m depth below ground, moist at 1.4 m below ground	3.5	No	Alluvium
3A	6/04/2017	Silty sand/ sandy clay	dry to moist at 1 m depth below ground, moist at 2.5 m below ground	3.5	No	Alluvium
4A	6/04/2017	Silty sand/ sandy clay	dry	Excavation terminated at 1.5 m (medium strong rock)	No	Bedrock
5A	6/04/2017	Silty sand/ sandy clay/ silty sandy clay	dry at 0.4 m depth below ground, dry to moist at 3-3.5 m	3.5	No	Alluvium
6A	6/04/2017	Silty sand	dry	Excavation terminated at 0.3 m (medium strong rock)	No	Bedrock
7A	6/04/2017	Silty sand/ silty sandy clay	dry	Excavation terminated at 0.6 m (medium strong rock)	No	Bedrock
8A	6/04/2017	Silty sand/ sandy clay	dry	Excavation terminated at 1.3 m (medium strong rock)	No	Bedrock
9A	6/04/2017	Silty sand/silty sandy clay/ sandy clay/ clayey sand	dry to moist at 1-2 m below ground, moist to wet at 2-3.5 m below ground	3.5	No	Alluvium
10A	6/04/2017	Silty sand/clayey sand/silty sandy clay/ sandy clay	dry to moist at 1.5-22 m below ground, moist at 2-3.5 m below ground	3.5	No	Alluvium

3. New monitoring bores

Five (5) new bores across 3 locations have been installed on behalf of QPRC to provide groundwater information for the Site . Details of bore installation and initial sampling results are provided in Appendix B (Coffey, 2019). These bores were installed in January 2019 and were located to coincide with three of the previously installed geotechnical holes: 1A, 2A and 9A.

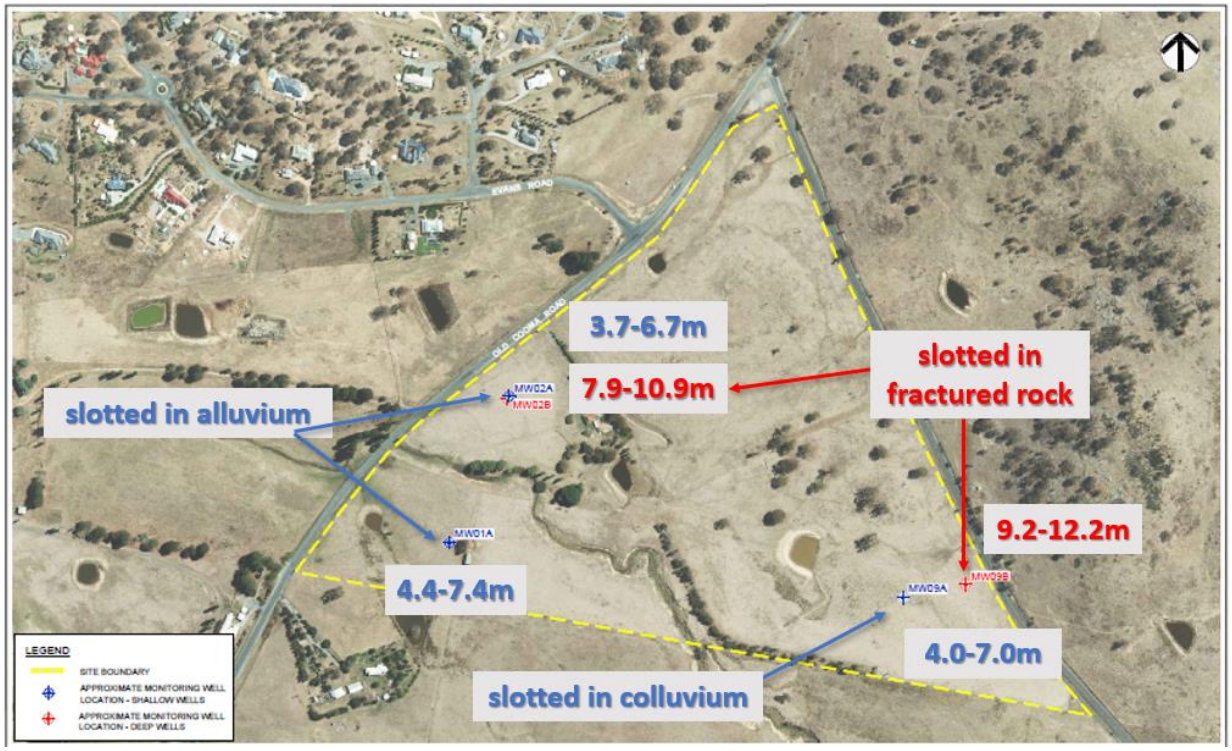

Figure 3-1: Locations of the five new monitoring bores on the Site showing slotted intervals for each bore

Based on the drilling records, the three new shallow bores (at sites 1A, 2A and 9A) are constructed within clayey sand-sandy clay alluvium/colluvium with the remaining two deep bores (named 2B and 9B at site 2A and 9A, respectively) constructed to monitor groundwater in the dacite (weathered and fractured) bedrock.

In-Situ Rugged Troll 100 data loggers were installed at each of the three (3) shallow bores (MW01A, MW02A and MW09A) on 13 February 2019, and an In-Situ Rugged BaroTroll data logger was installed at the top of the MW02A bore to monitor barometric pressure. Data is collected every fifteen (15) minutes, with each logger checked, data down-loaded and reinstalled on a monthly basis. Latest data were retrieved on 21 April, 2020.

Manual water level measurements were taken at all 5 bores during each data collection event to validate the collected logger data. Loggers have not proven to be completely reliable, however, with some data lost, notably at bore MW01A, with all loggers malfunctioning in February this year. This has resulted in some recent data gaps at all sites. All loggers were replaced on 31 March, 2020. The replacement bore at MW01A also malfunctioned and re-set, losing the data. This logger was replaced on 21 April, 2020.

4. Addressing the NRAR recommendations

4.1 Baseline groundwater and water quality

Time series for all collected data is presented in Figure 4-1. Water level data has now been collected over 15 months (January 2019 to April 2020) and continues with 3 data loggers in the shallow monitoring bores (in the alluvium of Bores MW01A and MW02A and the colluvium of MW09A) and on-going manual dipping on a monthly basis.

Distinct trends can be determined at each site (and each bore) providing information on groundwater recharge and movement and connectivity between shallow and deep aquifers. Comparison to the rainfall record illustrates the differing response at each location (Figure 4-1).

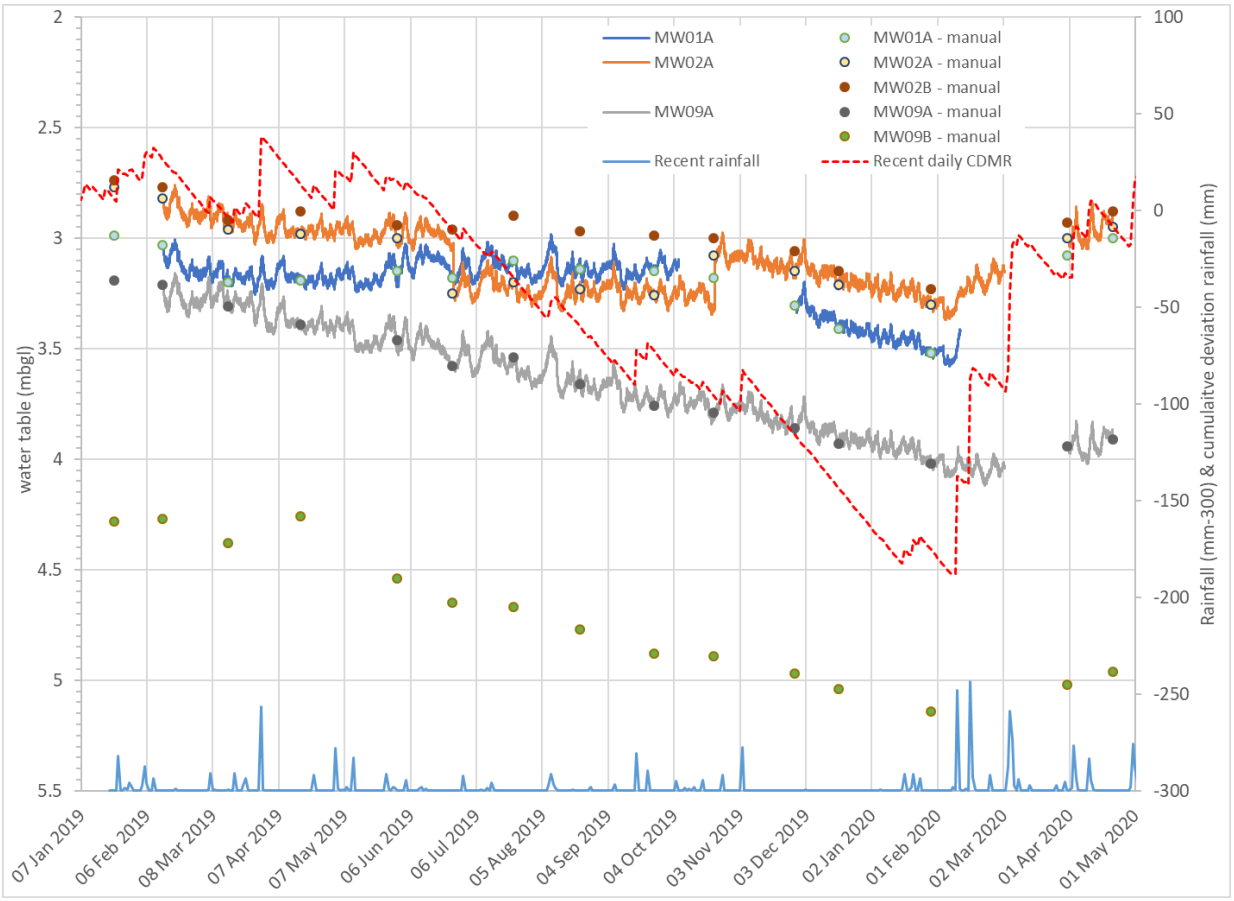

Figure 4-1: Summary chart of data retrieved from the five new monitoring bores at 1241 Cooma Road, Googong.

4.1.1 Site 1A – south of Church Creek

Throughout 2019, the shallow bore at site 1A remained steady (Figure 4-2), despite the regional rainfall deficit, until early October when the water level dropped quickly until mid-December, then began to rise, despite minimal rain in the district through November and December (less than the 10th percentiles across the recorded record). Unfortunately, the logger failed in December and the replacement logger also re-set and deleted the data. Manual measurements indicate that the water level returned to previous heights following the rains in early 2020.

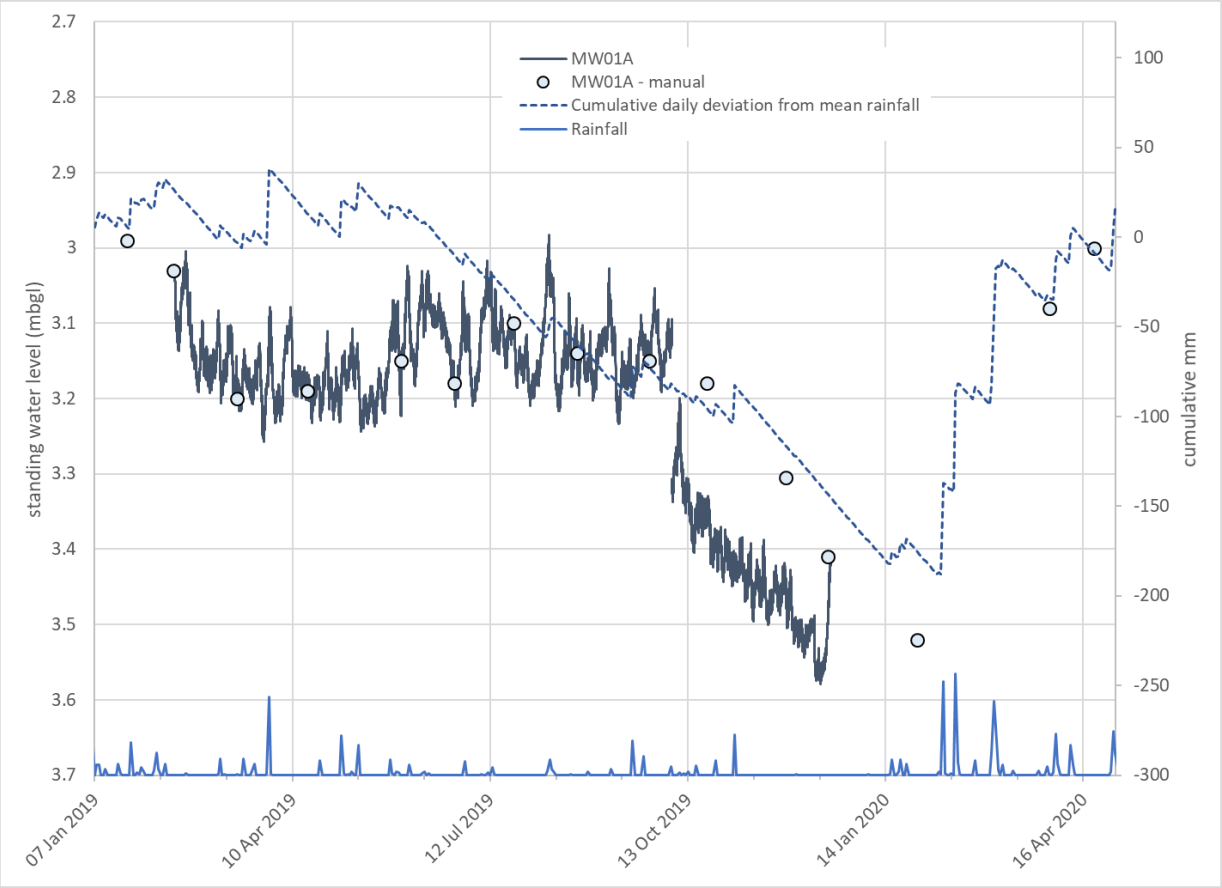

Figure 4-2: Water level at site 1A since January 2019

The significant drop occurred late in the prolonged "dry trend" in rainfall, following lower-than-average rainfall for October and November (23.4 and 23 mm, respectively, recorded at the Tuggeranong Weather Station – BoM #70339). It is plausible that the drop in water level was driven by external pumping. An active bore (likely stock and domestic use) to the south (GW020892) may have been used during this time. No records have been requested from the owners of this bore to date.

Significant drops are also observed following rainfall events. For example, the water level at MW01A dropped 150 mm during the period between rains from 15 July to 7 August 2019. This amounts to an average drop in water level of 6.5 mm/day. This drop in water level suggest a highly transmissive unit with low storage capacity. This would explain why an external stimulus, such as local pumping could have a significant impact.

Of note, manual measurements through October and November are higher than the corrected logger record and this may reflect the unstable nature of this logger which has now been retired from use.

4.1.2 Site 2 – north of Church Creek; west of homestead

The time series for site 2 (Figure 4-1) shows what appears to be the effects of pumping on the shallow bore at site 2A. The congruence between the logger and manual measurements confirm that this is not an instrumentation malfunction. It is likely that this reflects the impacts from pumping at the groundwater bore at Mount Campbell Estate (Figure 2-9) during a period of very low rainfall between June and November 2019 (Figure 4-3). No impacts are seen on the deep bore (2B *see* Figure 4-1) suggesting the two aquifers are isolated from each other.

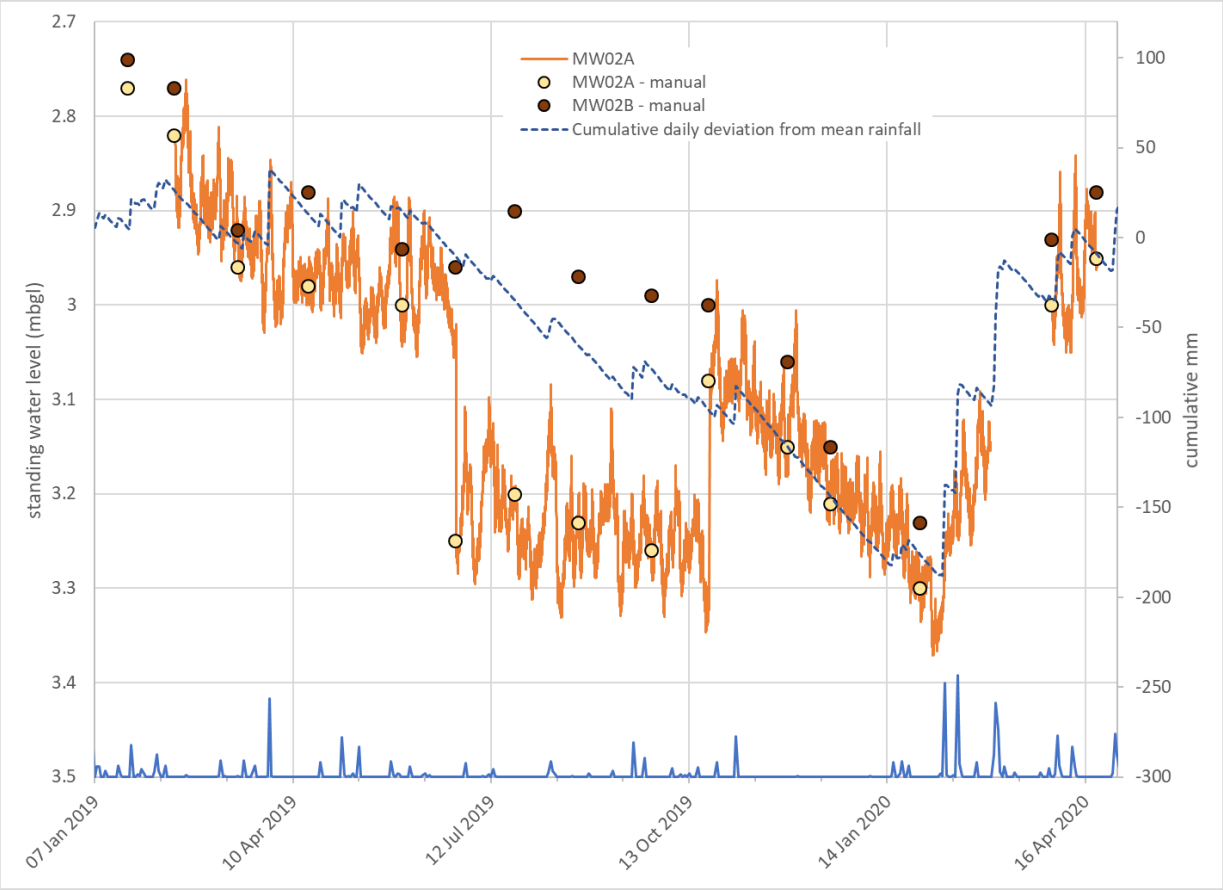

Figure 4-3: Local rainfall (Tuggeranong) compared to water levels at site 2A since January 2019

The deep bore constructed at this Site (MW02B) targeted groundwater in the underlying dacite country rock at 7.9 to 10.9 metres below ground. Water levels in this bore were consistently higher than MW02A indicating an upward pressure and separation between the two aquifers. This was emphasised when the shallow bore recorded a significant drop in June 2019, with the reduction in overlying pressure resulting in a rise in the water level in the underlying aquifer that then gradually receded over time until the shallow aquifer returned to normal levels in late October and water levels in the deep bore dropped to a comparable pressure difference to that prior to the change in level at MW02A. Both bores have tracked in parallel since that time, suggesting a common recharge source, but separation of the aquifers in the vertical sense by a confining unit.

The response of MW02A suggests impact from nearby pumping of the aquifer. The active bore to the west on Mount Campbell's Estate may therefore be tapping the same shallow groundwater unit, but not the deeper, bedrock aquifer and could be invoked as the source of the drawdown. The estate bore was not monitored during this time and construction details are not available.

Of note, the apparent response to external pumping occurs at a different time to that observed at MW01A, suggesting the formations on either side of Church Creek behave independently, suggesting that the creek acts as a boundary feature for the shallow groundwater system.

4.1.3 Site 9 – south-west corner of the Site

Water levels at the south-eastern bore location show a more subdued response to significant rainfall events (Figure 4-4).

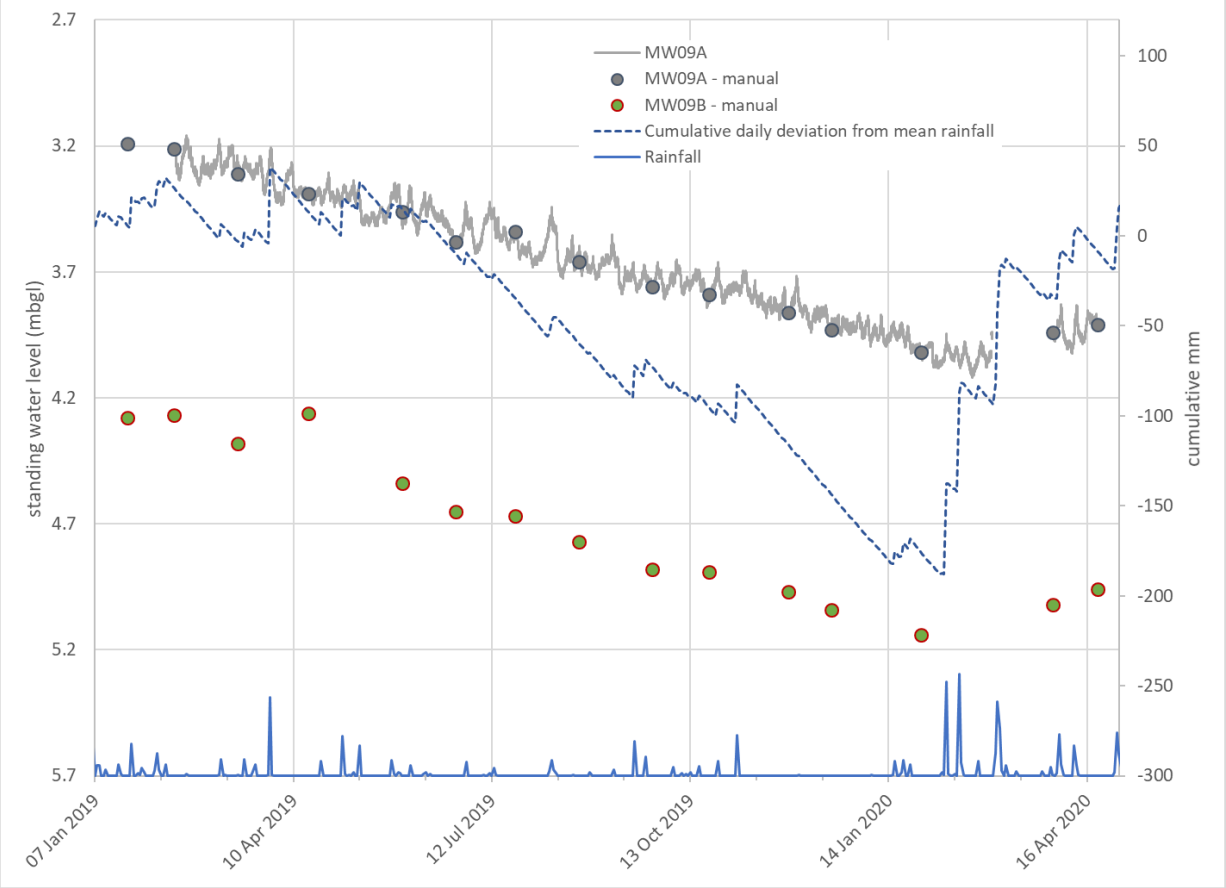

Figure 4-4: Water levels recorded at site 9 since January 2019 compared to regional rainfall.

Significant rainfall events at the beginning of this year (two events greater than 50 mm in February and a four-day event in March precipitating 83 mm) realised a reversal in the downward trend for the previous year, though not a significant rise.

Water levels for both aquifers follow similar trends, with a consistent metre separation over time. As the water levels in bore MW09B are higher than the base of the slots in bore MW09A (7 m), it can be assumed that an intervening confining layer separate the two aquifers.

4.1.4 Water tables and groundwater flow

Comparison of water levels across the Site show a fall in level from east to west; from high ground in the east down to uniform heights across the Church Creek floodplain (Figure 4-5). Indicative flow lines suggest that the creek acts as a drainage feature and boundary influence on shallow groundwater flow. Discordant response to external stimuli (presumed to be pumping from different bores) at locations 1 and 2 support the compartmentalisation of groundwater sources north and south of the creek. The

observed opposite level response for bores 2A and 2B at the same location strongly suggest the shallow alluvium and colluvium aquifer is separated from the deeper bedrock aquifer by a confining layer, likely the clayey-sand in the weathered zone above the dacite.

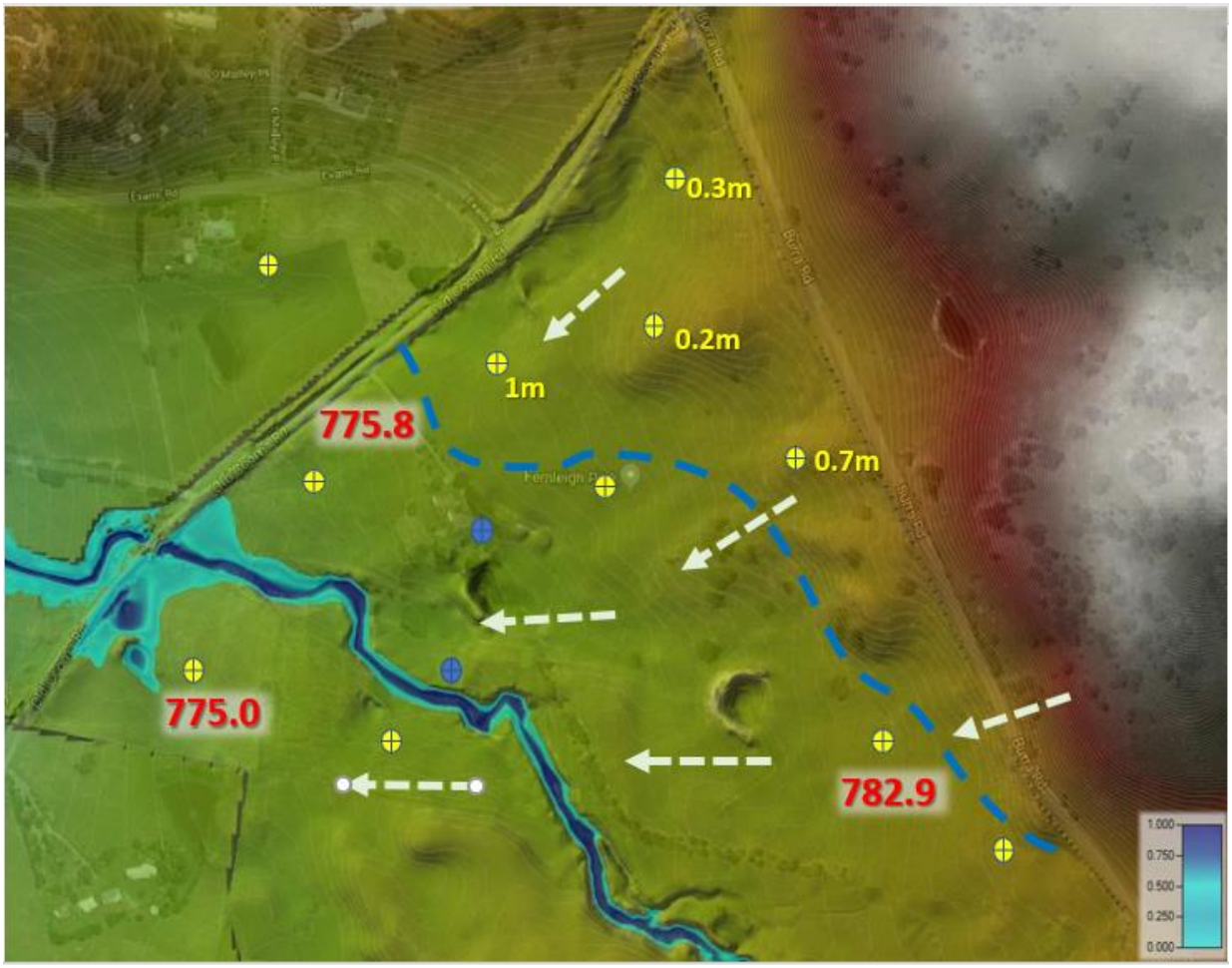

Figure 4-5: Groundwater flow (white arrows) overlain on modelled stream-flow. Maximum height of groundwater (mAHD) indicated for the shallow water table. Zone of very shallow soil/weathered zone indicated by the dashed line

Groundwater elevations, however, are comparable under normal conditions, for both aquifers (~775 mAHD at site 2 and ~783 mAHD at site 9), reflecting a common recharge source and flow direction.

4.1.5 Water quality

Following development of the monitoring bores (purging each well by a minimum of 3 bore casings, or until water quality readings stabilised), water quality measurements were taken using the field calibrated TPS 90FL-T water quality meter, measuring electrical conductivity (EC), pH, dissolved oxygen (DO), redox potential (Eh), temperature and turbidity. A photoionisation detector was then used to determine the presence of volatile organic compounds in the wells. Results are presented in Table 4-1.

All samples had moderate salinity (just above drinking guidelines) and were slightly acidic, reflecting both a short path from rainfall recharge to groundwater and flow through clay-rich sediments. The close proximity to the surface, combined with the short recharge distance resulted in relatively high oxygen contents (about half saturation) and positive redox, as expected with relatively high oxygen levels. Temperatures are cooler than local minimum temperatures for that time of year and likely represent residual temperatures from the previous winter. Whilst generally cloudy (reflecting the clayey nature of the host rocks), no significant volatiles were recorded indicating no contamination from surficial sources.

Table 4-1: Water quality measurements on five monitoring bores taken on January 22nd, 2019

Bore ID	Total well depth (mbtoc)	Water level (mbtoc)	Purge volume (L)	EC (µS/cm)	pH	DO (ppm)	Eh (mV)	T (˚C)	Volatiles (PID)	Turbidity (NTU)
MW01A	7.4	2.99	70	821	6.69	4.36	137	15.5	No odour nor sheen	Turbid (580)
MW02A	7.2	2.77	35	1594	6.51	3.87	72	15.5	No odour nor sheen	Cloudy (486)
MW02B	11.4	2.74	70	1315	6.36	3.05	87	13.5	No odour nor sheen	Slightly cloudy (17)
MW09A	7.0	3.19	30	690	6.61	2.27	101	13.7	No odour nor sheen (3.9 pm)	Very cloudy (755)
MW09B	12.2	4.28	55	1464	6.4	1.22	68	10.0	No odour nor sheen	Slightly cloudy (32)

Notes:
mbtoc = metres below top of casing
L = litres
µS/cm = micro Siemens per centimetre
ppm = parts per million, or milligrams per litre (~8 ppm DO = 100% saturated water)
mV = millivolts
NTU = nephelometric turbidity units

4.2 Assessment of cover and depth to bedrock

The additional bore logs generated through installation of the new monitoring bore network provide further ground material information to assess the capability of the Site to host grave sites. Specifically, depth to competent rock can now be estimated for much of the Site and this defines a zone where depth to hard rock is less than 3 m and therefore not suitable for grave sites (Figure 4-6).

Figure 4-6: Depth to competent bedrock. Shaded area marked where bedrock is less than 3 m below ground. Numbers in brackets inferred from bore construction records.

All locations investigated to the south of the shallow soil zone had suitable materials for soft excavation. Topsoil and alluvium ranges up to 4 m where logged, increasing to the south and west. Beneath this, incompetent weathered material extends up to 7 m on site and likely deeper to the south and west. Lower horizons tend to be clay-rich and form confining layers above the fractured dacite bedrock.

Further, the bore logs reveal that most sediments are clay-rich and the presence of highly permeable sediments is restricted to thin layers and not pervasive across the Site (Appendix B).

4.3 Hydrogeological assessment of present and future risks

The recent time series of water levels can be directly compared to the rainfall record and relative response estimated. Thus, water levels at site 1 (MW01A – Figure 4-2), show an initial response to rainfall events, but rapidly dissipate to an equilibrium level at about 3.15 m below ground level. At site 2 (MW02A – Figure 4-3) the water levels also responds immediately to all rainfall events, but only events greater than 30 mm appear to result in any significant departure from equilibrium. No rainfall results in

an average fall in water level of 2 mm/day. Rainfall of 250 mm over two months in summer led to a water level rise of 300 mm.

The bores to the south-east (MW9a and MW9B) show a subdued response to rainfall, with an apparent 2 week lag when sufficient rain falls (>100 mm) to cause a water level response (Figure 4-4).

To explain the previously measured high water levels in June 2018 the monitored data can be plotted against the long-term rainfall record (Figure 4-7). The rainfall record shows that the current phase of drying follows a significantly wetter period through 2016 and 2017. The spot read in 2018 was taken following the wetting period. Specifically, a steep rising trend in cumulative rainfall followed a sequence of high rainfall events late in 2017. That sequence is comparable, but lower, in volume (183 mm) to that recently observed in February this year (219 mm) that produced a similar cumulative increase in the rainfall record.

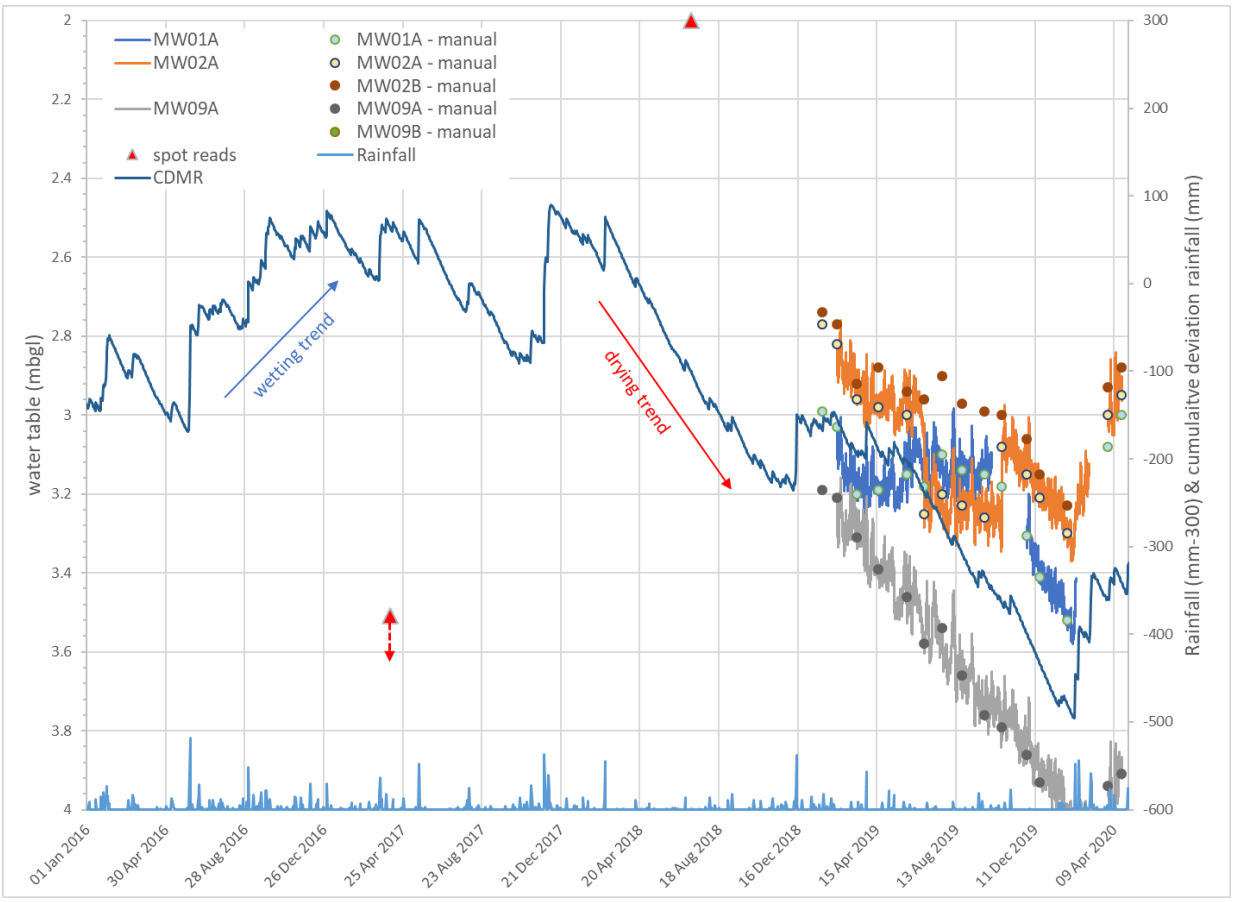

Figure 4-7: Longer term rainfall record and previous water level measurements on Site

Whilst the trends in rainfall are indicative of water level trends, longer records are required to estimate quantitative relationships. Thus, no geotechnical bores developed in April 2017 recorded groundwater, which suggest that water levels must have been at a depth of greater than 3.5 m across the Site, despite being during a climatically wetter period (Figure 4-7). Reference is made to the longer term rainfall record (Figure 2-4), whereby the recent drying trend is small in comparison to that realised through the Millennium Drought.

Water levels respond rapidly (within a day) to rainfall events in excess of 30 mm and do not respond significantly to events less than 30 mm. This suggests low storage potential in the sediments and/or

highly transmissive aquifers. The high clay content of most sediments encountered in bores suggests profile transmissivity would be low, though traces of gravel and some sand layers are indicated in the bore logs which could act as transmissive layers. The indication is that storativity is low, hence responses to water addition (recharge) or removal (pumping) is locally amplified, at least across the western side of the Site. The muted response observed at Site 9 indicates greater storage potential to the east and hence less response in those sediments to changes in water supply and demand.

4.3.1 Site zonation

Consideration of water levels across the Site, combined with understanding of ground conditions and with regard to previous studies on hydrology (Eco Logical Australia, 2019), geotechnical surveys (ACT Geotechnical Engineers, 2017) and regional groundwater surveys (HGC, 2001) allows an assessment of distinct zones across the Site and their applicability for gravesite development (Figure 4-88).

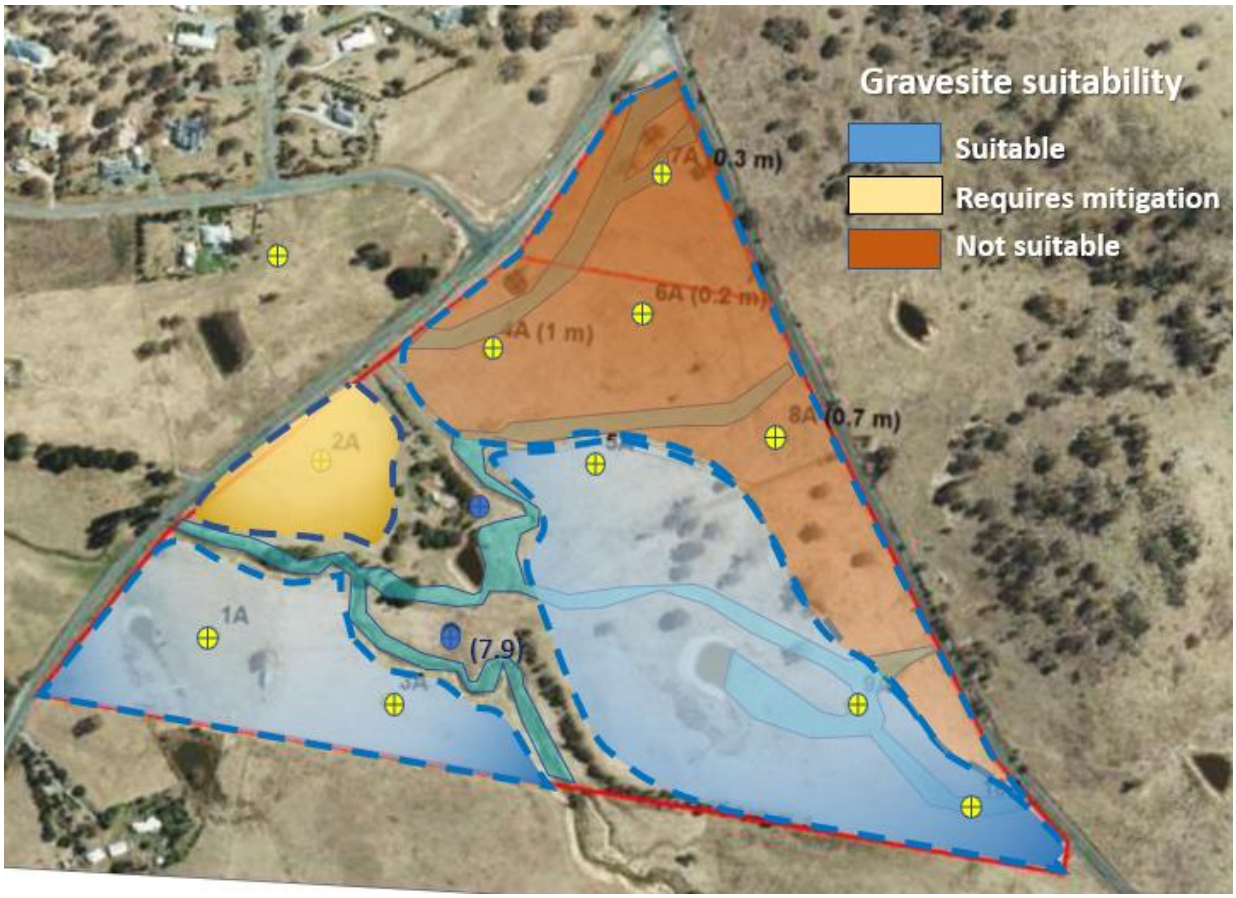

Figure 4-8: Site zonation for gravesite suitability

4.3.1.1 Suitable area

Suitable areas across the Site has the combination of adequate depth (>3 m) of unconsolidated material, overlying a clay base aquitard over the competent bedrock and has water levels that are consistently equal or greater than 3 m below ground surface. Deeper groundwater is physically separated from the

shallow system in the unconsolidated material and can be protected through preservation of the intervening clay-rich aquitard.

This zone covers the southern half of the Site and extends from the south-east corner, along the southern boundary to the south-west corner. Excluded areas include the shallow soils to the north and east and the immediate floodplain of Church Creek.

4.3.1.2 Area requiring further testing and monitoring and may require mitigation

An area north of Church Creek on the eastern boundary appears to maintain groundwater levels around 3 m below ground level but is susceptible to notable rises and falls in water levels in response to rainfall patterns. The area appears to respond rapidly to pumping from a bore to the west (Mount Campbell Estate bore) and this may provide a suitable mitigation measure when water levels rise to depths shallower than 3 m below ground surface. Continued monitoring is advised and particularly following rainfall events greater than 30 mm.

4.3.1.3 Area not suitable for gravesites

The area to the north of the Site has shallow soils and competent rock within 3 m of the ground surface making this region unsuitable for gravesites.

The riparian zone within 40 m of the high bank of the creek, as defined through flood modelling (Eco Logical Australia, 2018) should be avoided due to the potential for flooding and rapidly elevating water tables in the alluvium of the creek bed.

5. Consolidated response to NRAR specific recommendations

NRAR provided a number of specific recommendations to be addressed prior to finalising the proposed amendment to the LEP:

5.1 NRAR Recommendation #1

"Further investigation of the baseline groundwater levels and groundwater quality for a minimum 12 month period is undertaken prior to any further action to ensure there is sufficient depth to the water table."

5.1.1 Response

A network of five new monitoring bores (at three locations) have been installed across the Site, with nested sites in the east and west and a shallow bore to the south. Continuous logger monitoring of water levels has been undertaken over the past 15 months and manual spot readings have confirmed the accuracy of the loggers.

5.2 NRAR Recommendation #2

"Assessment of the cover-type material and depth to bedrock across the entire site to ensure that natural formations offer protection."

5.2.1 Response

Compilation of all geotechnical reports has provided a comprehensive picture of shallow ground materials allowing a distinction between shallow and deep unconsolidated profiles and demarking a zone with insufficient depth for gravesite development.

5.3 NRAR Recommendation #3

"Conduct a hydrogeological assessment of present and future risks should groundwater levels be less than 3 m below the ground surface … and:

a) Establish recommendations concerning appropriate management and treatment of leachates

b) Establish recommendations in order to prevent migration of decomposition products into the substrate and groundwater."

5.3.1 Response

Comparison of water levels with recent rainfall records allows an assessment of response to future events. Water levels respond to definable rainfall events and can be related to past rainfall trends. Rapid response to external stimuli (either addition through indirect rainfall recharge, or extraction through pumping) affords an opportunity to maintain deeper water levels, particularly in the western part of the Site where current water tables are close to 3 m below ground level.

The most appropriate course of management is to prevent water levels rising to depths less than 3 m below ground level through the use of monitoring and pumping as necessary.

a) Maintenance of the existing clay aquitard between the shallow and deep aquifers will restrict migration of any potential contaminants. No gravesites should be dug that penetrate this layer.

b) Groundwater from the shallow aquifer naturally uses the existing surficial drainage network and this system should be monitored and bunding and sedimentation ponds could be considered. The existing flow is currently impeded by the road to the west (Eco Logical Australia, 2018) and a suitable containment structure could be established at this location.

5.4 NRAR Recommendation #4

"Allowance for climatic effects should be considered."

5.4.1 Response

Current climate predictions for this region suggest a continued drying, punctuated by more severe storm events. Whilst the drying will maintain low water levels, it is likely that extreme events (>100 mm) could induce water level rise in excess of 0.5 m, based on current records. Mitigation actions, such as pumping can effectively reduce this potential and should be coupled with on-going monitoring to continue to build a full understanding of the dynamics of the aquifer systems.

5.5 Consolidated response to NRAR generic recommendations

NRAR also noted five relevant (hydrogeological) general recommendations for any new cemetery site (Section 1.2). Based on the studies undertaken to date, the proposed development can satisfy these recommendations through an on-going program of groundwater monitoring and continued awareness of rainfall patterns and the corresponding potential impacts on the water levels. Judicial use of local groundwater pumping can help lower water levels as required, with a natural watercourse providing a suitable discharge pathway. Water quality in the groundwater is good and would not pose any environmental stress to the surface system.

Groundwater could therefore be maintained at a depth greater than 3 m below the ground surface (general recommendation 1) and gravesites can be excavated a minimum of 1.5 m above the standing water level for a large portion of the Site as dictated by the depth to competent rock (general recommendation 5).

Depth to unaltered or unweathered bedrock is in excess of 6 m for much of the Site. Areas where bedrock is within 3 m of the land surface have been identified and can be avoided (general recommendation 6).

The floodplain adjacent to the creek lines has been determined through examination of digital elevation models and through flood modelling (Eco Logical Australia, 2018) and these zones should be avoided as gravesites (General recommendation 7).

Zonation of the Site allows distinction of areas where there is a high risk of impact from gravesites. Gravesites would be excluded from zones where water levels are consistently shallow; zones which are adjacent to the creek and where the shallow substrate is very permeable (general recommendation 8).

6. References

ACT Geotechnical Engineers 2017. *1204 Old Cooma Road, Googong, NSW: Geotechnical Investigation Report,* ACT Geotechnical Engineers Pty Ltd. Ref: MD/C8640 13 April 2017

Eco Logical Australia 2018. *Proposed cemetery site, Old Cooma Road – Hydrological Assessment*. Report prepared for Queanbeyan-Palerang Regional Council (QPRC)

Coffey 2019. *Monitoring well installation, Queanbeyan-Palerang Proposed Cemetery Site*. Project Reference: 754-CBREN225122-L01. Report prepared for Eco Logical Australia 24 January 2019

HGC 2001. *Groundwater investigation, Proposed Beatty Hill subdivision, Old Cooma Road, Williamsdale area.* Hydroilex Geotechnical Consultants.

QPRC 2012. *Planning Proposal for Cemetery and Crematorium, Lot 2 DP 112382 and Lot 126 DP 754881*. Queanbeyan-Palerang Regional Council.

SRLE, 2015. *Rural Residential Subdivision, Burra Road, Mount Pleasant: Flood Analysis and Concept Culvert Design*, Southern Region Land Engineering.

WSP 2012. *Water Sharing Plan for the Murrumbidgee Unregulated and Alluvial Water Sources.*

Appendix A NRAR response to initial documentation (2 October, 2018)

NSW GOVERNMENT | Natural Resources Access Regulator

Contact Tim Baker
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Arthean McBride
Queanbeyan-Palerang Regional Council
SeniorStrategic Town Planner
PO Box 90
QUEANBEYAN NSW 2620

Our ref V15/3876-2#78

22 October 2018

Dear Arthean

RE: Planning Proposal for new cemetery in Queanbeyan

I refer to your letter dated 10 August 2018 requesting consideration of a proposed amendment to the Queanbeyan Local Environmental Plan 2012. It is understood the amendment purpose is to:

- Add the term 'cemetery' to Schedule 1 of the LEP to make this use permissible with consent within Lot 2 DP 112382 and Lot 126 DP 754881.

The supporting documentation has been reviewed and the following key comments and recommendations are provided to address concerns raised by Council in regards to groundwater at the proposed site.

Comments

- The depth of the investigation holes are insufficient to define groundwater levels across the site and the timing ineffective to define the "wet weather" maximum groundwater levels across the site. Conclusions drawn from this data may cause errors in assessment of the site.
- The geotechnical investigation holes were drilled procedurally to a depth of 3.5m below ground level (bgl) and not designed to delineate groundwater levels across the site. In addition the investigation was conducted (6th April 2017) following a period of extreme low rainfall during January and February 2017. March 2017 had a single 3 day high rainfall event but this would not have been sufficient to add significantly to the water table levels with the majority of this high rainfall event reporting as surface runoff to the local streams.
- A groundwater level of less than 3m bgl within a cemetery site are insufficient to prevent potential groundwater impacts. A singular point measurement may be an anomaly however the investigation reports and data presented are insufficient to determine the groundwater level across the site. Further investigation is warranted to determine the maximum ('wet weather') groundwater levels as these are the level which will potentially be impacted the most.
- Concerns have been identified in relation to the suitability of the studies conducted to date and the potential impacts of the proposed cemetery to the groundwater source.

Recommendations prior to finalising the proposed amendment

1. Further investigation of the baseline groundwater levels and groundwater quality for a minimum 12 month period is undertaken prior to any further action to ensure there is sufficient depth to the water table. This should be performed by the installation of three monitoring bores to basement in a way to allow for determination of groundwater flow direction, i.e. not aligned), soil characterisation (logging during drilling) and water quality characterisation. The more significant information to obtain is the depth and variation of water levels. This can be obtained through the use of automated water level loggers placed in bores for the recommended 12 month period.
2. The further investigation is to include an assessment of the cover material type and depth to bedrock across the entire site to ensure that natural formations offer protection.
3. Using the data obtained under recommendation 1 and 2, conduct a hydrogeological assessment of present and future risks should groundwater levels be less than 3 m below the ground surface or occurs at, or less than, 1.5 m below the burial level; and
    a. establish recommendations concerning appropriate management and treatment of leachates;
    b. establish recommendations in order to prevent migration of decomposition products into the substrate and groundwater;
4. Allowance for potential rise in the water table, including climatic (drought versus non-drought), seasonal variations and extreme rainfall must be included in any further assessment.

Recommendation should the amendment be approved

- Before commencement of burials, best practices would require a minimum of three (3) groundwater monitoring bores are installed; constructed into bedrock to enable sufficient monitoring of groundwater levels, groundwater flow across the site and groundwater quality. These bores can be the same bores as those installed prior to determination. The risk assessment will inform the level of effort and frequency of monitoring requirements.

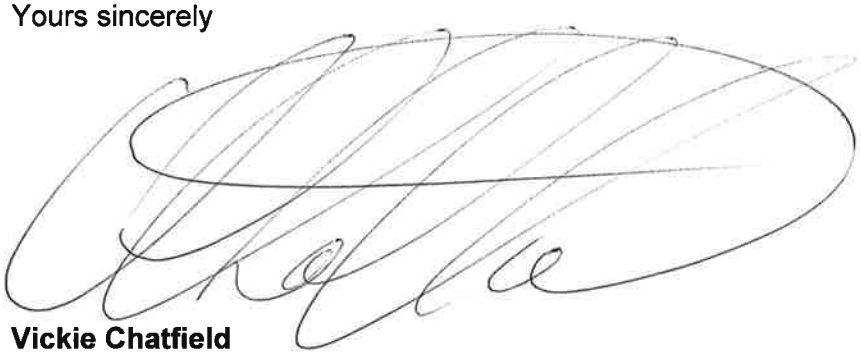
General Recommendations for any new cemetery site

1. The site should not have groundwater closer than 3m below ground level.
2. Burials should be at least 250 metres from any well, borehole or spring supplying water for human consumption or used in food production – for example at dairy farms, commercial vegetable gardens/farms, etc.
3. Burials should be at least 30 metres from any spring or watercourse not used for human consumption or not used in food production.
4. Burials should be at least 10 metres from any field drain, including dry ditches.
5. Burials should at least 1.5 metre clearance between the base of the grave and the top of the maximum groundwater level – burial sites should not have any standing water in them when dug.
6. Burial sites should not be dug in unaltered or unweathered bedrock (i.e. bedrock areas are recommended to be excluded from all burials)
7. Burial sites should not be dug in areas susceptible to groundwater flooding (e.g. decomposed – weathered bedrock zones may be noteworthy groundwater sources, buried alluvial sand - gravel deposits along watercourse lines are highly susceptible to groundwater flooding).
8. Cemeteries are not recommended to be located in areas where:
    a. The groundwater level is shallow

b. Seasonal or ephemeral floods occur
c. The substrate is very permeable (e.g., sands and gravels, fractured rocks, karst structures)

Should you have any further queries in relation to this submission please do not hesitate to contact Tim Baker 02 6841 7403.

Yours sincerely



Vickie Chatfield
Manager Water Regulatory Operations- West
Department of Industry- Natural Resources Access Regulator

Appendix B Coffey Monitoring Bore Installation Report

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coffey.com

24 January 2019

Our ref: 754-CBREN225122-L01

Eco Logical Australia
2/11 London Circuit
Canberra ACT 2601
Sent via email: RichardC@ecoaus.com.au

Attention: Dr Richard Cresswell

Dear Richard,

Monitoring Well Installation, Queanbeyan-Palerang Proposed Cemetery Site

1. Introduction

Eco Logical Australia (ELA) on behalf of Queanbeyan Palerang Regional Council (QPRC) engaged Coffey Services Australia Pty Ltd (Coffey) to install groundwater monitoring wells at three locations at a site located within Lot 2 DP112382 and Lot 126 DP754881, situated at 1241 Old Cooma Road, Googong (herein as the 'site'). Based on information provided by ELA, Coffey understands the site is being considered as a proposed development site for future use as a cemetery. The site location is shown in Figure 1, Attachment A, while a site layout plan is presented in Figure 2.

ELA have been assisting Queanbeyan-Palerang Regional Council (QPRC) with environmental factors, including an assessment of groundwater to assess the suitability of the site for the proposed use. Based on feedback from the regulator, a local understanding of the groundwater levels is required for 12 - 24 months period for the proposed future cemetery site.

This letter report summarises monitoring well installation works undertaken at the site by Coffey, which have been carried out in general accordance with our proposal (ref: 754-CBREN225122-P01) and the Minimum Construction Requirements for Water Bores in Australia 2012.

2. Background

A previous geotechnical assessment was undertaken at the study site by ACT Geotechnical Engineers in 2017[1], which included an investigation of subsurface conditions via ten auger holes. The assessment found depth to rock at the site is generally between 1m and 3.5m bgl in the northern portion of the site, with depth to bedrock exceeding 3.5m in the southern portion of the site.

[1] ACT Geotechnical Engineers Pty Ltd (2017). *1241 Old Cooma Road, Googong NSW Geotechnical Investigation Report*. Dated 13 April 2017, Ref: MD/C8640

Groundwater was not encountered within the upper 3.5m bgl across the study area and the soils were mostly dry to moist.

A registered groundwater bore search was conducted by ELA which indicated five (5) bores were placed on-site and/or within the 200m reporting boundary with bore depth around 20m bgl. Coffey subsequently carried out a site inspection on 07 July 2018 to assess/inspect the five indicated groundwater bores both on-site and around the site, which included gauging the bores for depth to water and total depth where they were readily accessible. In addition, where possible collection of water samples for field water quality measurement was undertaken. During the assessment one bore at the site (GW0209031.1) was able to be gauged with total well depth at 18.84m below ground level (bgl), and depth to groundwater at 2.04m bgl.

3. Objectives

The objective of works undertaken during this investigation was to supervise the installation of groundwater monitoring wells at three locations within the site, to assess depth to groundwater and to allow flow directions beneath the site to be interpreted.

4. Scope of works

4.1. Preliminaries and project management

The proposed scope of work was to drill and install 3 groundwater wells upto 20mbgl over two days of site activities. During site investigation works it was noted that shallow groundwater was noted in alluvial soils above the expected rock underlying the site. Therefore, in consultation with ELA during the first day of site works, the scope was amended such that three shallow boreholes / wells were to be drilled into the alluvial soils and then two deeper boreholes approximately 4m into the underlying rock would be drilled and installed, resulting in five wells in total being installed at the three nominated locations across the site.

The general scope of work for this assessment included the following preliminaries:

- Engagement of licenced drilling and service locating subcontractors;
- Preparation of a site safety plan, including Environmental Safe Work Method Statements (ESWMS) for all work tasks and a Site Safety Management Plan in accordance with our Health, Safety, Security and Environment (HSSE) Management System, and;
- Liaison with relevant staff from ELA and QPRC, along with site tenants.

4.2. Borehole drilling and installation

A Coffey environmental scientist/engineer attended the site between 18 and 20 December 2018, to select borehole locations, manage site safety and supervise service location and monitoring well drilling and installation works. Fieldwork methodology for borehole excavation included the following:

- Mobilisation to the site and liaison with the site tenant;
- Selection of the three investigation locations in accordance with the site plan provided by ELA (sent via email on 14 December 2018);
- Clearance of borehole locations from underground services utilising an accredited service locator, with reference to Dial-Before-You-Dig (DBYD) plans;
- Drilling of 100mm diameter boreholes utilising a track-mounted Geoprobe 7822DT drilling rig, and;

- Logging the borehole soil returns in accordance with the Unified Soil Classification System (USCS);

Boreholes were advanced using hand auger methods in the upper 0.5m bgl to minimise the risk of damage to unidentified buried services at the site. Boreholes were then advanced using the drilling rig with a solid-stem flight auger attachment until practical refusal in bedrock, below which, boreholes were advanced to target depth using an air hammer attachment. Selected site photographs for drilling works are shown in Attachment B, while bore logs for encountered ground conditions are shown in Attachment C.

4.3. Monitoring well installation

Where water-bearing formations were encountered in boreholes, 50 mm monitoring wells were installed in accordance with the Minimum Construction Requirements for Water Bores in Australia 2012. The general construction of monitoring wells included the following:

- Monitoring wells were lined with Class 18 PVC piping, with PVC slotted screens (3m in length) placed adjacent to the water-bearing formation;
- Boreholes were backfilled using gravel pack approximately 0.5m to 1m above the top of the screens. A minimum 500mm bentonite plug was installed over the underlying gravel pack, to isolate the targeted water bearing zone from other formations and prevent transfer of water between zones;
- Boreholes were backfilled to surface level using a cement/bentonite grout mix, with flush-mounted gatic covers installed to minimise risk of injury to, or interference from, livestock and site users.

Monitoring well locations were also recorded using hand-held GPS to an accuracy of ± 5m. GPS Coordinates are shown on each of the bore logs. Positions are provided in the MGA94 (Zone 55) co-ordinate system. Collection of survey data for well elevations was not included in the scope for this project.

4.4. Well development and monitoring

Following well installation on 20 January 2019 the wells were gauged then developed to collect field water quality measurements. These works included the following:

- All five wells were gauged to measure depth to groundwater from the top of the well casing;
- Monitoring wells were developed by purging a minimum of three well volumes, or until water quality measurements taken from purged groundwater had stabilised;
- Water quality measurements were then taken using a field calibrated TPS 90FL-T water quality meter, which included field measurements for dissolved oxygen (DO), Electrical Conductivity (EC), pH, redox potential, temperature and turbidity, and;
- Well headspace was measured using a photoionisation detector (PID) to determine the presence of volatile organic compounds in the wells.

5. Summary of ground conditions

Table 5.1 below provides a summary of subsurface conditions observed at the site, for detail, reference should be made to the Borehole Logs and accompanying explanation sheets, included as Appendix C.

Table 5.1 - Summary of ground conditions encountered during borehole drilling works

Material	Description	Depth to Top of Unit (m)	Range of Unit Thickness (m)
Topsoil	silty CLAY, low plasticity, brown, with rootlets and organic fines	0	0.05 to 0.2
Alluvium	Silty CLAY to clayey SAND, low to medium plasticity clay, brown to pale brown, fine to coarse grained sand, with traces of fine to medium grained gravel	0.05 to 0.2	1.0 to 4.0
Residual Soil	Clayey SAND, fine to medium grained, pale brown, medium plasticity clay, very dense	1.0 to 4.0	0.75 to 1.5
Dacite Bedrock	Extremely and highly weathered, very low to low strength	3.1 to 7.6	0.2 to 2.3
	Moderately to slightly weathered, generally low to medium strength	6.9 to 7.6	Unproven

6. Monitoring well installation summary

Three monitoring wells (MW01A, MW02A and MW09A) were installed in the shallow alluvial aquifer across the site at three locations, while two wells (MW02B and MW09B) were installed deeper in fractured bedrock at two locations shown in Figure 2. A summary of monitoring well construction details is shown in Table 6.1, below.

Table 6.1 - Summary of monitoring well construction details

Field ID	Depth to water (mbtoc)	Screen depth interval (m bgl)	Inferred water-bearing formation
MW01A	2.99	4.4 – 7.4	Alluvium
MW02A	2.77	3.7 – 6.7	Alluvium
MW02B	2.74	7.9 – 10.9	Fractured Bedrock
MW09A	3.19	4.0 – 7.0	Colluvium/Alluvium
MW09B	4.28	9.2 – 12.2	Fractured Bedrock

Soils encountered at the site generally comprised layers of alluvial silty CLAY and clayey SAND to depths of 1-4m below ground level (bgl), underlain by residual clayey SAND and DACITE bedrock.

7. Hydrogeological observations

Groundwater quality and gauging data measurements collected during field activities conducted on 22 January 2019 are presented in Table 1, Attachment D. Groundwater gauging and field measured water quality results are summarised in table 7.1 below:

Table 7.1 - Summary of groundwater monitoring results within shallow and deeper wells .

Measurement	Shallow wells (alluvium)	Deep wells (fractured rock)
Depth to standing water level (mbtoc)	2.77 to 3.19	2.74 to 4.28
Dissolved Oxygen (mg/L)	2.27 to 4.36	1.22 to 3.05
Oxidation-reduction potential (mV)	72 to 137	68 to 87
pH units	6.51 to 6.69	6.36 to 6.4
Electrical conductivity (µS/cm)	690 to 1594	1315 to 1464
Turbidity (NTU)	486 to 755	17.0 to 31.8

8. Closure

Groundwater wells were installed at three nominated locations across the site. Three monitoring wells (MW01A, MW02A and MW09A) were installed within shallow alluvial water-bearing zones, while two additional monitoring wells (MW02B and MW09B) were installed in deeper water-bearing zones within fractured bedrock.

The single gauging event in January 2019 indicated depths to groundwater between 2.77m and 3.19m in the shallow aquifer wells and 2.74m and 4.28m in the deeper fractured rock aquifer.

Longer term monitoring of groundwater levels is necessary to have a better understanding of seasonal variance in the groundwater elevations beneath the site. Coffey understand this will be undertaken under a separate scope and report. It should also be noted that a survey of well elevations was not included within the scope for this project. Survey data for elevations would be required to determine and groundwater flow direction beneath the site.

We draw your attention to the attached sheets titled “Important Information about your Coffey Environmental Report” which should be read in conjunction with this letter.

If you have any further questions, please do not hesitate to contact the undersigned.

For and on behalf of Coffey

Michael Carbone
Senior Associate Environmental Scientist

Attachments

Important Information about your Coffey Environmental Report

Attachment A – Figures 1 to 2

Attachment B – Selected site photographs

Attachment C – Borehole logs and well construction details

Attachment D – Well gauging and water quality data

Important information about your **Coffey** Environmental Report

Introduction

This report has been prepared by Coffey for you, as Coffey's client, in accordance with our agreed purpose, scope, schedule and budget.

The report has been prepared using accepted procedures and practices of the consulting profession at the time it was prepared, and the opinions, recommendations and conclusions set out in the report are made in accordance with generally accepted principles and practices of that profession.

The report is based on information gained from environmental conditions (including assessment of some or all of soil, groundwater, vapour and surface water) and supplemented by reported data of the local area and professional experience. Assessment has been scoped with consideration to industry standards, regulations, guidelines and your specific requirements, including budget and timing. The characterisation of site conditions is an interpretation of information collected during assessment, in accordance with industry practice.

This interpretation is not a complete description of all material on or in the vicinity of the site, due to the inherent variation in spatial and temporal patterns of contaminant presence and impact in the natural environment. Coffey may have also relied on data and other information provided by you and other qualified individuals in preparing this report. Coffey has not verified the accuracy or completeness of such data or information except as otherwise stated in the report. For these reasons the report must be regarded as interpretative, in accordance with industry standards and practice, rather than being a definitive record.

Your report has been written for a specific purpose

Your report has been developed for a specific purpose as agreed by us and applies only to the site or area investigated. Unless otherwise stated in the report, this report cannot be applied to an adjacent site or area, nor can it be used when the nature of the specific purpose changes from that which we agreed.

For each purpose, a tailored approach to the assessment of potential soil and groundwater contamination is required. In most cases, a key objective is to identify, and if possible quantify, risks that both recognised and potential contamination pose in the context of the agreed purpose. Such risks may be financial (for example, clean up costs or constraints on site use) and/or physical (for example, potential health risks to users of the site or the general public).

Limitations of the Report

The work was conducted, and the report has been prepared, in response to an agreed purpose and scope, within time and budgetary constraints, and in reliance on certain data and information made available to Coffey.

The analyses, evaluations, opinions and conclusions presented in this report are based on that purpose and scope, requirements, data or information, and they could change if such requirements or data are inaccurate or incomplete.

This report is valid as of the date of preparation. The condition of the site (including subsurface conditions) and extent or nature of contamination or other environmental hazards can change over time, as a result of either natural processes or human influence. Coffey should be kept appraised of any such events and should be consulted for further investigations if any changes are noted, particularly during construction activities where excavations often reveal subsurface conditions.

In addition, advancements in professional practice regarding contaminated land and changes in applicable statues and/or guidelines may affect the validity of this report. Consequently, the currency of conclusions and recommendations in this report should be verified if you propose to use this report more than 6 months after its date of issue.

The report does not include the evaluation or assessment of potential geotechnical engineering constraints of the site.

Interpretation of factual data

Environmental site assessments identify actual conditions only at those points where samples are taken and on the date collected. Data derived from indirect field measurements, and sometimes other reports on the site, are interpreted by geologists, engineers or scientists to provide an opinion about overall site conditions, their likely impact with respect to the report purpose and recommended actions.

Variations in soil and groundwater conditions may occur between test or sample locations and actual conditions may differ from those inferred to exist. No environmental assessment program, no matter how comprehensive, can reveal all subsurface details and anomalies. Similarly, no professional, no matter how well qualified, can reveal what is hidden by earth, rock or changed through time.

The actual interface between different materials may be far more gradual or abrupt than assumed based on the facts obtained. Nothing can be done to change the actual site conditions which exist, but steps can be taken to reduce the impact of unexpected conditions.

For this reason, parties involved with land acquisition, management and/or redevelopment should retain the services of a suitably qualified and experienced environmental consultant through the development and use of the site to identify variances, conduct additional tests if required, and recommend solutions to unexpected conditions or other unrecognised features encountered on site. Coffey would be pleased to assist with any investigation or advice in such circumstances.

Recommendations in this report

This report assumes, in accordance with industry practice, that the site conditions recognised through discrete sampling are representative of actual conditions throughout the investigation area. Recommendations are based on the resulting interpretation.

Should further data be obtained that differs from the data on which the report recommendations are based (such as through excavation or other additional assessment), then the recommendations would need to be reviewed and may need to be revised.

Report for benefit of client

Unless otherwise agreed between us, the report has been prepared for your benefit and no other party. Other parties should not rely upon the report or the accuracy or completeness of any recommendation and should make their own enquiries and obtain independent advice in relation to such matters.

Coffey assumes no responsibility and will not be liable to any other person or organisation for, or in relation to, any matter dealt with or conclusions expressed in the report, or for any loss or damage suffered by any other person or organisation arising from matters dealt with or conclusions expressed in the report.

To avoid misuse of the information presented in your report, we recommend that Coffey be consulted before the report is provided to another party who may not be familiar with the background and the purpose of the report. In particular, an environmental disclosure report for a property vendor may not be suitable for satisfying the needs of that property's purchaser. This report should not be applied for any purpose other than that stated in the report.

Interpretation by other professionals

Costly problems can occur when other professionals develop their plans based on misinterpretations of a report. To help avoid misinterpretations, a suitably qualified and experienced environmental consultant should be retained to explain the implications of the report to other professionals referring to the report and then review plans and specifications produced to see how other professionals have incorporated the report findings.

Given Coffey prepared the report and has familiarity with the site, Coffey is well placed to provide such assistance. If another party is engaged to interpret the recommendations of the report, there is a risk that the contents of the report may be misinterpreted and Coffey disowns any responsibility for such misinterpretation.

Data should not be separated from the report

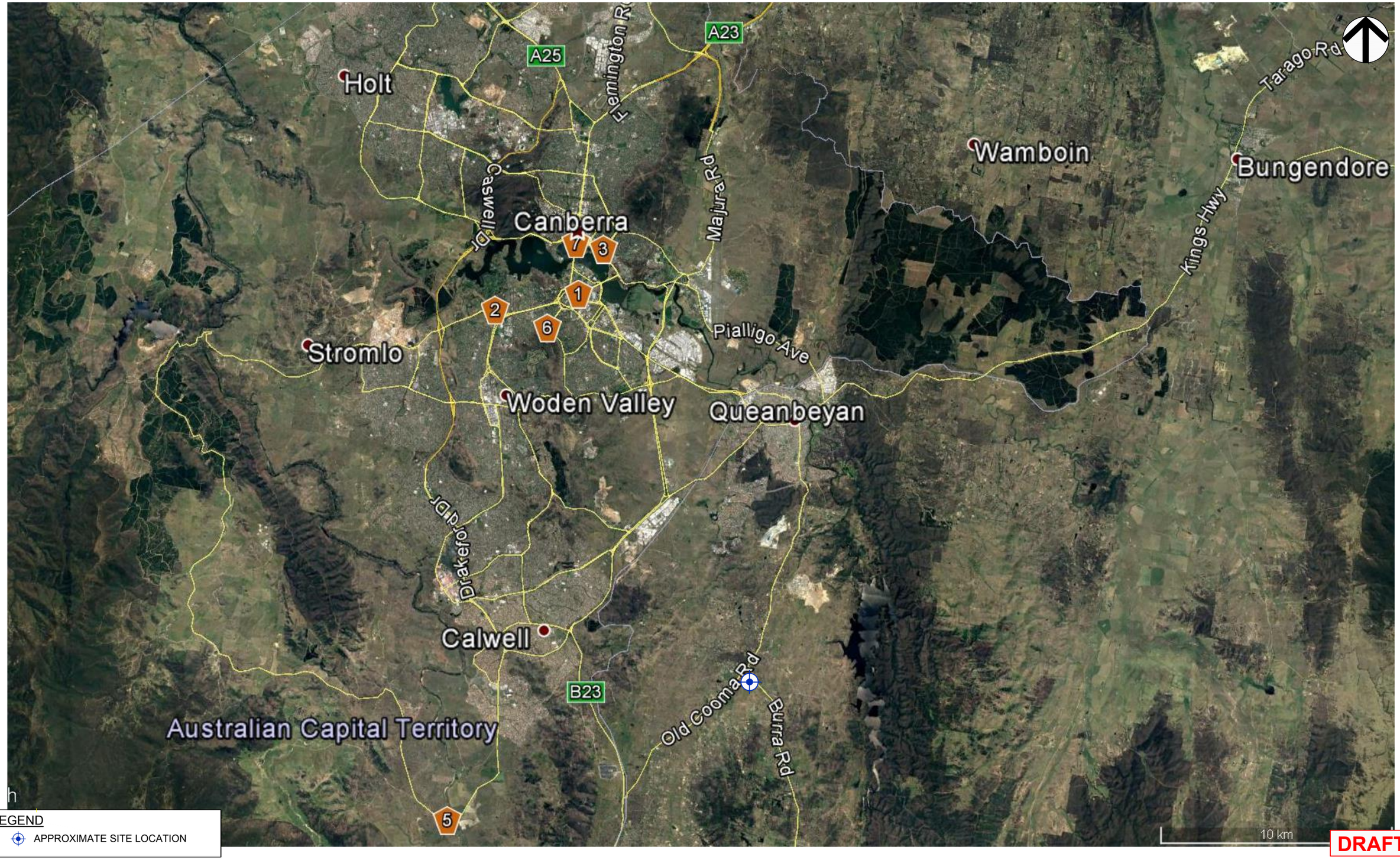
The report as a whole presents the findings of the site assessment and the report should not be copied in part or altered in any way. Logs, figures, laboratory data, drawings, etc. are customarily included in our reports and are developed by scientists or engineers based on their interpretation of field logs, field testing and laboratory evaluation of samples. This information should not under any circumstances be redrawn for inclusion in other documents or separated from the report in any way.

This report should be reproduced in full. No responsibility is accepted for use of any part of this report in any other context or for any other purpose or by third parties.

Responsibility

Environmental reporting relies on interpretation of factual information using professional judgement and opinion and has a level of uncertainty attached to it, which is much less exact than other design disciplines. This has often resulted in claims being lodged against consultants, which are unfounded. As noted earlier, the recommendations and findings set out in this report should only be regarded as interpretive and should not be taken as accurate and complete information about all environmental media at all depths and locations across the site.

Attachment A – Figures



LEGEND

APPROXIMATE SITE LOCATION

DRAFT

revision	no.	description	drawn	approved	date
	A	ORIGINAL ISSUE			

0 2.5 5 7.5 10

Scale (kilometres)

drawn	PP / AW
approved	-
date	14 / 01 / 19
scale	AS SHOWN
original size	A3

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client: QUEANBEYAN-PALERANG REGIONAL COUUNCIL

project: QPRC GROUNDWATER WELL INSTALLATION
1241 OLD COOMA RD, GOOGONG, NSW

title: GROUNDWATER MONITORING SITE LOCATION PLAN

project no: 754-CBREN225122-R01 | figure no: FIGURE 1 | rev: A

PLOT DATE: 14/01/2019 4:21:33 PM DWG FILE: F:\1. PROJECTS\1. SYDENENVOTHER OFFICES\CBR-ENC\BREN225122\CAD\754-CBREN225122-R01.DWG

revision	no.	description	drawn	approved	date
	A	ORIGINAL ISSUE			

50 0 50 100 150 200

Scale (metres) 1:4000

drawn	PP / AW
approved	-
date	14 / 01 / 19
scale	AS SHOWN
original size	A3

coffey
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client: QUEANBEYAN-PALERANG REGIONAL COUUNCIL

project: QPRC GROUNDWATER WELL INSTALLATION
1241 OLD COOMA RD, GOOGONG, NSW

title: GROUNDWATER MONITORING WELL LOCATION PLAN

project no: 754-CBREN225122-R01 | figure no: FIGURE 2 | rev: A

PLOT DATE: 14/01/2019 4:21:33 PM DWG FILE: F:\1. PROJECTS\1. SYDENEN\VOTHER OFFICE\SCBR-EN\CBREN225122\CAD\754-CBREN225122-R01.DWG

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Attachment B – Selected site photographs

Attachment B – Selected Site Photographs

Figure 1 - Location of MW01A in the south west portion of the site, marked by an orange traffic cone. Borehole MW01A was positioned adjacent to a shed and stockyard, on generally flat alluvial soils.

Figure 2 - Location of MW02A and MW02B, in the western portion of the site, marked by an orange traffic cone. Boreholes were situated on flat alluvial soil and spaced approximately 1.5m apart.

Figure 3 - Location of MW09A, in the eastern portion of the site, marked by an orange traffic cone. Borehole MW09A was excavated into alluvial soil in a slight valley.

Figure 4 – Drilling borehole MW02B. Boreholes were excavated using a solid stem flight auger attachment from 0.5m bgl until auger refusal in bedrock, below which, deeper boreholes (MW02B and MW09B) were drilled into bedrock using an air hammer methods.

Figure 5 - Groundwater encountered during drilling for MW02B, using an air hammer attachment.

Figure 6 – Hand auger excavation in borehole MW02A. All boreholes were excavated/drilled using hand auger methods within the upper 0.5m bgl to minimise the likelihood of damage to underground services.

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Attachment C – Bore logs

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Environmental Log - Monitoring Well

Hole ID.	***MW01A***
sheet:	1 of 1
project no.	***754-CBREN225122***
client: ***Eco Locgical Australia***	date started: ***20 Dec 2018***
principal:	date completed: ***20 Dec 2018***
project: ***QPRC Monitoring Well Installation***	logged by: ***TX***
location: ***1241 Old Cooma Rd, Googong NSW***	checked by: ***MC***

position: E: 700,090; N: 6,074,233 (MGA94) | surface elevation: Not Specified | angle from horizontal: 90°

equipment type: Geoprobe 7822DT, Track mounted | drilling fluid: None | hole diameter : 100 mm

drilling information			well details	material substance							
method & support	water	samples & field tests	MW01A	RL (m)	depth (m)	graphic log	classification symbol	material description **SOIL TYPE**: plasticity or particle characteristic, colour, secondary and minor components	moisture condition	consistency / relative density	structure and additional observations
HA					0.0			**TOPSOIL: SILT**: brown, with traces of fine angular gravel and rootlets.	D	F	**TOPSOIL**
								Silty CLAY: low to medium plasticity, brown.	D	F	**ALLUVIUM**
								Gravelly SILT: low to medium liquid limit, brown, fine to medium sub-angular gravel.	D	F	
					1.0			**Sandy SILT**: low to medium liquid limit, brown, medium to coarse grained sand.	D	F - St	**RESIDUAL SOIL**
					2.0						
					3.0			**Sandy SILT**: low to medium liquid limit, brown, medium to coarse grained sand, increasing penetration resistance.	<Wp	VSt	
					4.0						
					5.0			**DACITE**: grey-brown, extremely weathered, recovered as gravelly sand, medium to coarse grained sand, fine to medium sub-angular gravel.	D	VSt - H	
					6.0			5.7 m: increasing mositure	W	H	
					7.0						
					8.0			Monitoring Well MW01A terminated at 7.40 m Refusal			**well details:** bore construction license: DL2090, Class 2 drilling company: Epoca Environmental` driller: Daniel Fox **backfill details:** 0.0-2.9m: Grout 2.9-3.9m: Bentonite 3.9-7.4m: Sand **standpipe MW01A details:** stickup: 0.0m 4.4-7.4m: screen
					9.0						

SS — N — HA

22/01/19 11:00

CDF_0_9_06_LIBRARY.GLB rev:AR Log COF PIEZOMETER: ENVIRONMENTAL 754-CBREN225122.GPJ <<DrawingFile>> 24/01/2019 16:31

method

AD	auger drilling*
AS	auger screwing*
HA	hand auger
W	washbore
AH	air hammer
HA	hand auger
SS	solid stem flight auger
*	bit shown by suffix
e.g.	AD/T
B	blank bit
T	TC bit
V	V bit

support

M	mud
C	casing
N	nill

water

10-Oct-12 water level on date shown
water inflow
water outflow

samples & field tests

ALT	air lift test
B	bulk disturbed sample
D	disturbed sample
E	environmental sample
SS	split spoon sample
U##	undisturbed sample ##mm diameter
WS	water sample
HB	hammer bouncing
N	standard penetration test (SPT)
N*	SPT - sample recovered
Nc	SPT with solid cone
PID	photoionization detector
R	refusal

classification symbol & soil description
based on Unified Classification System

moisture

D	dry
M	moist
W	wet
Wp	plastic limit
Wl	liquid limit

consistency / relative density

VS	very soft
S	soft
F	firm
St	stiff
VSt	very stiff
H	hard
Fb	friable
VL	very loose
L	loose
MD	medium dense
D	dense
VD	very dense

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Environmental Log - Monitoring Well

Hole ID.	***MW02A***
sheet:	1 of 1
project no.	***754-CBREN225122***
client:	***Eco Locgical Australia***
date started:	***19 Dec 2018***
principal:	
date completed:	***19 Dec 2018***
project:	***QPRC Monitoring Well Installation***
logged by:	***PP***
location:	***1241 Old Cooma Rd, Googong NSW***
checked by:	***MC***

position: E: 700,189; N: 6,074,447 (MGA94) | surface elevation: Not Specified | angle from horizontal: 90°

equipment type: Geoprobe 7822DT, Track mounted | drilling fluid: None | hole diameter : 100 mm

drilling information			well details	material substance							
method & support	water	samples & field tests	MW02A	RL (m)	depth (m)	graphic log	classification symbol	material description **SOIL TYPE**: plasticity or particle characteristic, colour, secondary and minor components	moisture condition	consistency / relative density	structure and additional observations
HA					0.0			**TOPSOIL: Silty CLAY**: low plasticity, grey, trace fine sand, rootlets and fine to medium gravel.	D	F	**TOPSOIL**
								CLAY: medium to high plasticity, brown-grey mottled, trace fine to medium sand.	<Wp	F	**ALLUVIUM**
					1.0			**CLAYEY SAND**: fine to medium grained, brown, sand is rounded, medium plasticity clay.	D - M	MD	
					2.0						
					3.0						
					4.0			**Sandy CLAY**: medium plasticity, brown, fine to medium sand, traces of fine sub-rounded gravel.	<Wp	F - St	**RESIDUAL SOIL**
								CLAYEY SAND: fine to medium grained, pale grey-brown, medium plasticity clay, sand is rounded to sub-rounded, traces of fine sub-rounded gravel.	M - W		
					5.0						
					6.0						
SS					7.0			**DACITE**: red-brown, highly to extremely weathered, very low to medium strength.			**WEATHERED BEDROCK**
N	22/01/19 11:15							Monitoring Well MW02A terminated at 7.20 m Refusal			**well details:** bore construction license: DL2090, Class 2 drilling company: Epoca Environmental` driller: Daniel Fox **backfill details:** 0.0-2.3m: Grout 2.3-2.8m: Bentonite 2.8-7.2m: Sand **standpipe MW02A details:** stickup: 0.0m 3.7-6.7m: screen
					8.0						
					9.0						

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method

AD	auger drilling*
AS	auger screwing*
HA	hand auger
W	washbore
AH	air hammer
HA	hand auger
SS	solid stem flight auger
*	bit shown by suffix
e.g.	AD/T
B	blank bit
T	TC bit
V	V bit

support

M	mud
C	casing
N	nill

water

10-Oct-12 water level on date shown
water inflow
water outflow

samples & field tests

ALT	air lift test
B	bulk disturbed sample
D	disturbed sample
E	environmental sample
SS	split spoon sample
U##	undisturbed sample ##mm diameter
WS	water sample
HB	hammer bouncing
N	standard penetration test (SPT)
N*	SPT - sample recovered
Nc	SPT with solid cone
PID	photoionization detector
R	refusal

classification symbol & soil description
based on Unified Classification System

moisture

D	dry
M	moist
W	wet
Wp	plastic limit
Wl	liquid limit

consistency / relative density

VS	very soft
S	soft
F	firm
St	stiff
VSt	very stiff
H	hard
Fb	friable
VL	very loose
L	loose
MD	medium dense
D	dense
VD	very dense

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Environmental Log - Monitoring Well

Hole ID.	***MW02B***
sheet:	1 of 2
project no.	***754-CBREN225122***
client: ***Eco Locgical Australia***	date started: ***18 Dec 2018***
principal:	date completed: ***19 Dec 2018***
project: ***QPRC Monitoring Well Installation***	logged by: ***PP***
location: ***1241 Old Cooma Rd, Googong NSW***	checked by: ***MC***

position: E: 700,187; N: 6,074,445 (MGA94) | surface elevation: Not Specified | angle from horizontal: 90°

equipment type: Geoprobe 7822DT, Track mounted | drilling fluid: None | hole diameter : 100 mm

drilling information			well details	material substance						
method & support	water	samples & field tests	MW02B	RL (m)	depth (m)	graphic log	classification symbol	material description **SOIL TYPE**: plasticity or particle characteristic, colour, secondary and minor components	moisture condition	consistency / relative density	structure and additional observations
HA					0.0			**TOPSOIL: Silty CLAY**: low plasticity, dark grey, rootlets and organic fines.	<Wp	S	**TOPSOIL/COLLUVIUM**
								CLAY: high plasticity, brown-grey mottled, traces of fine to medium sand.	<Wp	F	**ALLUVIUM**
					1.0			**CLAYEY SAND**: fine to medium grained, brown, rounded to sub-rounded, medium plasticity clay, traces of fine sub-angular gravel.	D	MD	
					2.0						
					3.0						
					4.0			**Sandy CLAY**: medium plasticity, brown, fine to medium grained sand, traces of gravel.	<Wp	St	**RESIDUAL SOIL**
								CLAYEY SAND: fine to medium grained, pale brown, medium plasticity clay, traces of fine gravel, sub-rounded.	D - M	MD	
					5.0						
					6.0			**CLAYEY SAND**: fine to medium grained, pale brown, medium plasticity clay, traces of fine gravel, sub-rounded.	W	MD	
					7.0						
								DACITE: red-brown-grey mottled, slighty weathered, high strength.			**WEATHERED BEDROCK**
					8.0						
					9.0						

SS — C — AH — N

22/01/19 11:25

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method

AD	auger drilling*
AS	auger screwing*
HA	hand auger
W	washbore
AH	air hammer
HA	hand auger
SS	solid stem flight auger
*	bit shown by suffix
e.g.	AD/T
B	blank bit
T	TC bit
V	V bit

support

M	mud
C	casing
N	nill

water

10-Oct-12 water level on date shown
water inflow
water outflow

samples & field tests

ALT	air lift test
B	bulk disturbed sample
D	disturbed sample
E	environmental sample
SS	split spoon sample
U##	undisturbed sample ##mm diameter
WS	water sample
HB	hammer bouncing
N	standard penetration test (SPT)
N*	SPT - sample recovered
Nc	SPT with solid cone
PID	photoionization detector
R	refusal

classification symbol & soil description
based on Unified Classification System

moisture

D	dry
M	moist
W	wet
Wp	plastic limit
Wl	liquid limit

consistency / relative density

VS	very soft
S	soft
F	firm
St	stiff
VSt	very stiff
H	hard
Fb	friable
VL	very loose
L	loose
MD	medium dense
D	dense
VD	very dense

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Environmental Log - Monitoring Well

Hole ID.	***MW02B***
sheet:	2 of 2
project no.	***754-CBREN225122***
client:	***Eco Locgical Australia***
date started:	***18 Dec 2018***
principal:	
date completed:	***19 Dec 2018***
project:	***QPRC Monitoring Well Installation***
logged by:	***PP***
location:	***1241 Old Cooma Rd, Googong NSW***
checked by:	***MC***

position: E: 700,187; N: 6,074,445 (MGA94) | surface elevation: Not Specified | angle from horizontal: 90°

equipment type: Geoprobe 7822DT, Track mounted | drilling fluid: None | hole diameter : 100 mm

drilling information			well details	material substance							
method & support	water	samples & field tests		RL (m)	depth (m)	graphic log	classification symbol	material description **SOIL TYPE**: plasticity or particle characteristic, colour, secondary and minor components	moisture condition	consistency / relative density	structure and additional observations
AH N					11.0			**DACITE**: red-brown-grey, extremely weathered seam, very low strength. **DACITE**: red-brown-grey, slightly weathered, high strength.			
					12.0 13.0 14.0 15.0 16.0 17.0 18.0 19.0			Monitoring Well MW02B terminated at 11.40 m Target depth			**well details:** bore construction license: DL2090, Class 2 drilling company: Epoca Environmental` driller: Daniel Fox **backfill details:** 0.0-7.3m: Grout 7.3-7.8m: Bentonite 7.8-11.4m: Sand **standpipe MW02B details:** stickup: 0.0m 7.9-10.9m: screen

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method

AD	auger drilling*
AS	auger screwing*
HA	hand auger
W	washbore
AH	air hammer
HA	hand auger
SS	solid stem flight auger
*	bit shown by suffix
e.g.	AD/T
B	blank bit
T	TC bit
V	V bit

support

M	mud
C	casing
N	nill

water

10-Oct-12 water level on date shown
water inflow
water outflow

samples & field tests

ALT	air lift test
B	bulk disturbed sample
D	disturbed sample
E	environmental sample
SS	split spoon sample
U##	undisturbed sample ##mm diameter
WS	water sample
HB	hammer bouncing
N	standard penetration test (SPT)
N*	SPT - sample recovered
Nc	SPT with solid cone
PID	photoionization detector
R	refusal

classification symbol & soil description
based on Unified Classification System

moisture

D	dry
M	moist
W	wet
Wp	plastic limit
Wl	liquid limit

consistency / relative density

VS	very soft
S	soft
F	firm
St	stiff
VSt	very stiff
H	hard
Fb	friable
VL	very loose
L	loose
MD	medium dense
D	dense
VD	very dense

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Environmental Log - Monitoring Well

Hole ID.	***MW09A***
sheet:	1 of 1
project no.	***754-CBREN225122***
client:	***Eco Locgical Australia***
date started:	***18 Dec 2018***
principal:	
date completed:	***18 Dec 2018***
project:	***QPRC Monitoring Well Installation***
logged by:	***PP/TX***
location:	***1241 Old Cooma Rd, Googong NSW***
checked by:	***MC***

position: E: 700,702; N: 6,074,185 (MGA94) | surface elevation: Not Specified | angle from horizontal: 90°

equipment type: Geoprobe 7822DT, Track mounted | drilling fluid: None | hole diameter : 100 mm

drilling information			well details	material substance								
method & support	water	samples & field tests	MW09A	RL (m)	depth (m)	graphic log	classification symbol	material description **SOIL TYPE**: plasticity or particle characteristic, colour, secondary and minor components	moisture condition	consistency / relative density	structure and additional observations
HA					0.0			**TOPSOIL: Clayey SILT**: low liquid limit, brown, significant rootlets.	M	MD	**TOPSOIL**
									D	S	**COLLUVIUM**
								Silty CLAY: low to medium plasticity, brown, traces of fine sub-rouned gravel.	D	MD	**ALLUVIUM**
					1.0			**CLAYEY SAND**: medium to coarse grained, brown, low plasticity clay, traces of fine to medium sub-rounded gravel.	D	MD	
									D	L	
								CLAYEY SAND: fine grained, yellow-brown, low plasticity clay.	D - M	F	
					2.0			**Sandy SILT**: low liquid limit, yellow-brown, fine to medium grained sand, traces of fine to medium sub-rounded gravel.			
								CLAY: medium plasticity, brown, traces of fine grained sand, occasional orange mottling.			
					3.0						
SS	22/01/19 11:45							**CLAY**: medium plasticity, brown, significant medium to coarse sand, traces of fine sub-rounded gravel.	M	F	
N					4.0			**CLAYEY SAND**: fine to medium grained, brown, low plasticity clay.	D - M	S	
					5.0						
								SAND: fine to medium grained, brown, traces of clay and fine sub-rounded gravel.	D	MD	
					6.0			**CLAYEY SAND**: medium to coarse grained, brown, medium plasticity clay, traces of fine gravel.	D		
								Sandy CLAY: medium plasticity, brown, medium to coarse grained sand.	M		**RESIDUAL SOIL**
					7.0			Monitoring Well MW09A terminated at 7.60 m Refusal			**well details:** bore construction license: DL2090, Class 2 drilling company: Epoca Environmental` driller: Daniel Fox **backfill details:** 0.0-3.0m: Grout 3.0-3.5m: Bentonite 3.5-7.6m: Sand **standpipe MW09A details:** stickup: 0.0m 4.0-7.0m: screen
					8.0						
					9.0						

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method

AD	auger drilling*
AS	auger screwing*
HA	hand auger
W	washbore
AH	air hammer
HA	hand auger
SS	solid stem flight auger
*	bit shown by suffix
e.g.	AD/T
B	blank bit
T	TC bit
V	V bit

support

M	mud
C	casing
N	nill

water

10-Oct-12 water level on date shown
water inflow
water outflow

samples & field tests

ALT	air lift test
B	bulk disturbed sample
D	disturbed sample
E	environmental sample
SS	split spoon sample
U##	undisturbed sample ##mm diameter
WS	water sample
HB	hammer bouncing
N	standard penetration test (SPT)
N*	SPT - sample recovered
Nc	SPT with solid cone
PID	photoionization detector
R	refusal

classification symbol & soil description
based on Unified Classification System

moisture

D	dry
M	moist
W	wet
Wp	plastic limit
Wl	liquid limit

consistency / relative density

VS	very soft
S	soft
F	firm
St	stiff
VSt	very stiff
H	hard
Fb	friable
VL	very loose
L	loose
MD	medium dense
D	dense
VD	very dense

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Environmental Log - Monitoring Well

Hole ID.	***MW09B***
sheet:	1 of 2
project no.	***754-CBREN225122***
client: ***Eco Locgical Australia***	date started: ***19 Dec 2018***
principal:	date completed: ***20 Dec 2018***
project: ***QPRC Monitoring Well Installation***	logged by: ***PP/TX***
location: ***1241 Old Cooma Rd, Googong NSW***	checked by: ***MC***

position: E: 700,755; N: 6,072,954 (MGA94) | surface elevation: Not Specified | angle from horizontal: 90°

equipment type: Geoprobe 7822DT, Track mounted | drilling fluid: None | hole diameter : 100 mm

drilling information			well details	material substance							
method & support	water	samples & field tests	MW09B	RL (m)	depth (m)	graphic log	classification symbol	material description **SOIL TYPE**: plasticity or particle characteristic, colour, secondary and minor components	moisture condition	consistency / relative density	structure and additional observations
HA					0.0			**TOPSOIL: Silty CLAY**: low plasticity, dark brown, rootlets and organic fines, traces of fine to medium sand.	D - <Wp	F	**TOPSOIL**
									<Wp	F	**TOPSOIL/COLLUVIUM**
								Silty CLAY: medium plasticity, grey, traces of rootlets, fine sand.	<Wp	F - St	**COLLUVIUM**
					1.0			**CLAY**: medium to high plasticity, red-brown-grey mottled, traces of rootlets.	D - M	MD	
								CLAYEY SAND: fine to medium grained, pale brown, low plasticity clay, traces of fine to medium sub-rounded to sub-angular gravel.			
					2.0			**CLAYEY SAND**: medium to coarse grained, brown, traces of fine sub-angular gravel, poorly graded.		MD	
					3.0			**DACITE**: grey-brown, extremely weathered, recovered as gravelly sand, medium to coarse grained, fine angular gravel (igneous fragments).	D - M	VD	**WEATHERED BEDROCK**
					4.0						
					5.0						
					6.0				M		
					7.0			changed to air hammer, auger refusal at 6.9m **DACITE**: grey-brown, slightly weathered, very high strength, water inflow observed.			
					8.0			**DACITE**: grey-brown, slightly weathered, very high strength.			
					9.0						
SS	22/01/19										
C											
AH											
N											

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method

AD	auger drilling*
AS	auger screwing*
HA	hand auger
W	washbore
AH	air hammer
HA	hand auger
SS	solid stem flight auger
*	bit shown by suffix
e.g.	AD/T
B	blank bit
T	TC bit
V	V bit

support

M	mud
C	casing
N	nill

water

10-Oct-12 water level on date shown
water inflow
water outflow

samples & field tests

ALT	air lift test
B	bulk disturbed sample
D	disturbed sample
E	environmental sample
SS	split spoon sample
U##	undisturbed sample ##mm diameter
WS	water sample
HB	hammer bouncing
N	standard penetration test (SPT)
N*	SPT - sample recovered
Nc	SPT with solid cone
PID	photoionization detector
R	refusal

classification symbol & soil description
based on Unified Classification System

moisture

D	dry
M	moist
W	wet
Wp	plastic limit
Wl	liquid limit

consistency / relative density

VS	very soft
S	soft
F	firm
St	stiff
VSt	very stiff
H	hard
Fb	friable
VL	very loose
L	loose
MD	medium dense
D	dense
VD	very dense

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Environmental Log - Monitoring Well

Hole ID.	***MW09B***
sheet:	2 of 2
project no.	***754-CBREN225122***
client: ***Eco Locgical Australia***	date started: ***19 Dec 2018***
principal:	date completed: ***20 Dec 2018***
project: ***QPRC Monitoring Well Installation***	logged by: ***PP/TX***
location: ***1241 Old Cooma Rd, Googong NSW***	checked by: ***MC***

position: E: 700,755; N: 6,072,954 (MGA94) | surface elevation: Not Specified | angle from horizontal: 90°

equipment type: Geoprobe 7822DT, Track mounted | drilling fluid: None | hole diameter : 100 mm

drilling information			well details	material substance							
method & support	water	samples & field tests		RL (m)	depth (m)	graphic log	classification symbol	material description **SOIL TYPE**: plasticity or particle characteristic, colour, secondary and minor components	moisture condition	consistency / relative density	structure and additional observations
AH N					11.0			**DACITE**: grey-brown, slightly weathered, very high strength. *(continued)*			**WEATHERED BEDROCK**
					12.0			Monitoring Well MW09B terminated at 12.20 m Target depth			**well details:** bore construction license: DL2090, Class 2 drilling company: Epoca Environmental` driller: Daniel Fox **backfill details:** 0.0-7.7m: Grout 7.7-8.7m: Bentonite 8.7-12.2m: Sand **standpipe MW09B details:** stickup: 0.0m 9.2-12.2m: screen
					13.0						
					14.0						
					15.0						
					16.0						
					17.0						
					18.0						
					19.0						

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method
- AD auger drilling*
- AS auger screwing*
- HA hand auger
- W washbore
- AH air hammer
- HA hand auger
- SS solid stem flight auger
- * bit shown by suffix
- e.g. AD/T
- B blank bit
- T TC bit
- V V bit

support
- M mud
- C casing
- N nill

water
- 10-Oct-12 water level on date shown
- water inflow
- water outflow

samples & field tests
- ALT air lift test
- B bulk disturbed sample
- D disturbed sample
- E environmental sample
- SS split spoon sample
- U## undisturbed sample ##mm diameter
- WS water sample
- HB hammer bouncing
- N standard penetration test (SPT)
- N* SPT - sample recovered
- Nc SPT with solid cone
- PID photoionization detector
- R refusal

classification symbol & soil description
based on Unified Classification System

moisture
- D dry
- M moist
- W wet
- Wp plastic limit
- Wl liquid limit

consistency / relative density
- VS very soft
- S soft
- F firm
- St stiff
- VSt very stiff
- H hard
- Fb friable
- VL very loose
- L loose
- MD medium dense
- D dense
- VD very dense

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Attachment D – Water quality and gauging data

Table 1
Water Quality Measurements
QPRC proposed cemetery site, January 2019

Well ID	Date Measured	Total well depth	Depth to water	Dissolved Oxygen	Redox Potential (ORP)	pH	EC	Temperature	Total Purge Volume	Comments
		(mbtoc)	(mbtoc)	(mg/L)	(mV)		(µS/cm)	(^{o}C)	(L)	
MW01A	22 January 2019	7.4	2.99	4.36	137	6.69	821	15.5	70	No odour or sheen, turbid (580 NTU)
MW02A	22 January 2019	7.2	2.77	3.87	72	6.51	1594	15.5	35	No odour or sheen, cloudy (486 NTU)
MW02B	22 January 2019	11.4	2.74	3.05	87	6.36	1315	13.5	70	No odour or sheen, slightly cloudy (17.0 NTU)
MW09A	22 January 2019	7.0	3.19	2.27	101	6.61	690	13.7	30	No odour or sheen, very cloudy (755 NTU), PID = 3.9ppm
MW09B	22 January 2019	12.2	4.28	1.22	68	6.4	1464	10.0	55	No odour or sheen, slightly cloudy (31.8 NTU)

Notes

mbtoc = metres below top of well casing
L = Litres
ID = Identification
mg/L = milligrams per litre
mV = millivolts
MW = Monitoring Well
µS/cm = microsiemens per centimetre
WQP = Water Quality Probe
^{o}C = degrees
NTU = Nephelometric turbidity units

Equipment

TPS 90FL-T

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Appendix C Registered groundwater bore details

Hydro Code	Latitude	Longitude	Easting	Northing	Ref Elevation (mAHD)	Bore Depth (m)	Drilled Depth (m)	Drilled Date	Major Lithology	Lithological description	Function Type
GW400062.1.1	-35.442476	149.189309	698713	6075684	756	90	90	4/02/1992	DCIT	Dacite	Household Use
GW020893.1.1	-35.457886	149.214262	700940	6073924	793.14	0	13.7	1/10/1952	CLAY	Clay yellow	Unknown
GW020903.1.1	-35.453719	149.207595	700345	6074400	782.08	0	7.9	1/01/1953	CLAY	Clay yellow some sand	Stock water
GW020890.1.1	-35.453442	149.202317	699866	6074441	776.15	19.8	19.8	1/10/1952	PRPR	Porphyry water supply	Unknown
GW067501.1.1	-35.437996	149.207135	700342	6076145	789.09	42	42	12/10/1989	GRNT	Black granite	Household Use
GW400206.1.1	-35.43233	149.213428	700927	6076761	778.12	39.6	39.6	28/04/1997	None	Soft shale.	Household Use
GW401352.1.1	-35.441325	149.189609	698743	6075811	756.63	78	78	31/12/1991	SLTE	Slate, soft	Household Use
GW401068.1.1	-35.458808	149.198345	699493	6073854	775.49	36	36	21/10/1999	BRKN	Broken brown shale	Household Use
GW400503.1.1	-35.442026	149.189296	698713	6075734	758.72	60.8	60.8	28/11/1994	None	Topsoil	Unknown
GW400504.1.1	-35.439188	149.196655	699388	6076034	735.8	60.8	60.8	5/12/1994	DCIT	Dacite	Household Use
GW400813.1.1	-35.437753	149.199745	699672	6076187	759.01	54	54	22/04/1998	HDBD	Hard grey black granite	Household Use
GW401683.1.1	-35.443137	149.202545	699913	6075584	788.92	121	121	23/05/2001	GRNT	Granite, broken	Household Use
GW401777.1.1	-35.471224	149.194716	699133	6072484	784.25	84	84	20/08/2001	SHLE	Shale, highly weathered yellow	Household Use
GW402438.1.1	-35.463971	149.19178	698884	6073295	776.22	75	75	26/05/2003	TPSL	Topsoil, and clay	Household Use
GW402285.1.1	-35.443879	149.188005	698591	6075531	738.38	66	66	18/12/2002	DCIT	Dacite	Household Use
GW020904.1.1	-35.45483	149.207317	700317	6074277	780.21	19.8	19.8	1/02/1953	PRPR	Porphyry decomposed	Stock water
GW402298.1.1	-35.438405	149.199269	699627	6076116	752.54	85	85	24/03/2003	SHLE	Shale, soft yellow	Household Use
GW401991.1.1	-35.439906	149.199848	699676	6075948	753.75	48	48	5/02/1992	DCIT	Dacite	Stock water
GW063668.1.1	-35.433997	149.211761	700772	6076579	773.01	22.9	22.9	1/09/1986	GRNT	Granite soft bands water supply	Household Use
GW020892.1.1	-35.456775	149.203428	699959	6074069	780.38	20.4	20.4	1/11/1952	CLAY	Clay yellow	Unknown
GW402109.1.1	-35.436553	149.215528	701108	6076288	789.63	23	23	2/12/2002	SHLE	Shale, weathered soft yellow	Household Use
GW400502.1.1	-35.444078	149.187975	698588	6075509	736.75	38	38	23/11/1994	None	Volcanics	Household Use

Hydro Code	Latitude	Longitude	Easting	Northing	Ref Elevation (mAHD)	Bore Depth (m)	Drilled Depth (m)	Drilled Date	Major Lithology	Lithological description	Function Type
GW403097.1.1	-35.444116	149.214394	700986	6075451	808.53	100	100	22/04/2001	TPSL	Topsoil	Household Use
GW403206.1.1	-35.44473	149.207586	700366	6075397	850.52	156	156	13/01/2004	CLAY	Clay	Household Use
GW403582.1.1	-35.449801	149.193442	699070	6074863	756.62	42	42	30/10/2002	SFBD	Soft volcanics	Unknown
GW403149.1.1	-35.43495	149.204271	700090	6076489	773.08	42	42	1/07/2005	SHLE	Shale, brown	Household Use
GW403879.1.1	-35.45677	149.193501	699058	6074090	781.55	71	71	30/10/2006	CLAY	Clay/shale - fine	Household Use
GW404208.1.1	-35.440783	149.191723	698936	6075867	743.04	82	0	7/02/2003	n/a	n/a	Household Use
GW405005.1.1	-35.442774	149.198739	699568	6075632	757.28	66	66	22/09/2008	TPSL	Topsoil	Household Use
GW404566.1.1	-35.465893	149.186025	698357	6073093	775.42	42	0	28/06/1999	n/a	n/a	Household Use
GW404883.1.1	-35.441447	149.196842	699399	6075783	743.22	10	0	1/11/1991	n/a	n/a	Household Use
GW404954.1.1	-35.444451	149.185841	698393	6075472	755.25	102	102	11/12/2008	BSLT	Basalt	Household Use
GW411306.1.1	-35.459158	149.196508	699325	6073819	775.11	36	36	22/04/2010	CLAY	Clay - brown	Stock water
GW409828.1.1	-35.432707	149.206032	700255	6076734	751.92	45	45	20/12/2009	TPSL	Topsoil	Household Use
GW414710.1.1	-35.435691	149.206984	700334	6076401	765.88	60	0	26/11/2002	n/a	n/a	Household Use
GW414353.1.1	-35.470525	149.193577	699031	6072564	783	114	114	11/05/2010	GRNT	Granite, blue	Household Use
GW414415.1.1	-35.433867	149.212607	700849	6076592	778.35	23.5	0	10/09/2010	n/a	n/a	Household Use
GW414765.1.1	-35.460443	149.193788	699075	6073682	775.22	5	0	15/09/2011	n/a	n/a	Household Use

Green shaded bores occur within the project area; orange shaded bores occur within 200 m of the project boundary

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SYSTEM CERTIFICATION ISO 9001 SGS
SYSTEM CERTIFICATION ISO 14001 SGS
SYSTEM CERTIFICATION AS 4801 SGS

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