Australian Government

BUILDING OUR FUTURE

M12 Motorway Environmental Impact Statement

Appendix N Groundwater quality and hydrology assessment report

Roads and Maritime Services | October 2019

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Glossary of terms and abbreviations

Term/Acronym	Meaning
AHD	Australian Height Datum
AIP	Aquifer Interference Policy
ASS	Acid Sulfate Soils
BGL	Below Ground Level
BH	Borehole
BOM	Bureau of Meteorology
BTEXN	Benzene Toluene Ethylbenzene Xylenes and Naphthalene
CEMP	Construction environmental management plan
DPIE	Department of Planning, Industry and Environment
EC	Electrical conductivity
EIS	Environmental Impact Statement
GDE	Groundwater dependent ecosystem
LTAAEL	Long-term average annual extraction limit
NWQMS	National Water Quality Management Strategy
RL	Relative Level
Roads and Maritime	Roads and Maritime Services
SEARs	Secretary's environmental assessment requirements
TDS	Total dissolved solids
TSS	Total suspended solids
WAL	Water access license
WM Act	*Water Management Act 2000 (NSW)*
WM Reg	Water Management Regulation 2018 (NSW)
WQO	Water Quality Objective
WSP	Water Sharing Plan

Executive summary

Background

Roads and Maritime Services (Roads and Maritime) is seeking approval under Part 5, Division 5.2 of the *Environmental Planning and Assessment Act 1979* (EP&A Act) to construct and operate the M12 Motorway project to provide direct access between the Western Sydney Airport at Badgerys Creek and Sydney's motorway network (the project). The project has been determined to be a controlled action under Section 75 of the *Environment Protection and Biodiversity Conservation Act 1999* (Commonwealth) (EPBC Act) for significant impact to threatened species and communities (Section 18 and Section 18A of the EPBC Act). As such, the project requires assessment and approval from the Commonwealth Government.

The M12 Motorway would run between the M7 Motorway at Cecil Hills and The Northern Road at Luddenham for a distance of about 16 kilometres and would be opened to traffic prior to opening of the Western Sydney Airport.

Purpose of this report

This report has been prepared to support the environmental impact statement (EIS) for the M12 Motorway project. The EIS has been prepared to address the Secretary's Environmental Assessment Requirements (SEARs) for the project (SSI 9364) and to enable the Minister for Planning and Public Spaces and the Commonwealth Minister for the Environment to make a determination on whether the project can proceed. The report presents an assessment of the construction and operational activities for the project that have the potential to impact on groundwater.

This groundwater assessment was undertaken by considering:

- The existing environmental conditions and values
- The potential impacts from the project on groundwater systems
- Appropriate monitoring and mitigation measures to ensure potential impacts are addressed.

A dewatering assessment was undertaken to estimate potential groundwater inflows (seepage) and subsequent potential drawdown which could occur if road cuttings extend below the water table. As dewatering of cuts beneath the water table is a potential cause of changes to groundwater flows, volumes and levels, this dewatering assessment forms a key part of this groundwater impact assessment.

Overview of potential impacts

The project is assessed to have minimal potential to directly interact with groundwater systems, with direct potential interaction expected to be limited to:

- One road cutting (cut) that is located approximately 1.5 kilometres east of The Northern Road which may intersect the water table by up to about 1.6 metres over a distance of about 250 metres. This cut is referred to as the 'western cut' in this report.
- Bridge footings, where piles are drilled below the water table.

Potential groundwater inflows from the western cut are assessed to be very low (maximum of 6.75 kilolitres per day) with minimal (about 1.6 metres at cut face and extent of influence of about 60 metres) accompanying groundwater level drawdown predicted. Negligible impacts to groundwater are anticipated to occur due to dewatering of the western cut.

Due to exemptions, a Water Access License (WAL) is not required to license potential groundwater inflows from the western cut. However, for the purpose of informing water accounting, a take of 2.46 megalitres per year is considered appropriate and conservative.

Groundwater quality at the bore (BH104) representative of the western cut had copper and zinc concentrations above the ANZECC/ARMCANZ (2000) trigger values for the protection of 95 per cent of freshwater species. However, the water quality at this location does not indicate a risk to human health, nor are impacts anticipated to occur due to intercepted groundwater from the cut being discharged to surface water.

Changes to water table levels in areas where bridge footings extend beneath the water table are qualitatively predicted to be minor and localised. Such changes are not expected to affect the local groundwater flow system or alter groundwater-surface water exchange in the region of the creeks, as piled footings would readily accommodate local groundwater flow diversion around the pile.

Groundwater contamination risks represent a low risk.

The contribution of the project to cumulative groundwater and hydrology impacts in the region, when considered collectively with impacts from surrounding projects such as the Western Sydney Airport, The Northern Road Upgrade, Metro Western Sydney Airport and major subdivisions and land releases, would be negligible. Nevertheless, as a collective, these projects may lead to reduced groundwater levels due to reduced recharge associated with increased impervious area, and potentially altered groundwater recharge chemistry, such as increased nutrient concentrations as a result of urban run-off.

The quality of surface water runoff from the project during the operational phase is anticipated to improve compared to existing conditions at all sensitive receiving waterways. Therefore, the potential for adverse groundwater quality impacts from infiltration of surface water runoff during operation is negligible.

Summary of environmental management measures

Risks associated with accidental spills or leakages of hazardous materials (such as fuels, lubricants and hydraulic oils), including subsequent risk of groundwater contamination, during the construction and operational phase of the project, will be managed through the construction environmental management plan (CEMP) and the implementation of the environmental management measures outlined in Appendix M and Appendix O of the EIS.

A groundwater monitoring program will be implemented to observe any changes in groundwater quality and levels that may be caused by the project and inform appropriate management responses. The monitoring program will include collection of baseline data for comparison to construction and operational monitoring data to understand, and respond to, any impacts from the project.

Conclusions

Based on a detailed review of baseline groundwater level and quality data, along with an analysis of the existing environmental setting and an assessment of the proposed alignment, the project is expected to generate negligible impacts on groundwater quality, flow and levels.

1. Introduction

1.1 Background

Roads and Maritime Services (Roads and Maritime) is seeking approval under Part 5, Division 5.2 of the *Environmental Planning and Assessment Act 1979* (EP&A Act) to construct and operate the M12 Motorway project to provide direct access between the Western Sydney Airport at Badgerys Creek and Sydney's motorway network (the project). In addition, the project has been determined to be a controlled action under Section 75 of the *Environment Protection and Biodiversity Conservation Act 1999* (Commonwealth) (EPBC Act) (EPBC 2018/8286) for significant impact to threatened species and communities (Section 18 and Section 18A of the EPBC Act). As such, the project requires assessment and approval from the Commonwealth Government.

The M12 Motorway would run between the M7 Motorway at Cecil Hills and The Northern Road at Luddenham for a distance of about 16 kilometres and would be opened to traffic prior to opening of the Western Sydney Airport. The project would commence about 30 kilometres west of the Sydney central business district, at its connection with the M7 Motorway. The project traverses the local government areas of Fairfield, Liverpool and Penrith. The suburbs of Cecil Park and Cecil Hills are found to the east of the M12 Motorway, with Luddenham to the west.

The project is predominately located in greenfield areas. The topography in and around the project comprises rolling hills and small valleys between generally north–south ridge lines. The existing land uses are semi-rural residential, recreational, agricultural, commercial and industrial. The main residential areas are Kemps Creek, Mount Vernon and Cecil Hills.

The project is required to support the opening of the Western Sydney Airport by connecting Sydney's motorway network to the airport. The project would also serve and facilitate the growth and development of the western Sydney which is expected to undergo significant development and land use change over the coming decades. The motorway would provide increased road capacity and reduce congestion and travel times in the future and would also improve the movement of freight in and through western Sydney.

The project location is shown in **Figure 1-1** in relation to its regional context.

1.2 Project overview

The project would include the following key features:

- A new dual-carriageway motorway between the M7 Motorway and The Northern Road with two lanes in each direction with a central median allowing future expansion to six lanes
- Motorway access via three interchanges/intersections:
  - A motorway-to-motorway interchange at the M7 Motorway and associated works (extending about four kilometres within the existing M7 Motorway corridor)
  - A grade separated interchange referred to as the Western Sydney Airport interchange, including a dual-carriageway four lane airport access road (two lanes in each direction for about 1.5 kilometres) connecting with the Western Sydney Airport Main Access Road
  - A signalised intersection at The Northern Road with provision for grade separation in the future
- Bridge structures across Ropes Creek, Kemps Creek, South Creek, Badgerys Creek and Cosgroves Creek
- Bridge structure across the M12 Motorway into Western Sydney Parklands to maintain access to the existing water tower and mobile telephone/other service towers on the ridgeline in the vicinity of Cecil Hills, to the west of the M7 Motorway

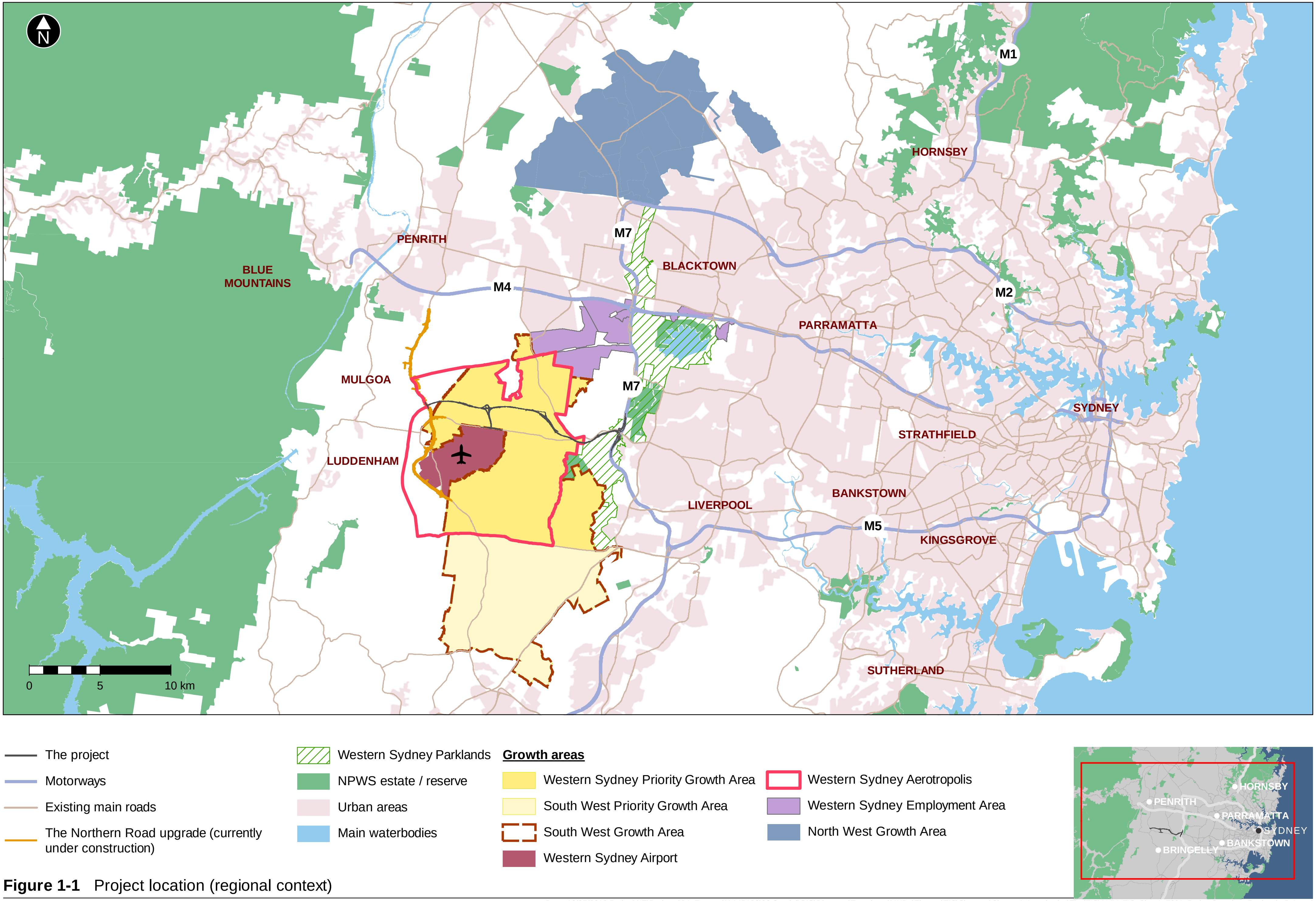

Figure 1-1 Project location (regional context)

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- Bridge structures at interchanges and at Clifton Avenue, Elizabeth Drive, Luddenham Road and other local roads to maintain local access and connectivity
- Inclusion of active transport (pedestrian and cyclist) facilities through provision of pedestrian bridges and an off-road shared user path including connections to existing and future shared user path networks
- Modifications to the local road network, as required, to facilitate connections across and around the M12 Motorway including:
  - Realignment of Elizabeth Drive at the Western Sydney Airport, with Elizabeth Drive bridging over the airport access road and future passenger rail line to the airport
  - A realignment of Clifton Avenue over the M12 Motorway, with associated adjustments to nearby property access
  - Relocation of Salisbury Avenue cul-de-sac, on the southern side of the M12 Motorway
  - Realignment of Wallgrove Road north of its intersection with Elizabeth Drive to accommodate the M7 Motorway northbound entry ramp
- Adjustment, protection or relocation of existing utilities
- Ancillary facilities to support motorway operations, smart motorways operation in the future and the existing M7 Motorway operation, including gantries, electronic signage and ramp metering
- Other roadside furniture including safety barriers, signage and street lighting
- Adjustments of waterways, where required, including Kemps Creek, South Creek and Badgerys Creek
- Permanent water quality management measures including swales and basins
- Establishment and use of temporary ancillary facilities, temporary construction sedimentation basins, access tracks and haul roads during construction
- Permanent and temporary property adjustments and property access refinements as required

The project overview presented in this document represents the design outlined in the M12 Motorway EIS. If the project is approved, a further detailed design process would follow, which may include variations to the design. Flexibility has been provided in the design to allow for refinement of the project during detailed design, in response to any submissions received following the exhibition of the environmental impact statement (EIS), or if opportunities arise to further minimise potential environmental impacts.

The key features of the project are shown on **Figure 1-2**.

1.2.1 Key features of project description related to groundwater

Cuttings and embankments

Cuttings would generally have a slope of three (horizontal) to one (vertical) (about 18 degrees). Through Western Sydney Parklands the slope of cuttings is increased to two (horizontal) to one (vertical). Benches (flat steps in the slope) are provided at regular intervals to improve stability.

Embankments would have a slope of four (horizontal) to one (vertical) (about 14 degrees) up to a height of 2.5 metres. Where embankment height exceeds 2.5 metres the slope is steepened to two (horizontal) to one (vertical) (about 26 degrees) with benches provided at regular intervals to improve stability.

The cuttings are subject to change following geotechnical analysis and design development. The location and dimension of cuttings, retaining walls and embankments would be confirmed during detailed design. Deep cuttings and high embankment fills are not proposed along local roads. Cuttings would range in depth with the deepest cut expected to be about 15 metres. Embankments would range in height up to about 13 metres.

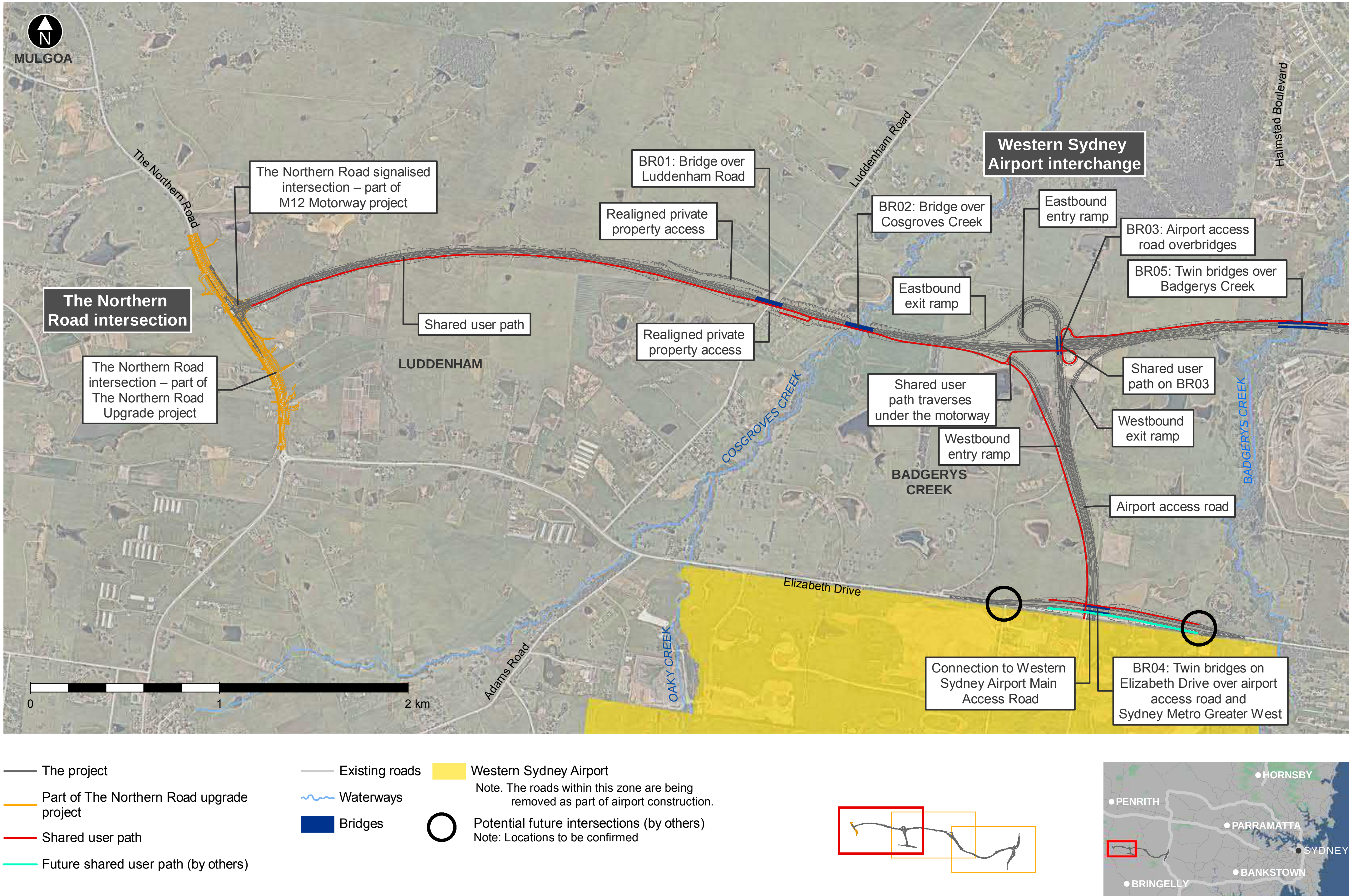

Figure 1-2 Key features of the project

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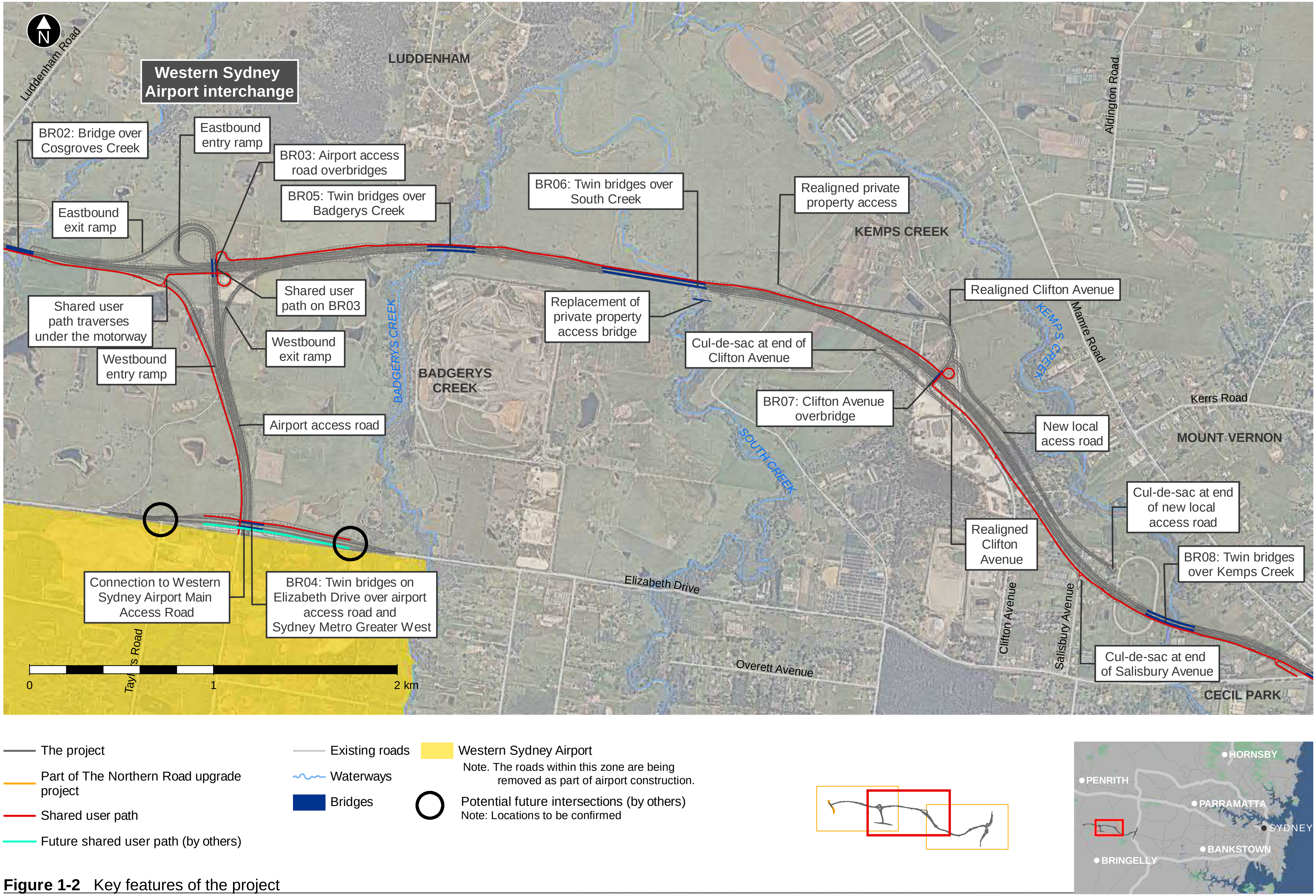

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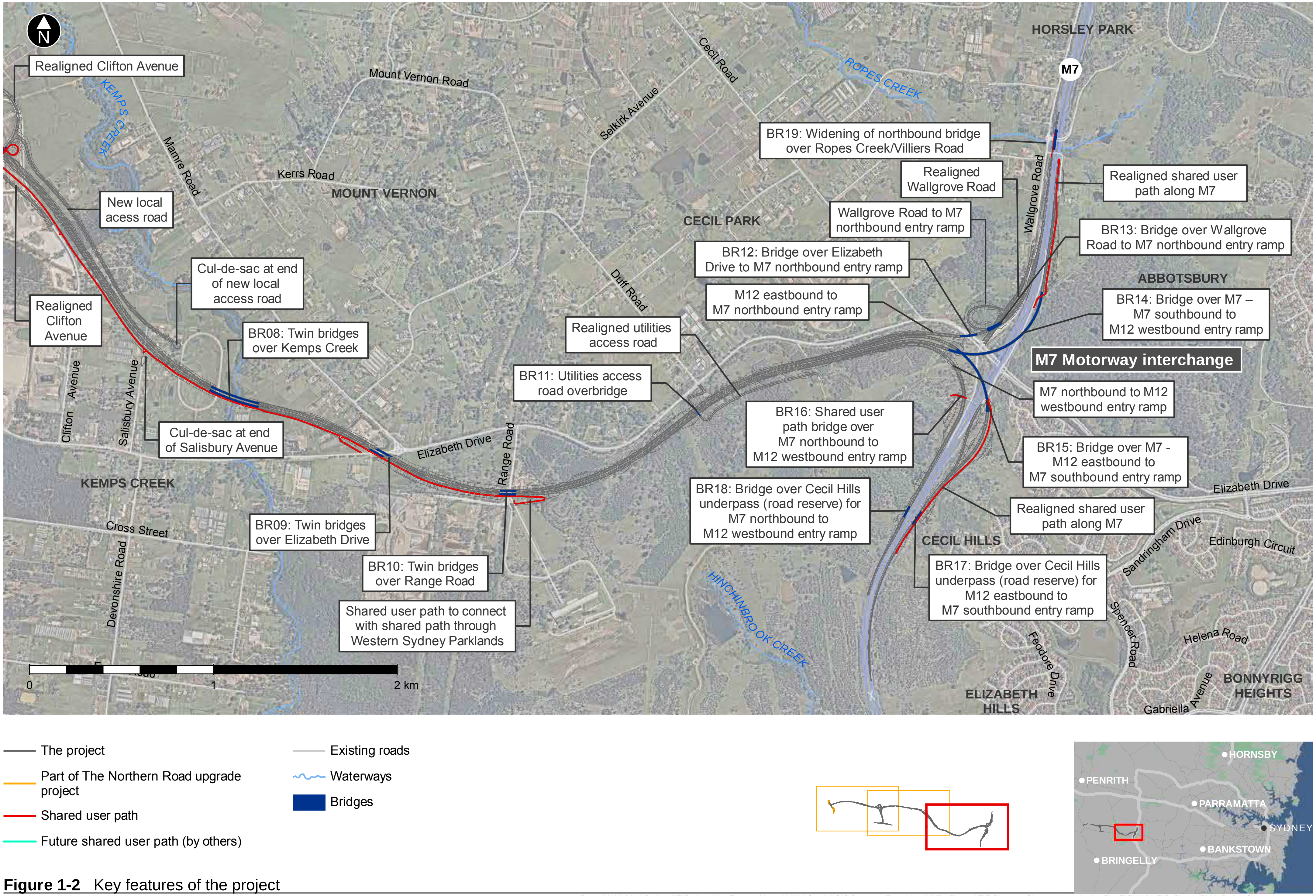

Figure 1-2 Key features of the project

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Bridges

The project would include 18 new bridge sites along the length of the motorway and one widening of an existing bridge (at Ropes Creek). Bridges relevant to this groundwater assessment include the bridges which span the project's major creeks. These include bridges which have been assigned bridge reference BR02 (over Cosgroves Creek), BR05 (twin bridges over Badgerys Creek), BR06 (twin bridges over South Creek) and BR08 (twin bridges over Kemps Creek). These bridges range in length from about 140 metres to 560 metres, have been designed as multi-span precast concrete Super-T girder structures and have all been designed to have openings to accommodate flooding.

1.3 Purpose and scope of this report

This report has been prepared to support the EIS for the project. The EIS has been prepared to address the Secretary's Environmental Assessment Requirements (SEARs) for the project (SSI 9364), as well as the Australian Government assessment requirements under the EPBC Act. The EIS for the project provides sufficient information to enable the NSW Minister for Planning and Public Spaces and the Commonwealth Minister for the Environment to make a determination on whether the project can proceed. The report presents an assessment of the construction and operational activities for the project that have the potential to impact on groundwater.

The scope of the report is generally limited to groundwater and primary objectives are to:

- Summarise proposed development details that are relevant to groundwater
- Summarise key legislation and policy relevant to groundwater
- Summarise the local geological and hydrogeological setting
- Outline and assess potential groundwater related impacts which may arise due to the project
- Where required, outline measures to mitigate potential groundwater related impacts which may arise due to the project
- Outline a brief groundwater monitoring program for the project.

1.4 SEARs

On 18 June 2018, the Secretary of the NSW Department of Planning, Industry and Environment (DPIE) (Planning and Assessment) issued to Roads and Maritime the draft Secretary's environmental assessment requirements (SEARs) for the M12 Motorway EIS. The SEARS were finalised and reissued on 12 July 2018. The project was then determined to be a controlled action under the EPBC Act, and updated SEARs were issued on 30 October 2018 that include the Commonwealth assessment requirements under the EPBC Act. **Table 1-1** lists those requirements relating specifically to the assessment of the project's potential impacts on groundwater, with a reference to the chapter or section of this report where each requirement is addressed.

Table 1-1 SEARs (groundwater and hydrology)

Secretary's requirement	Where addressed
14. Water - Hydrology	
1. The Proponent must describe (and map) the existing hydrological regime for any surface and groundwater resource (including reliance by users and for ecological purposes) likely to be impacted by the project, including stream orders, as per the FBA.	**Section 4.3**, **Section 4.9 and Section 4.11,** and Appendix M of the EIS
2. The Proponent must prepare a detailed water balance for ground and surface water including the proposed intake and discharge locations, volume, frequency and duration.	The project does not involve the use of groundwater and potential groundwater inflow volumes to project road cuttings are negligible (**Section 5.1.1** and **Section 5.2.1**), therefore, the water balance applies only to surface water and is addressed in Appendix M of the EIS
3. The Proponent must assess (and model if appropriate) the impact of the construction and operation of the project and any ancillary facilities (both built elements and discharges) on surface and groundwater hydrology in accordance with the current guidelines, including: (a) natural processes within rivers, wetlands, estuaries, marine waters and floodplains that affect the health of the fluvial, riparian, estuarine or marine system and landscape health (such as modified discharge volumes, durations and velocities), aquatic connectivity and access to habitat for spawning and refuge;	**Section 5** and Appendix M of the EIS
(b) impacts from any permanent and temporary interruption of groundwater flow, including the extent of drawdown, barriers to flows, implications for groundwater dependent surface flows, ecosystems and species, groundwater users and the potential for settlement;	**Section 5.1.2**, **Section 5.1.6, Section 5.2.2 and Section 5.2.6**
(c) changes to environmental water availability and flows, both regulated/licensed and unregulated/rules-based sources;	**Section 5.1.1, Section 5.2.1, Section 5.1.6**, **Section 5.2.6** and Appendix M of the EIS
(d) direct or indirect increases in erosion, siltation, destruction of riparian vegetation or a reduction in the stability of river banks or watercourses;	Appendix M of the EIS
(e) minimising the effects of proposed stormwater and wastewater management during construction and operation on natural hydrological attributes (such as volumes, flow rates, management methods and re-use options) and on the conveyance capacity of existing stormwater systems where discharges are proposed through such systems; and	Appendix M of the EIS
(f) water take (direct or passive) from all surface and groundwater sources with estimates of annual volumes during construction and operation.	**Section 5.1.8** and **Section 5.2.8**
4. The Proponent must identify any requirements for baseline monitoring of hydrological attributes.	Baseline monitoring results are outlined in **Section 7.2**

Secretary’s requirement	Where addressed
15. Water – quality	
1. The Proponent must: (a) state the ambient NSW Water Quality Objectives (NSW WQO) and environmental values for the receiving waters relevant to the project, including the indicators and associated trigger values or criteria for the identified environmental values;	**Section 3.5** and Appendix M of the EIS
(b) identify and estimate the quality and quantity of all pollutants that may be introduced into the water cycle by source and discharge point and describe the nature and degree of impact that any discharge(s) may have on the receiving environment, including consideration of all pollutants that pose a risk of non-trivial harm to human health and the environment;	**Section 5.1.1, Section 5.1.3, Section 5.1.10, Section 5.2.1, Section 5.2.3, Section 5.2.10** and Appendix M of the EIS
(c) identify the rainfall event that the water quality protection measures will be designed to cope with;	Appendix M of the EIS
(d) assess the significance of any identified impacts including consideration of the relevant ambient water quality outcomes;	**Section 5.1.3, Section 5.1.10, Section 5.2.3, Section 5.2.10, Section 5.3** and Appendix M of the EIS
(e) demonstrate how construction and operation of the project will, to the extent that the project can influence, ensure that: • where the NSW WQOs for receiving waters are currently being met they will continue to be protected; and	**Section 3.5, Section 5.1.3, Section 5.1.10, Section 5.2.3, Section 5.2.10, Section 5.3** and Appendix M of the EIS
• where the NSW WQOs are not currently being met, activities will work toward their achievement over time;	**Section 3.5, Section 5.3** and Appendix M of the EIS
(f) justify, if required, why the WQOs cannot be maintained or achieved over time;	**Section 3.5 Section 5.3, Section 5.1.3, Section 5.2.3,** and Appendix M of the EIS
(g) demonstrate that all practical measures to avoid or minimise water pollution and protect human health and the environment from harm are investigated and implemented;	**Sections 5.1.10, Section 5.2.10, Section 5.3, Section 7** and Appendix M of the EIS
(h) identify sensitive receiving environments (which may include estuarine and marine waters downstream) and develop a strategy to avoid or minimise impacts on these environments; and	**Section 4.9.6, Section 5.1.10, Section 5.2.10, Section 7** and Appendix M of the EIS
(i) identify proposed monitoring locations, monitoring frequency and indicators of surface and groundwater quality.	Baseline monitoring results are outlined in **Section 4.9.2** and **Section 4.9.5** and a groundwater monitoring program for construction and operation is outlined in **Section 7.2**
17. Soils	
1. The Proponent must verify the risk of acid sulfate soils (Class 1, 2, 3 or 4 on the Acid Sulfate Soil Risk Map) within, and in the area likely to be impacted by, the project.	**Section 4.7**
2. The Proponent must assess the impact of the project on acid sulfate soils (including impacts of acidic runoff offsite) in accordance with the current guidelines.	**Section 4.7**
3. The Proponent must assess whether the land is likely to be contaminated and identify if remediation of the land is required, having regard to the ecological and human health	**Sections 5.1.10, Section 5.2.10** and **Appendix O** of the EIS

Secretary’s requirement	Where addressed
risks posed by the contamination in the context of past, existing and future land uses. Where assessment and/or remediation is required, the Proponent must document how the assessment and/or remediation would be undertaken in accordance with current guidelines.	
4. The Proponent must assess whether salinity is likely to be an issue and if so, determine the presence, extent and severity of soil salinity within the project area.	**Section 4.6, Section 5.1.9** and **Section 5.2.9**
5. The Proponent must assess the impact of the project on soil salinity and how it may affect groundwater resources and hydrology.	**Section 4.6, Section 5.1.9** and **Section 5.2.9**

2. Policy and planning setting

2.1 Water Act 1912, Water Management Act 2000 and Water Management Regulation 2018

Water resources in NSW are administered under the *Water Act 1912* and the *Water Management Act 2000* (WM Act) by the Regions, Industry, Agriculture & Resources Group of the DPIE (RIAR). The WM Act governs the issue of water access licences and approvals for those water sources (rivers, lakes, estuaries and groundwater) in NSW where water sharing plans (WSP) have commenced. The WSP for the study area has commenced, and the area is therefore governed under the WM ACT (see **Section 2.2**).

In accordance with section 5.23(1) of the EP&A Act, the following approvals, which may have otherwise been required to undertake the project, would not be required for approved State significant infrastructure:

- Water use approval under section 89 of the WM Act
- Water management work approval (including a water supply works approval) under section 90 of the WM Act
- Activity approval under section 91 of the WM Act.
- Under Schedule 4 1(2) of the Water Management Regulation 2018 (WM Reg), road authorities are exempt from the need for a WAL.

2.2 Water sharing plan

Numerous WSPs are established throughout NSW for both surface water and groundwater. The purpose of a water sharing plan is to provide water users with a clear picture of when and how water will be available for extraction, protect the fundamental environmental health of the water source and ensure the water source is sustainable in the long-term. WSPs are sometimes subdivided into subset areas, referred to as ‘sources’, based on groundwater system characteristics.

The project is located in the area covered by the Water Sharing Plan for the Greater Metropolitan Region Groundwater Sources 2011 (NSW Government, 2015), and is within the Sydney Basin Central Groundwater Source.

Within the applicable WSP source, according to the NSW Water Register (Water NSW, 2019), as of May 2019 there are currently 162 groundwater access licences, with a total licensed volume of 3429 megalitres per year. The long-term average annual extraction limit (LTAAEL) for the Sydney Basin Central water source is 45,915 megalitres per year (NSW Government, 2015), which is 25 per cent of the estimated annual recharge for the area. As such, there is currently up to 42,486 megalitres per year of water available under the LTAAEL (correct as of May 2019). These volumes are relevant to the project as collectively they demonstrate that large volumes of unallocated groundwater exists. Whilst the project does not require a WAL, if the project were to result in groundwater extraction, the extraction volume can be placed into context with regards to water availability.

2.3 NSW Aquifer Interference Policy (2012)

The NSW Aquifer Interference Policy (AIP) (DPI NOW, 2012) outlines minimal impact considerations for water table and groundwater pressure drawdown for high priority groundwater dependent ecosystems (GDEs), as identified in the WSP, high priority culturally significant sites (as identified in the WSP) and existing groundwater supply bores. Water quality impact considerations are also outlined.

In accordance with the AIP, the project is situated within a ‘less productive groundwater source’ on the basis of low water supply bore numbers, expected low yields and expected moderate to high salinity, for which the following minimal impact considerations apply:

- A maximum cumulative pressure head or water table decline of two metres at any bore. If this condition cannot be met, then appropriate studies will need to demonstrate to the Minister’s satisfaction that decline in head will not prevent the long-term viability of the affected water supply works unless make good provisions apply.
- Any change in groundwater quality should not lower the beneficial use category of the groundwater source beyond 40 metres from the activity. If this condition cannot be met, then appropriate studies will need to demonstrate to the Minister’s satisfaction that the change in groundwater quality will not affect the long-term viability of the dependent ecosystem.

The term ‘beneficial use category’ is synonymous with the term ‘environmental value’, which is defined as values or uses of the groundwater that support aquatic ecosystems, primary industries, recreation and aesthetics, drinking water, industrial water, and cultural and spiritual values (ANZECC/ARMCANZ, 2000a).

Impact limits to high priority GDEs and culturally significant sites as outlined in the AIP are not applicable for the project as high priority GDEs and culturally significant sites are not mapped within approximately 10 kilometres of the project.

Potential groundwater level impacts at surrounding bores are assessed in **Section 5.1.5** and **Section 5.2.5** whilst potential impacts to groundwater quality are assessed in **Section 5.1.3** and **Section 5.2.3**. Demonstrated compliance with the AIP minimal impact considerations is summarised in **Section 5.3**.

2.4 Groundwater Dependent Ecosystems Policy

The NSW State Groundwater Dependent Ecosystems Policy (Department of Land and Water Conservation, 2002a) implements the WM Act by providing guidance on the protection and management of GDEs. It sets out management objectives and principles to:

- Ensure that the most vulnerable and valuable ecosystems are protected
- Manage groundwater extraction within defined limits thereby providing flow sufficient to sustain ecological processes and maintain biodiversity
- Ensure that sufficient groundwater of suitable quality is available to ecosystems when needed
- Ensure that the precautionary principle is applied to protect GDEs, particularly the dynamics of flow and availability and the species reliant on these attributes
- Ensure that land use activities aim to minimise adverse impacts on GDEs.

The above objectives and principles are upheld through the groundwater assessment’s criteria (**Section 3.5**), which included the AIP minimal impact considerations.

2.5 National Water Quality Management Strategy

The National Water Quality Management Strategy (NWQMS) (Australian Government, 2000) is the adopted national approach to protecting and improving water quality in Australia. It consists of a number of guideline documents, of which certain documents relate to protection of surface water resources and others relate to the protection of groundwater resources.

The primary document relevant to the assessment of groundwater risks for the project is the Guidelines for Groundwater Quality Protection in Australia (Australian Government, 2013). This document sets out a high-level risk-based approach to protecting or improving groundwater quality for a range of groundwater beneficial uses (called ‘environmental values’), including aquatic ecosystems, primary industries (including irrigation and general water users, stock drinking water, aquaculture and human consumption of aquatic foods), recreational and aesthetic values (eg swimming, boating and aesthetic appeal of water bodies), drinking water, industrial water and cultural values.

For the purpose of this assessment, ‘environmental values’ pertaining to aquatic ecosystems, primary industries, industrial water, and cultural values are considered potentially applicable. ‘Environmental values’ pertaining to drinking water are not applicable due to poor groundwater quality (**Section 4.9.5**). Values pertaining to recreational and aesthetic values are considered not applicable as the creeks that the project crosses, which may be fed by groundwater baseflow at times, are not used for these purposes in the area of the project.

There are no high priority culturally significant sites listed in the schedule of the WSP. Historically, a natural spring fed watercourse located about 300 metres east of Badgerys Creek within the project construction and operational footprints may have been an important water source for past communities during the drier cycles of seasonal variation (Appendix I of the EIS). This natural spring has now been in-filled by land practices. Therefore, cultural values are not considered applicable to the project.

3. Assessment methodology

3.1 Overview

The assessment of potential groundwater related impacts arising from project has been implemented as follows:

- Characterisation of the existing environment including climate, topography, geology, and groundwater occurrence, quality and use, including groundwater dependent ecosystems (GDEs)
- Dedicated field investigations including drilling, permeability testing, monitoring bore installation, and groundwater level and quality monitoring
- Creation of a conceptual groundwater model
- Establishment of groundwater impact assessment criteria
- Assessment of the project's potential to interfere with the water table and underlying groundwater systems
- Estimation of groundwater inflows into project cuts and associated groundwater level drawdown extents
- Assessment of potential groundwater related impacts against the minimal impact considerations of the AIP (**Section 2.3**) and to address groundwater related issues raised in the SEARs (**Section 1.4**)
- Recommendations for monitoring and management of identified impacts and risks, including mitigation measures as appropriate.

The specific methodologies used for these components of the methodology are described in the following sections.

3.2 Study area

The 'groundwater study area' (**Figure 3-1**) that was used to inform the groundwater impact assessment included the project construction footprint and a two kilometre buffer with the exception of a discrete location to the west of the construction footprint. At this location, the buffer was extended to about three kilometres to capture an existing bore in Luddenham (bore GW108933.1.1).

3.3 Desktop assessment

Raw data is collected to enable characterisation of existing groundwater conditions across the study area. Sources included:

- The Bureau of Meteorology's (BOM) Australian Groundwater Explorer (BOM, 2018a) is reviewed to investigate registered groundwater bores and associated groundwater level records in the region of the project
- The BOM's Groundwater Dependent Ecosystem (GDE) Atlas (BOM, 2018b) is reviewed to investigate the potential for GDEs to exist within the study area
- Rainfall data from gauging stations in/around the study area, from the BOM (BOM, 2018c)
- The Water Register (http://www.water.nsw.gov.au/water-licensing/registers) for data on existing groundwater users, including Water Access Licence (WAL) holders and stock and domestic users.

Publicly available maps are also used, including geological maps, topography and drainage maps and soil maps.

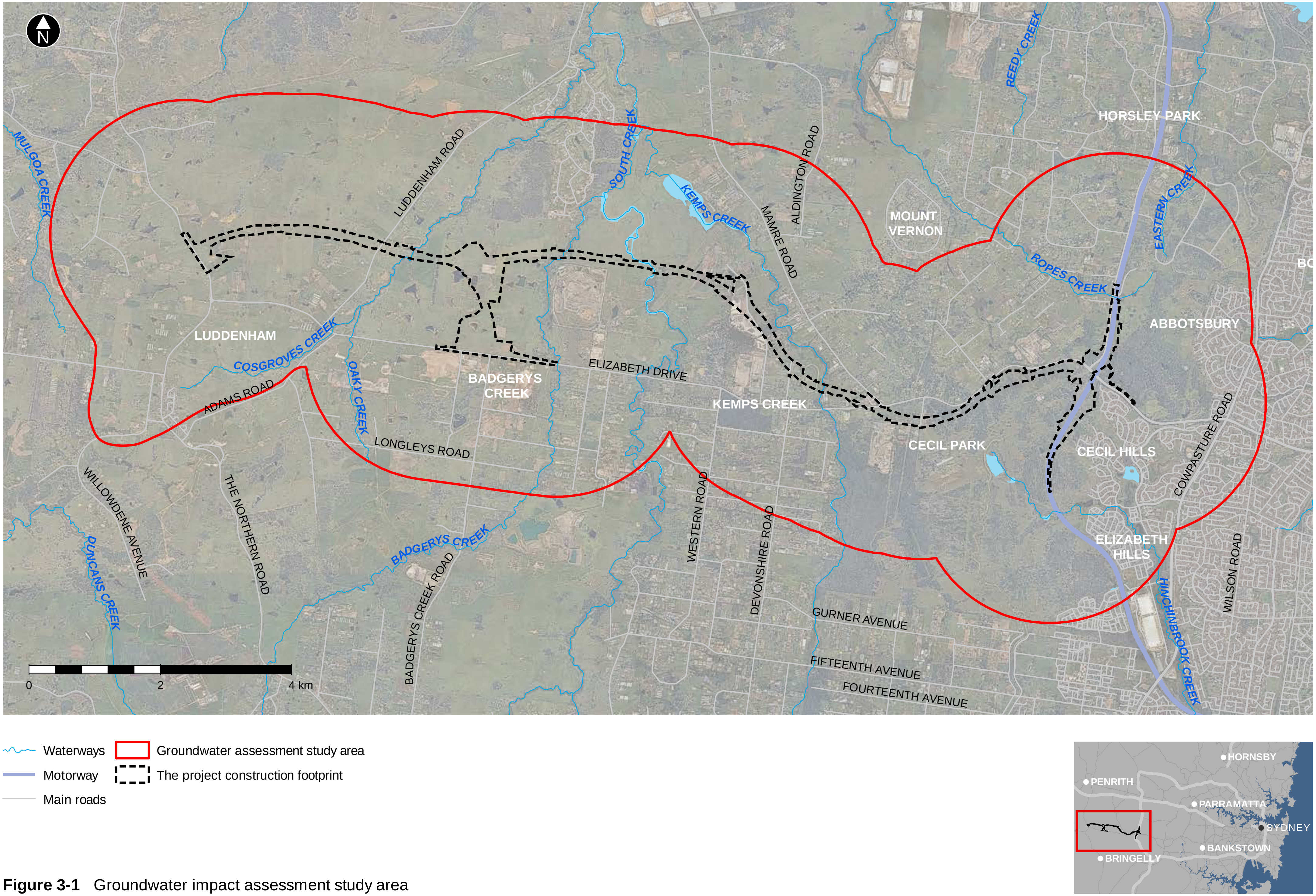

Figure 3-1 Groundwater impact assessment study area

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3.4 Site investigations

3.4.1 Drilling program

For the purpose of informing geotechnical design, a contamination assessment and this hydrogeological assessment, geotechnical drilling was carried out as part of project investigations. The drilling program incorporated 31 project groundwater monitoring bores. Project groundwater monitoring bore locations are shown in **Figure 3-2**.

3.4.2 Groundwater level and quality monitoring

Project groundwater monitoring bores were subject to groundwater level and quality sampling.

Hydraulic testing through slug tests was undertaken at five of the project monitoring bores. The location of the five project monitoring bores where hydraulic conductivity was undertaken is demonstrated in **Figure 3-3**.

The location of the 25 project groundwater monitoring bores that produced groundwater level logger data that was used in the assessment, and the three project bores where manual dip data is used is shown in **Figure 3-4**.

The locations of the 10 project groundwater monitoring bores that were selected for groundwater quality sampling are demonstrated in **Figure 3-5**.

Further information on groundwater monitoring locations, groundwater levels and groundwater quality results are provided in **Section 4.9.1, Section 4.9.2** and **Section 4.9.5** respectively.

3.5 Criteria

3.5.1 Groundwater quality objective and assessment criteria

Overview

Although primarily applicable to surface water, as identified in the SEARs the desired performance outcome (item 15) for the project in relation to water quality is that:

> *“The project is designed, constructed and operated to protect the NSW Water Quality Objectives where they are currently being achieved, and contribute towards achievement of the Water Quality Objectives over time where they are currently not being achieved, including downstream of the project to the extent of the project impact including estuarine and marine waters (if applicable)”.*

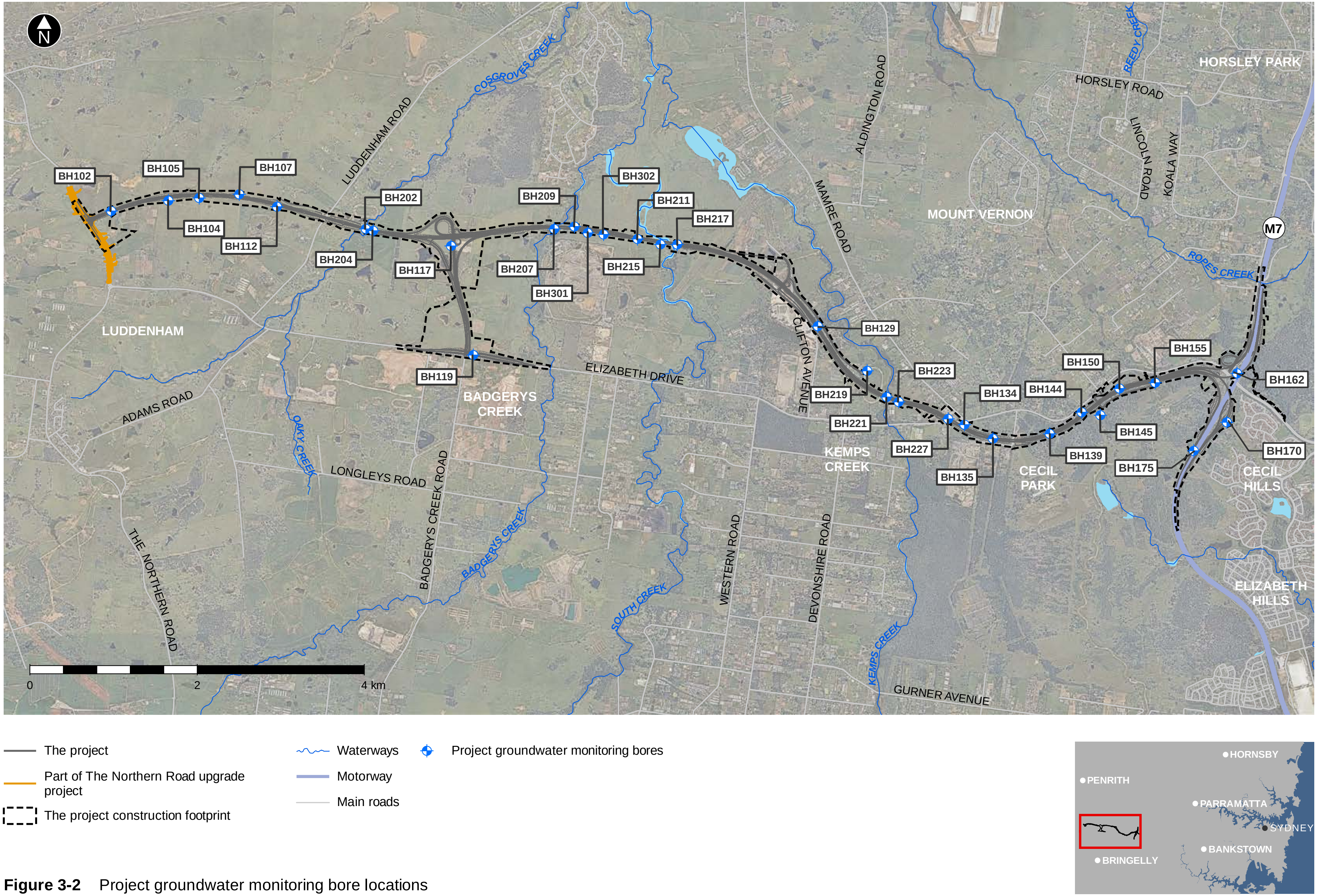

Figure 3-2 Project groundwater monitoring bore locations

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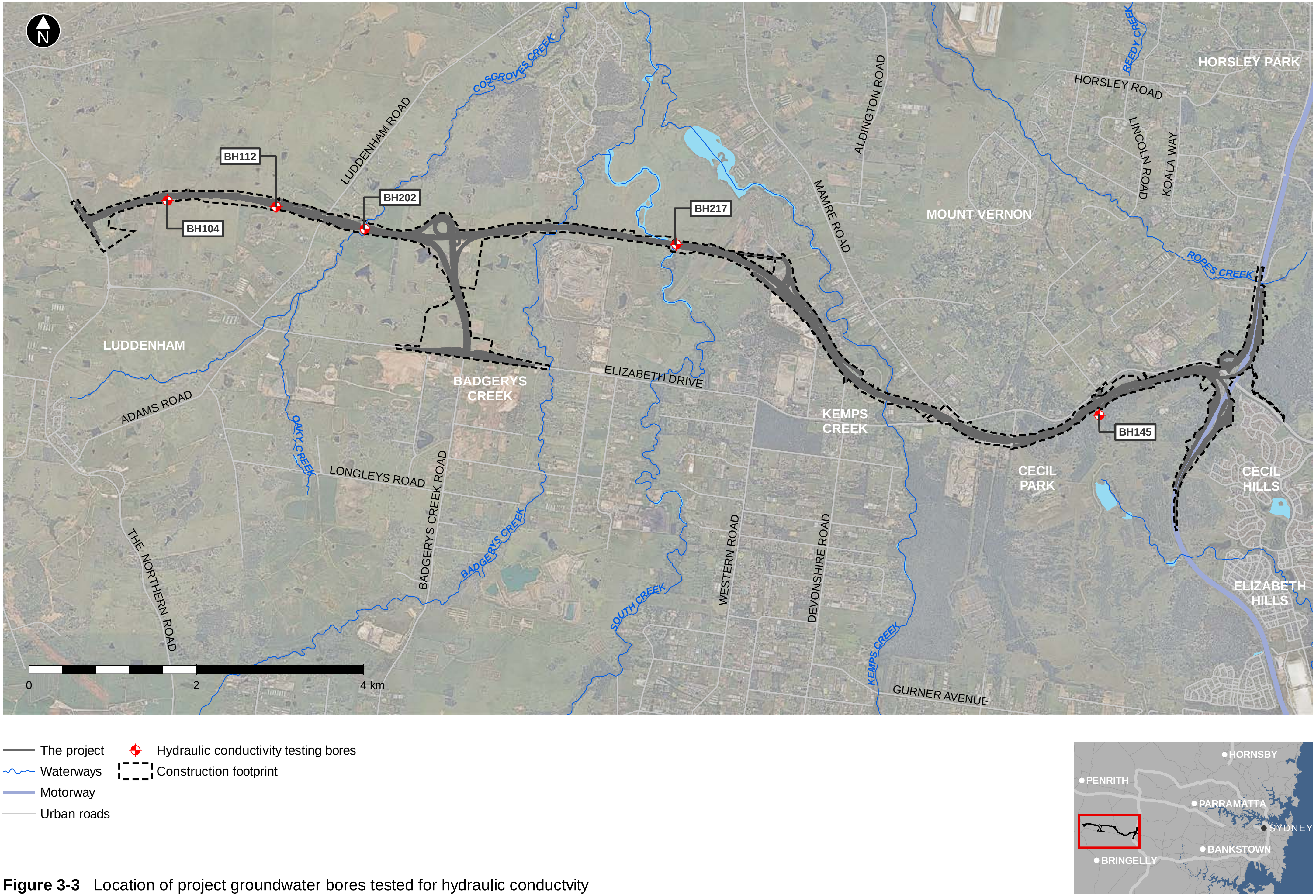

Figure 3-3 Location of project groundwater bores tested for hydraulic conductvity

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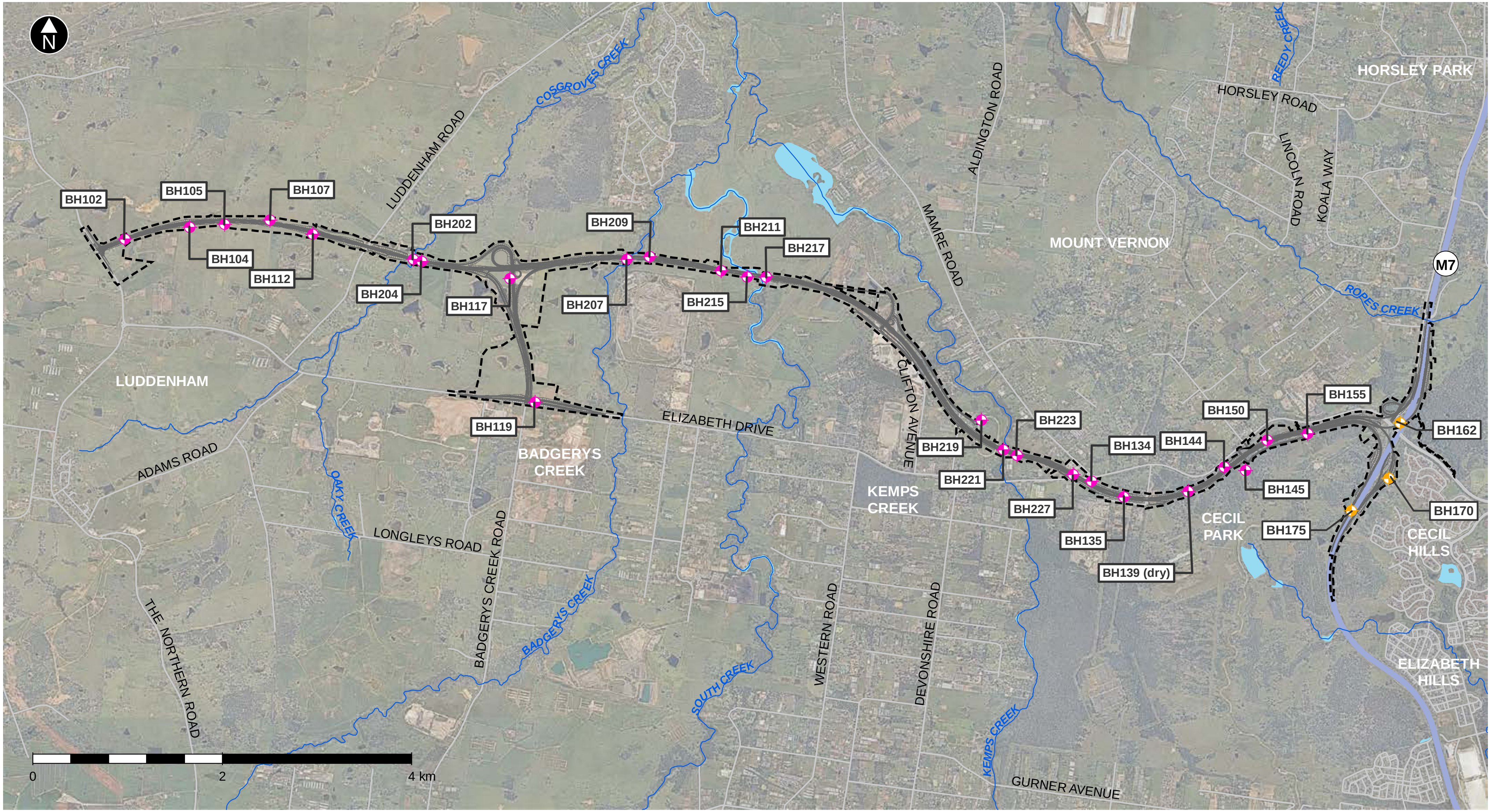

Figure 3-4 Location of project groundwater bores used for groundwater level monitoring

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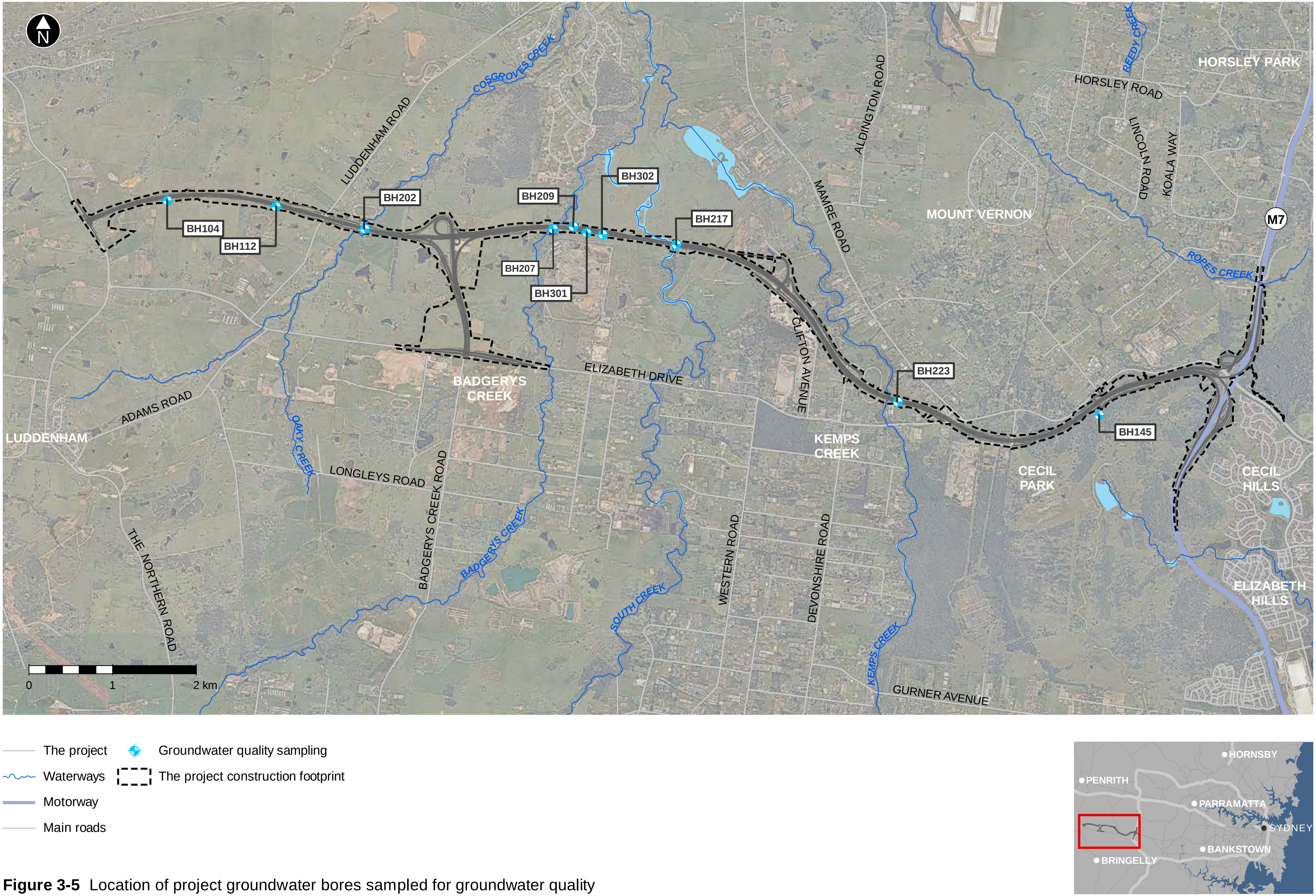

Figure 3-5 Location of project groundwater bores sampled for groundwater quality

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Project groundwater quality objective

In line with the desired performance outcome for water quality quoted above, the groundwater quality objective for the project is to ensure design, construction and operation of the project has a neutral or beneficial effect to groundwater quality.

For the purpose of this assessment, a neutral or beneficial effect to groundwater quality is defined as an effect that does not lower the beneficial use category of the groundwater system, or an effect that raises the beneficial use category of the groundwater system.

Groundwater quality assessment criteria

The project is located primarily within the Hawkesbury-Nepean catchment. NSW Water Quality Objectives (WQOs) were not developed for the Hawkesbury-Nepean catchment, because at the time WQOs were approved by the government for catchments across NSW (September 1999), the Hawkesbury- Nepean was subject to an independent inquiry by the Healthy Rivers Commission (HRC).

The HRC inquiry determined water quality objectives that recognise the communities 'environmental values' and uses of the waterways. These water quality objectives were agreed to by the NSW Government through a statement of Joint Intent in 2001. Existing groundwater quality in this assessment is therefore compared to:

- HRC water quality objectives for total nitrogen and total phosphorus (the guidelines only cover these two analytes)
- The Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC/ARMCANZ, 2000) (commonly referred to as the 'ANZECC Water Quality Guidelines'), for analytes other than total nitrogen and total phosphorus. The project's catchment is considered to represent a "slightly modified freshwater system" (ANZECC/ARMCANZ, 2000). Therefore, for assessment of groundwater quality, a protection level of 95 per cent for freshwater ecosystems is used. ANZECC Water Quality Guidelines trigger values for lowland rivers are also used.
- The AIP's minimal impact considerations for groundwater quality, which stipulates that 'any change in groundwater quality should not lower the beneficial use category (defined in **Section 2.3**) of the groundwater source beyond 40 metres from the activity'.

These criteria were developed to provide a basis for assessing whether "no more than minimal harm", which is a WM Act concept, would occur to groundwater systems and associated environments, due to the granting of a water access license.

The HRC concentration for total nitrogen and total phosphorus is 0.7 mg/L and 0.035 mg/L respectively and the ANZECC Water Quality Guidelines concentrations are tabulated in **Annexure F**.

It should be noted that the HRC and ANZECC Water Quality Guidelines values are not standards and should not be regarded as such. The ANZECC Water Quality Guidelines recognise that monitoring programmes, including their performance objectives and assessment criteria, should focus on specific issues, not on default guideline values. As a result, consideration is given to background water quality in this assessment.

3.5.2 Groundwater level impact assessment criteria

Potential groundwater impacts are assessed against the AIP minimal impact considerations, which are summarised in **Section 2.3** and reported more fully alongside demonstrated project compliance in **Section 5.3**.

3.6 Impact assessment methodology

3.6.1 Overview

An assessment of dewatering impacts was undertaken to estimate potential groundwater inflows and reductions to groundwater levels if road cuttings (excavations) extend below the water table and are drained. Dewatering (such as through drainage of road cuttings) results in depressurisation of the groundwater system and has the potential to cause changes to groundwater flows and levels. The dewatering assessment is integral to the groundwater impact assessment because dewatering of cuts that extend below the water table is considered the primary project activity that could result in changes (reductions) to groundwater levels.

The dewatering inflow assessment was based on the application of Darcy's law, with inputs informed by project groundwater bore monitoring results and project design levels of the road. Darcy's law describes flow through porous media, which is proportional to hydraulic conductivity (measure of the ease with which water will pass through soil/rock), area and hydraulic gradient (slope of water table or piezometric head).

The assessment assumed a worst-case design scenario, where road cuttings below the baseline water table level would be permanently drained.

3.6.2 Dewatering assessment methodology

Potential groundwater inflow zones

Groundwater inflow zones would occur in areas where the project's proposed road level is below the water table. To identify potential groundwater inflow zones, existing groundwater levels from the project's groundwater monitoring bores were compared to the project's proposed vertical alignment. This was done by plotting the maximum groundwater level, monitored by data loggers at 24 project groundwater monitoring bores, on a long section that included existing ground level and the project's road design level.

Groundwater inflow volume estimation

To estimate potential groundwater 'take' (inflow) generated by the project cuts intersecting the water table, cross sectional Darcy's Law is used. This method is suitable for estimating cross sectional flow intersected by the project's cuttings. The form of Darcy's Law applied is described below:

$$Q = KIA$$

where:

Q = groundwater inflow (kL/d)

K = hydraulic conductivity (m/d)

I = hydraulic gradient (m/m)

A = saturated cross sectional area (square metres)

To account for uncertainty and incorporate sensitivity analysis into the assessment, three different hydraulic conductivity values are applied. The three values comprised the maximum of estimates from slug tests at project groundwater monitoring bores and upper and mid-range values obtained from literature.

Similarly, to account for uncertainty and incorporate sensitivity analysis into the assessment, three different groundwater gradients area applied:

- Low gradient (0.04 m/m)
- Medium gradient (0.10 m/m)
- High gradient (0.30 m/m).

Drawdown extent estimation

Due to drainage, interception of groundwater flow by project cuts that extend below the water table could potentially reduce groundwater levels in the region of the cuts. The outer limit of the area that could be subjected to reduced groundwater levels was estimated using the Cooper-Jacob (1946) equation:

Radius of influence (m) = $(2.25Tt/S)^{0.5}$, where

T = transmissivity (m^2/d)

t = time (d)

S = storage

3.7 Key assumptions

The key assumptions relied on in the development of this report are:

- Predicted groundwater inflows and associated impacts are based on the design outlined in the M12 Motorway EIS. Any subsequent changes to the design may alter the impacts outlined herein would need to be considered during the detailed design stage of the project
- The existing environment is characterised based on project specific data and other data available in the public domain. The resulting interpretations are considered to reasonably represent the existing environment and the potential impacts associated with the project
- Field investigations carried out for the project occurred in tandem with the writing of this report. Any subsequent data that changes the conceptual hydrogeological model (described in **Section 4.11**) or findings of this report would be considered during the detailed design stage of the project.

Typically, sub-surface conditions are based on interpretation of background data and samples taken, and consequently contain an element of uncertainty. This report contains interpretations and conclusions which are uncertain due to the nature of the investigations, comprising:

- This report is based on assumptions that the site conditions as revealed through sampling are indicative of conditions throughout the site.
- The findings are the result of standard assessment techniques used in accordance with normal practices and standards, and (to the best of the author’s knowledge) they represent a reasonable interpretation of the current conditions on the site.
- Sampling techniques, by definition, cannot determine the conditions between the sample points and so this report cannot be taken to be a full representation of the sub-surface conditions.
- This report provides an indication of the likely sub surface conditions only.

Conditions encountered when site work commences may be different from those inferred in this report, for the reasons explained above and hence the findings, observations and conclusions expressed in this report are linked to the information available at the time of writing.

4. Existing environment

This section includes a description of the existing environment and has been informed by the desktop investigations and field inspections undertaken for the project.

4.1 Climate

4.1.1 Overview

To assess long-term average monthly rainfall and evaporation for the study area, rainfall and evaporation statistics are sourced from the Bureau of Meteorology's (BOM) Badgerys Creek observation station and the BOMs Sydney Observatory Hill observation station respectively (BOM, 2018c). Rainfall statistics are sourced from the Badgerys Creek observation station because this station is close to the study area. Evaporation statistics are sourced from the Sydney Observatory Hill observation station because it is not available from the Badgerys Creek observation station. Whilst evaporation rates are likely higher in the study area than for the BOM's Sydney Observatory Hill observation station, the data is considered suitable for the purpose of assessing broad scale rainfall and evaporation trends.

Review of the Bureau of Meteorology's (BOM) rainfall data for the Badgerys Creek observation station indicated that the mean monthly rainfall for the study area ranges from 22.6 millimetres in July to 98.5 millimetres in February, with an average annual rainfall of about 681 millimetres.

Based on mean daily evaporation data from BOM's Sydney Observatory Hill observation station, evaporation exceeds rainfall for all months except June, where the average monthly rainfall surplus (ie rainfall minus evaporation) is about 25 millimetres. Average monthly rainfall, evaporation and rainfall surplus is summarised in **Table 4-1**.

Table 4-1 Average monthly rainfall, evaporation and rainfall surplus

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Mean Rainfall (mm) [1]	79.4	98.5	81.3	49.4	37.0	61.4	22.6	36.8	32.3	51.4	69.0	57.1	680.9
Mean Evaporation (mm) [2]	142.6	109.2	96.1	78.0	58.9	36.0	46.5	58.9	75.0	102.3	129.0	136.4	1068.9
Rainfall surplus (mm)	-63.2	-10.7	-14.8	-28.6	-21.9	25.4	-23.9	-22.1	-42.7	-50.9	-60.0	-79.3	-388.0

Notes: [1] Source: BOM's Badgerys Creek observation station. [2] Source: BOM's Sydney Observatory Hill observation station.

4.1.2 Observed rainfall during groundwater monitoring period

During 2018, observed monthly rainfall at the BOM's Badgerys Creek Station was 26 millimetres, 54 millimetres, 31 millimetres, 29 millimetres, 9 millimetres, 21 millimetres and 31 millimetres lower than long-term monthly average values for the months of February, March, April, May, June, July and August respectively. Evaporation during these same months ranged from about two to 2.6 times higher than historical long-term average values. The months of February to August comprise the groundwater level monitoring period documented in this report for the majority of monitoring bores.

Cumulative rainfall deviation (CRD) is defined as the cumulative of observed rainfall minus long-term average rainfall. CRD often corelates to groundwater levels measured at bores which respond to rainfall recharge. CRD analysis involves plotting the cumulative of observed monthly rainfall minus the historical long-term average monthly rainfall for that month. The line slope indicates drought and high rainfall periods. When the line slope increases, higher than average rainfall has occurred and when the line slope decreases below average rainfall has occurred.

A CRD plot of rainfall at the BOM's Badgerys Creek AWS station from January 1996 (close to start of available data set) through to February 2019 is provided in **Annexure A**, Figure 3 along with the groundwater monitoring period documented in this report. The CRD trends suggest that whilst the project's groundwater monitoring period corresponds with low rainfall and high evaporation, CRD during the monitoring period is quite close to a peak occurring in March 2017. This peak occurred following a pronounced minimum that occurred in December 2006. Based on the CRD trends and timing of the project's groundwater monitoring period, groundwater levels measured during the monitoring period are anticipated to be higher than long-term averages.

4.2 Topography

The topography of the study area may be characterised into three general terrain types:

- Rolling Hills Terrain, which occurs in the western and eastern portions of the proposed alignment
- Flat to Gently Undulating Terrain, which occurs in the central portion of the alignment
- Creek Channels/Alluvial Floodplain Terrain, which dissects the Flat to Gently Undulating Terrain within the central portion of the alignment.

Within the Rolling Hills Terrain, the topography typically comprises rounded hills with slopes of five degrees to 20 degrees, ie around 10 per cent to 35 per cent grade, and local relief of typically up to 10 metres to 30 metres. Within this general terrain type, the ground surface levels along the alignment range from about relative level (RL) 70 metres Australian Height Datum (AHD) to RL115 metres AHD.

The topography of the Flat to Gently Undulating Terrain in the central portion of the alignment typically comprises gentle rises and undulations with broad rounded crests with slopes of 0 degrees to 5 degrees, ie up to around 8 per cent grade, and local relief of up to about 15 metres. Ground surface levels along the central portion of the alignment range from about RL 35 metres AHD to RL 70 metres AHD. The Flat to Gently Undulating Terrain type is dissected by the Creek Channel/Alluvial Floodplain Terrain type by four meandering creeks, Cosgroves Creek, Badgerys Creek, South Creek and Kemps Creek, with each creek flowing to the north.

The topography of the alluvial floodplains adjacent to the creeks comprises low slopes of about 0 to 2 degrees, which extend from the creek channels out to a maximum distance of about 500 metres.

4.3 Hydrology

4.3.1 Catchment description

The project is located within the Hawkesbury-Nepean catchment, a catchment covering more than 22,000 square kilometres which provides drinking water, recreational opportunities, agricultural and fisheries produce and tourism resources for the Sydney Metropolitan area. The Hawkesbury-Nepean Catchment is of national significance, being the longest coastal catchment in NSW flowing 470 kilometres from the headwaters of the Nepean River in Goulburn before joining the Hawkesbury River in Sydney's west and draining to Broken Bay.

There are many major drainage features flowing in this catchment including the Hawkesbury, Nepean, Mulwaree, Wingecarribee, Wollondilly, Mulwaree, Tarlo, Nattai, Coxs, Kowmung, Grose, Capertee, Colo and Macdonald. There are also several creeks including Berowra, Mangrove, Cattai, South and Mooney creeks. The catchment contains a variety of landscapes including rainforest, open woodlands, heathlands, wetlands and highland freshwater streams.

The project lies within the Lower Nepean River Management Zone of the Hawkesbury-Nepean Catchment. Whilst almost half the Hawkesbury-Nepean Catchment is protected in national parks and water catchment reserves, the project lies within the South Creek subcatchment which has been extensively modified and disturbed due to increasing urbanisation and associated land clearing. The Hawkesbury River is the ultimate downstream receiving environment and is located about 29 kilometres from the project at the closest point.

Existing land uses within the study area are predominately semi-rural and include residential, agricultural, commercial and industrial. The largest residential areas are the suburbs of Kemps Creek, Mount Vernon and Horsley Park. Agricultural land uses include poultry farms, farms producing tomatoes and cucumbers, Christmas tree farm and wholesale nurseries. Commercial uses are generally located within the Kemps Creek village and include service stations, food stores, hardware and maintenance shops. Industrial uses include the Elizabeth Drive landfill and quarry site (Roads and Maritime, 2016).

Within the study area there are a number of existing transport and utilities infrastructure including the M7 motorway, Elizabeth drive, the Sydney Water Upper Canal system and major electrical infrastructure (Roads and Maritime, 2016).

The catchment is shale based and characterised by meandering streams. The project is located within the Cumberland Plain, a subregion of the Sydney Basin which consists of relatively flat and low-lying topography. However, small ridgelines are present around Horsley Park, Orchard Hills and Cecil Hills.

The project intersects Cosgroves Creek, Badgerys Creek, South Creek, Kemps Creek and Ropes Creek, and drains to Hinchinbrook Creek as shown on **Figure 4-1**. With the exception of Hinchinbrook Creek, these creeks drain into South Creek which then flows north to join the Hawkesbury River at Windsor. The South Creek subcatchment covers around 490 square kilometres and generally flows from south to north. The confluence of Kemps Creek and Badgerys Creek into South Creek is about three kilometres north of Elizabeth Drive (Roads and Maritime, 2016). There are also numerous farm dams in the area.

The South Creek subcatchment is one of the most degraded subcatchments of the Hawkesbury-Nepean. Catchment vegetation clearance and increasing urbanisation has dramatically altered the hydrological and sediment regimes. The hydrology of the catchment has been substantially altered due to increasing impervious surfaces which has in turn altered the geomorphology and ecology of the watercourse. Additional flow is also derived from a number of major Sewerage Treatment Plants (STPs) which discharge into the catchment (HNCMA 2007).

4.3.2 Key watercourses

Watercourses within the study area have been classified according to the Strahler stream classification system where waterways are given an order according to the number of additional tributaries associated with each waterway (Strahler, 1952). A first order stream, otherwise known as headwater streams begin at the top of a catchment. They are generally the smaller tributaries that carry water from the upper reaches of the catchment to the main channel of the river and are rarely named. Where two first order streams join, the section downstream of the junction is referred to as a second order stream. Additionally, where two second order streams join, the waterway downstream is classified third order and so on. Where a lower order stream (eg first) joins a higher order stream (eg third) the area downstream of the junction retains the higher order.

The following watercourses are shown in **Figure 4-1**.

Cosgroves Creek

Cosgroves Creek in the location at which the project would cross (about 500 metres east of where the project would cross Luddenham Road) is an ephemeral fourth order stream (Strahler, 1952) with a series of disconnected pools and named and unnamed tributaries including Oaky Creek. Cosgroves Creek originates in Luddenham and flows for about 8.5 kilometres until it drains into South Creek. The catchment is largely rural with some residential estates (Twin Creek Golf and Country Club).

The hydrological sub-catchment of Cosgroves Creek (draining to South Creek) is about 2165 hectares, of which 15 per cent (325 hectares) is classified as impervious surfaces (GHD, 2016a).

Badgerys Creek

Badgerys Creek in the location at which the project would cross (about 2.8 kilometres east of where the project would cross Luddenham Road) is a fourth order stream of about 16 kilometres in length, originating near Bringelly. The creek then flows north and then north east before its confluence with South Creek in the suburb of Badgerys Creek. Land use within the Badgerys Creek catchment consists of agricultural (grazing of naturalised and modified pastures) and rural residential. Ecologically sensitive riparian vegetation also exists within the catchment (GHD, 2016a) as do small areas of landfill and native forest.

The hydrological subcatchment of Badgerys Creek (draining to South Creek) is about 2800 hectares of which 12 per cent (335 hectares) is classified as impervious surfaces (GHD, 2016a). Badgerys Creek is the largest tributary of South Creek in the study area.

South Creek

South Creek in the location at which the project would cross (about 1.1 kilometres west of the Clifton Avenue cul-de-sac) is a major fifth order tributary of the Hawkesbury-Nepean River that originates in the low hills near Narellan and runs for over 64 kilometres in a northerly direction through the Western Cumberland Plain to Windsor where it flows into the Hawkesbury River. The South Creek catchment is a shale based catchment that encompasses most of the Cumberland Plain of western Sydney. South Creek is tidal in its lower reaches. South Creek drains a catchment of 414 square kilometres and is joined by 17 tributaries including Badgerys, Cosgroves, Kemps, Ropes and Eastern Creek.

The South Creek Catchment is currently regarded as one of the most seriously degraded subcatchments in the Sydney Region, largely due to long-term clearing of vegetation and increased impervious areas due to urbanisation. This has resulted in dramatic alterations to the hydrology, geomorphology and ecology of the watercourse (Rae 2007). The water quality of South Creek is influenced by discharge from a number of wastewater plants and runoff from stormwater and agriculture areas.

Kemps Creek

Kemps Creek in the location at which the project would cross (about 930 metres north-west of the Mamre Road/Elizabeth Drive intersection) is a tributary of South Creek and is a fourth order stream which flows into the Hawkesbury-Nepean River. The creek originates about two kilometres east of Catherine Fields and flows for about 17 kilometres through the suburbs of Rossmore, Bringelly, Austral and Kemps Creek before entering South Creek north of Elizabeth Drive. The creek flows through a predominately semi-rural setting, although urbanisation has increased in recent years (Liverpool City Council (LCC), 2003).

Kemps Creek catchment is known to suffer from drainage problems, due to limited hydraulic capacity in the creek channels, filling activities on the floodplain and inadequate hydraulic capacity at culverts and bridges (LCC, 2003). As a result of drainage problems there have been considerable earthworks to control water including construction of dams to store water, construction of channels or banks to divert flow of water and enlarging the creek channel to reduce flood levels (LCC, 2003). Land use within the Kemps Creek sub-catchment largely includes agriculture (grazing, market gardens, poultry), residential, commercial and extractive industry.

Ropes Creek

Ropes Creek in the location at which the project would cross (immediately west of the existing M7 Motorway crossing) is an ephemeral first order tributary of South Creek that rises in south western Sydney near Fairfield and generally flows in a northerly direction for about 23 kilometres before reaching its confluence with South Creek. Ropes Creek has been extensively cleared of vegetation, other than around the waterways, for agricultural activities to take place. The catchment has a long history of flooding (BMT, 2013). The Ropes Creek catchment also contains two well defined open channel tributaries.

Ropes Creek is traversed by several major roads including the M7 Motorway at Cecil Park, the M4 Western Motorway between Erskine Park and Colyton and the Great Western Highway and Main Western Railway Line east of Oxley Park.

Hinchinbrook Creek

Hinchinbrook Creek at its closest point to the project is a fourth order stream. Hinchinbrook Creek drains to the sub-catchment of Cabramatta Creek which lies within the Georges River catchment. The creek originates in Cecil Hills and flows through the suburbs of Elizabeth Hills and Hinchinbrook before it enters Cabramatta Creek at Hoxton Park. The health of Hinchinbrook Creek has been measured using the ecological indicators of water quality, vegetation and macroinvertebrates by the Georges River Combined Councils Committee (GRCCC). The overall health rating (2014-15) for Hinchinbrook Creek was poor due to the poor condition or lack of riparian vegetation and the low diversity of macroinvertebrates which were dominated by pollutant tolerant animals. Water quality however was good.

4.3.3 Watercourse geomorphology

Geomorphology of the main watercourses is summarised in **Table 4-2**.

Table 4-2 Watercourse geomorphology summary

Watercourse	Geomorphological description
Cosgroves Creek	Cosgroves Creek is a discontinuous channel with steep channel gradient, a depth of about two metres and an average channel width of about five metres. The substrate consists of silty clay. Undercutting occurs at meander bends, suggesting a high potential for erosion at this site.
Badgerys Creek	Badgerys Creek is an incised meandering channel with irregular bank morphology due to abundant riparian vegetation and woody debris. Undercutting occurs along the length of the channel. The channel has a steep gradient with a channel depth greater than three metres and average channel width of about five metres.
South Creek	South Creek has a moderate gradient and a discontinuous channel and lies within a largely un-vegetated floodplain. Some bank undercutting occurs along the imposed right bank. The depth of the channel appears shallow and channel width is about seven metres.
Kemps Creek	Kemps Creek has a moderate gradient and a discontinuous channel with irregular bank morphology. The creek is laterally unconfined and undercutting occurs at creek bends. The channel depth appears shallow with a silty clay substrate. The channel width averages about three metres.
Ropes Creek	Ropes Creek is a highly modified drainage channel transitioning to a laterally confined low gradient channel. The channel was completely dry upon inspection with minimal bank definition. No undercutting is apparent due to vegetation overgrowth and shallow depth.
Hinchinbrook Creek	Hinchinbrook Creek is a highly modified drainage channel consisting of a series of large disconnected pools. This section of the creek contains an artificial rock wall barrier downstream. The natural substrate consists of silty clays, with isolated sections of channel erosion and bank undercutting occurring at the channel meanders. The channel depth is greater than two metres.

Due to a history of clearing, construction of dams along the watercourses and ongoing agricultural activities, the waterways in the study area are considered to be in moderate geomorphic condition despite sections of well vegetated riparian zones.

4.3.4 Existing water quality summary

Appendix M of the EIS includes a review of water quality at Badgerys Creek, Cosgroves Creek, South Creek, Kemps Creek and Hinchinbrook Creek.

Appendix M of the EIS concludes that overall the water quality of creeks within the study area could be classified as poor and degraded due to low dissolved oxygen concentrations and elevated nutrients. Additionally, heavy metal concentrations are elevated for some creeks. Badgerys Creek generally exhibited the poorest water quality of the waterways (based on available data) with a greater number of indicators exceeding recommended guidelines. Additionally, concentrations are generally higher in Badgerys Creek compared to other creeks.

4.4 Geology

Based on review of the Penrith 1:100,000 geological map (Geological Survey of NSW, 1991) (**Figure 4-1**) and completed project geotechnical borehole logs, the study area includes two surface geological units as follows:

- Quaternary Alluvium (which is located in the vicinity of all of the project's creek crossings except Ropes Creek)
- Bringelly Shale bedrock.

4.4.1 Quaternary Alluvium

The Penrith 1:100,000 geological map (Geological Survey of NSW, 1991) indicates the alluvium comprises fine grained sand, silt and clay. Project boreholes adjacent to the project's four creek crossings with mapped alluvial material encountered silty sand, sandy clay, gravelly clay, silty clay, clayey silt, sandy silt, clayey sand and sandy gravel above the bedrock. As the bedrock occurs, at depths ranging from about 2.5 metres below ground level (BGL) to 7.0 metres BGL, the alluvium deposits are relatively thin. Based on geological mapping (Geological Survey of NSW, 1991) within the study area, the widths of the alluvium deposits are of the order of 300 metres, 700 metres, one kilometre and 500 metres for Cosgroves Creek, Badgerys Creek, South Creek and Kemps Creek respectively.

4.4.2 Bringelly Shale and underlying units

The Penrith 1:100,000 geological map (Geological Survey of NSW, 1991) indicates Bringelly Shale comprises shale, carbonaceous claystone, claystone, laminite, fine to medium grained lithic sandstone, rare coal and tuff. Project boreholes encountered siltstone, sandstone and interlaminated siltstone and sandstone at typical depths of about one metre BGL to five metres BGL.

With reference to the Penrith 1:100,000 geological map (Geological Survey of NSW, 1991), Bringelly Shale is the upper member of the Wianamatta Group. The Wianamatta Group was deposited during a single mostly regressive period following subsidence of the Hawkesbury Sandstone alluvial plain. Deposition of sediment continuously during the period resulted in the shoreline progressing eastwards and a vertical accumulation of sediments, beginning with offshore low energy marine muds at the base of the group (Ashfield Shale), which became a shoreline sand deposit (Minchinbury Sandstone), and finally into alluvial plain deposits (Bringelly Shale).

The Bringelly Shale was deposited in an alluvial plain environment that included swampy organic rich sediments, overbank alluvial clays, channel sands and lake deposits, which is why the unit has variable sedimentary rock types.

Bringelly Shales are often deeply weathered to depths of up to 10 metres. The formation typically weathers to form clays and silty clays of medium to high plasticity, and of low permeability. Based on project boreholes and regional experience, it is expected that where Bringelly Shale is present near the surface, ground conditions would comprise one metre to five metres of high plasticity, low permeability residual clays over highly weathered bedrock.

The underlying Minchinbury Sandstone differs to Bringelly Shale in being a relatively thin stratigraphic unit that separates the overlying Bringelly Shale from the underlying Ashfield Shale. The unit comprises fine to medium-grained quartz lithic sandstone comprising more than 15 per cent calcite, high quantities of quartzite and limited amounts of felspar, which differentiates it from the sandstones that occur in the Bringelly Shale

Ashfield Shale which occurs below the Minchinbury Sandstone comprises dark grey to black claystone, siltstone, shale and fine grained sandstone-siltstone laminate.

Bringelly Shale is the only anticipated bedrock unit to be intersected by the project alignment. The Minchinbury Sandstone and Ashfield Shale units are anticipated to occur sufficiently below the project alignment to not be intersected.

4.4.3 Intrusions

No igneous intrusions are shown on the geological map (Geological Survey of NSW, 1991) to be present on the project alignment. The Luddenham Dyke is located approximately two kilometres to the south west of The Northern Road intersection and there are volcanic necks to the north, closer to the M4 Motorway. Igneous dykes are often difficult to identify in this part of Sydney with limited surface exposures as the weathered dykes are often similar to weathered shale bedrock. Based on previous experience with rail and road route studies throughout Sydney, it is anticipated that two to four igneous dykes/intrusions may be present along the project alignment.

4.4.4 Structures

The Penrith 1:100,000 geological map (Geological Survey of NSW, 1991) indicates that the project alignment may be crossed at two locations by faulting or folding as follows:

- Narellan Lineament: The overall north/south linearity of South Creek suggests that it may be structurally controlled. In addition to this, there are also a number of north east trending tributaries into the South Creek channel, such as Cosgrove Creek, which may be an expression of regional faulting trends.
- Rossmore Anticline: This feature is described as a structural high within the Wianamatta Group. The geological map (Geological Survey of NSW, 1991) shows this feature ending at Elizabeth Drive, just to the east of the intersection with Luddenham Road. However, this feature may extend further north crossing the western end of the alignment. If this is the case, then bedrock bedding dips in the vicinity of such a feature could be altered and potentially dipping to the west on the western side of this structure.

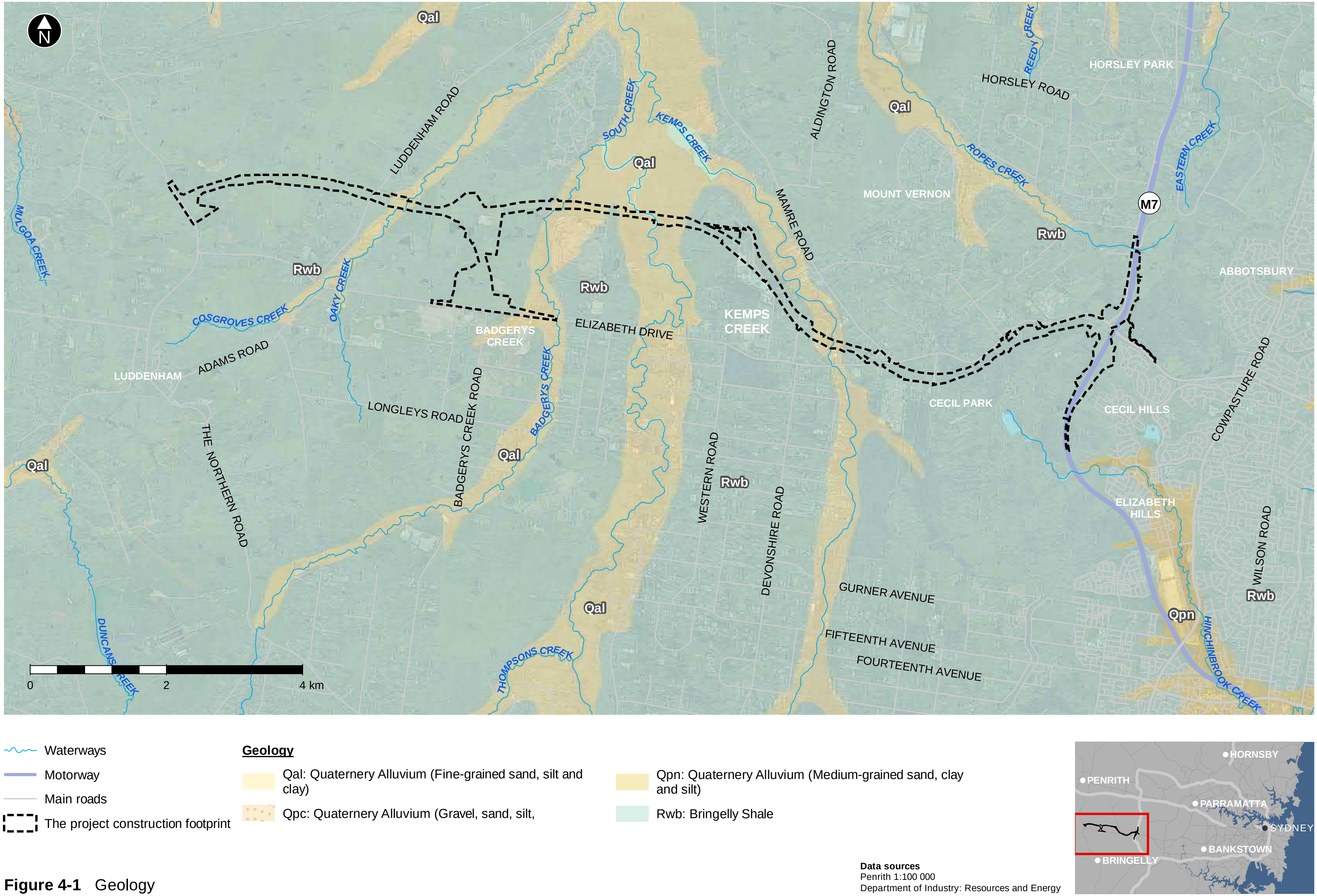


Figure 4-1 Geology

Data sources
Penrith 1:100 000
Department of Industry: Resources and Energy

4.5 Soil landscapes

Based on a review of the 1:100,000 scale Soil Landscape Map for Penrith, the study area includes four soil landscapes as follows:

- South Creek: Fluvial deposits which are located along all four creek channels
- Blacktown: Residual soils located in the flat to gently undulating terrain between creek channels
- Luddenham: Residual soils located on the low rolling hills at both ends of the alignment
- Picton: Residual and colluvial soils located at the eastern end of the alignment.

The location and extent of each soil landscape is closely related to surface landform and topography.

South Creek soils are located within all four creek channels that cross the alignment. These soils are described as Quaternary alluvium derived from Wianamatta Group shales that comprise deep sandy, sandy clay and clay soils that were deposited as part of the current active South Creek drainage network. This is a dynamic soil landscape with many areas of erosion and deposition. Relevant limitations for development include high erodibility, shrink-swell potential, salinity, low fertility and localised areas of permanently high water tables or seasonal waterlogging.

Blacktown soils are located on the flat to gently undulating terrain between creek channels and are described as shallow to moderately deep clays and silty clays derived from the Bringelly Shales. Relevant limitations for development include strongly acidic, low fertility, high shrink-swell, low permeability potential for salinity, high erodibility.

Luddenham soils are located on the low rolling hills at both ends of the alignment. This soil landscape is derived from Bringelly Shales and is described as shallow to moderately deep, typically comprising clays, and sandy clays where Minchinbury Sandstone may be present. Moderately inclined slopes of 10-20 per cent are the dominant landform and as a result development limitations included high erosion hazards, together with a high shrink-swell potential and low permeability and low fertility.

There is an area of Picton soil landscape located in the rolling hills at the eastern end of the alignment. This soil landscape occurs on steep sided slopes over Wianamatta Group shales usually with a southern aspect and where there are slope gradients more than 20 per cent. Picton soils are described as shallow to deep residual and colluvial clays. Of particular note for this soil landscape is that there is potential for mass movement and slope instability, ie land sliding.

4.6 Salinity

The *Salinity Potential in Western Sydney 2002 Map* (Department of Land and Water Conservation, 2002b) shows the soils along the alignment generally have a moderate salinity potential with the exception of high salinity potential in the areas of Cosgrove Creek, in areas of low lying land to the east and west of Cosgrove Creek and along Kemps Creek, and with the exception of small areas of known soil salinity along the proposed alignment to the east of Range Road.

Areas of moderate salinity potential are defined as where Wianamatta Group Shales or tertiary alluvial terraces are present. Additional saline areas may be present which have not yet been identified or may occur if site conditions change adversely.

Areas of high salinity potential are defined as those areas where expected soil, geology, topography and groundwater conditions predispose a site to salinity. These areas are most commonly drainage systems or low lying/flat grounds where there is a high potential for the ground to become waterlogged.

Areas of known salinity are defined as those areas where saline soils have been identified or air photo interpretation and field observations have identified visual indicators of land salinity such as bare earth or waterlogging.

With reference to the above, areas of current or potential soil salinity are expected along the alignment where there is alluvium, waterlogged ground or shallow groundwater.

4.7 Acid sulfate soil and rock

4.7.1 Acid Sulfate Soils

Acid Sulfate Soils (ASS) is the common name for naturally occurring sediments and soils containing iron sulphides. The exposure of these soils to oxygen by drainage or excavation, oxidises the iron sulphides and generates sulfuric acid. The sulfuric acid can be readily released into the environment, with potential adverse effects on the natural and built environments. The majority of ASS are formed when available sulfate (which occurs widely in seawater, marine sediment, or saturated decaying organic material) reacts with dissolved iron and iron minerals forming iron sulfide minerals, the most common being pyrite. This generally limits their occurrence to deeper marine sediments and low lying sections of coastal floodplains, rivers and creeks where surface elevations are less than about RL five metres AHD.

The Australian Soil Resource Information System’s (ASRIS 2018) online ASS risk map indicates the project is mapped within an area considered to have an extremely low probability of ASS occurrence, indicating that there is no known or expected occurrence of ASS within the construction footprint.

Additionally, a search was undertaken within Penrith Council (2010) and Liverpool Council (2008) LEPs for ASS risk maps for the construction footprint to determine the probability off ASS occurrence. The search found no ASS risk maps exist for the construction footprint within the LEPs and therefore conclusions can be drawn that there is no known or expected occurrence of ASS within the construction footprint.

4.7.2 Acid rock

Acid rock is defined as rock that contains sulfide or sulfate minerals (commonly pyrite) which has the potential to oxidise when exposed and produce sulfuric acid. Acid Rock is potentially an issue where the sulfide bearing rock that has previously been protected from weathering, or is below the water table, becomes exposed such as in deep cuttings.

Sedimentary pyrite is a common constituent of organic rich, typically fine-grained marine and anoxic terrestrial sediments. Coal measures and carbonaceous mudstones are typically where sedimentary pyrite would be anticipated.

To date, no occurrences of acid rock have been documented within Bringelly Shales soil landscapes and on this basis, the potential for encountering acid rocks along the project alignment is considered to be extremely low.

4.8 Groundwater dependent ecosystems

GDEs are ecological communities that are dependent, either entirely or in part, on the presence of groundwater for their health or survival. The NSW DPI Water Risk Assessment Guidelines for Groundwater Dependent Ecosystems (Serov et al., 2012) adopts the definition of a GDE as:

> “Ecosystems which have their species composition and natural ecological processes wholly or partially determined by groundwater”.

GDEs might rely on groundwater for the maintenance of some or all of their ecological functions, and that dependence can be variable, ranging from partial and infrequent dependence, ie seasonal or episodic, to total continual dependence.

The Bureau of Meteorology’s GDE Atlas (BOM, 2018b) was reviewed to investigate the potential for GDEs to exist within the study area. The atlas mapping is shown in **Figure 4-2** and summarised as follows:

- South Creek is mapped as a high potential aquatic GDE (based on national assessment).
- Moderate to high potential terrestrial GDEs (based on national assessment) are mapped within the study area, generally in the region of the five creek crossings, but also in isolated areas away from the creeks. These GDEs were described as either Cumberland Shale Hills Woodland or Cumberland River Flat Forest.
- Several isolated areas away from the creeks – mapped as low to high potential terrestrial GDEs.

Additionally, Appendix 2 of the water sharing plan legislation (NSW Government) indicated that no High Priority GDEs (karst and wetlands) are mapped within approximately 10 kilometres of the study area.

4.9 Hydrogeology

4.9.1 Project groundwater investigations and data set overview

The project’s existing hydrogeological environment is characterised based on data collected from the project’s groundwater monitoring network, which included:

- 31 groundwater monitoring bores installed for the purpose of informing geotechnical design and a range of environmental assessments associated with the project’s Environmental Impact Statement (EIS). Project groundwater monitoring bore locations are shown in **Figure 3-2.**
- Manual groundwater level measurements on two dates (date of data logger install and date of logger download in August, 2018) for 25 of the 31 project groundwater monitoring bores, and on one date (date of data logger install or date of well development) for three of the 31 project groundwater monitoring bores. Three of the 31 project groundwater monitoring bores did not have groundwater level measurements as two were primarily installed for the purpose of gas monitoring and one bore (BH129) could not be accessed after it was constructed as the landowner could not be contacted to approve site access.
- Monitoring of groundwater levels at a two hourly interval by data loggers at 25 of the 31 project groundwater monitoring bores. An additional three project groundwater monitoring bores were equipped with data loggers. However, logger data from these three bores had not been downloaded at the time of this report. Information that may become available from those bores would be considered in future groundwater investigations during detailed design.

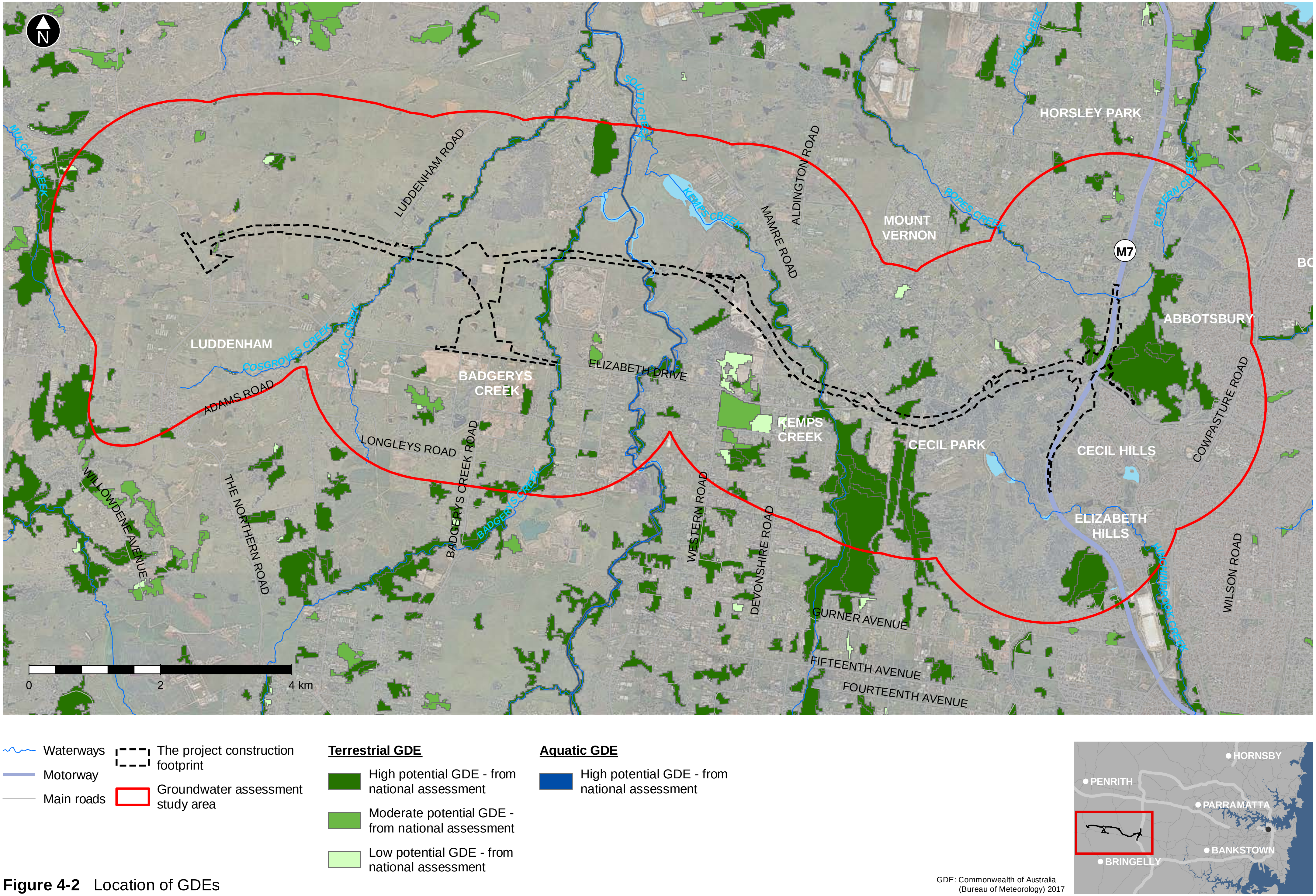


Figure 4-2 Location of GDEs

GDE: Commonwealth of Australia (Bureau of Meteorology) 2017

Date: 1/07/2019 Path: J:\IE\Projects\04_Eastern\IA145100\08 Spatial\GIS\Directory\Templates\MXDs\Figures\EIS\SpecialistReports\Groundwater\FinalEIS\JAJV_EIS_GW_F005_GDE_r4v1.mxd
Created by : HK | QA by : AA

- The three project groundwater monitoring bores which were not equipped with data loggers to measure groundwater levels were primarily installed for the purpose of gas monitoring (BH301 and BH302) or could not be accessed (BH129).
- Groundwater level data logging commenced upon bore installation during February 2018 to August 2018 and will be ongoing as outlined in the groundwater monitoring program (**Section 7.2**).
- Groundwater sampling and subsequent laboratory analysis for a range of analytes relevant to general groundwater quality characterisation, assessing the contamination status of groundwater and assessing aggressivity of groundwater to inform engineering design elements of the project.

Ten project bores were sampled once and laboratory tested for the following analytes:

- Heavy metals (eight)
- Total recoverable hydrocarbons
- BTEXN
- Ammonia
- Nutrients
- pH, EC, TDS, TSS, Turbidity
- Major anions and cations
- Hydraulic testing at five bores was undertaken to enable estimation of hydraulic conductivity. The five bores comprised three bores located in the areas of the deepest cuts (water columns in bores spanned Bringelly Shale) and two bores located in areas of alluvium (water columns in bores spanned alluvium and Bringelly Shale).

Additionally, the above investigations and data were supplemented with public domain groundwater bore data and GDE mapping, both of which are detailed in **Section 4.9.3** and **Section 4.8** of this report.

A summary of groundwater level and quality monitoring undertaken for the project is provided in **Table 4-3**. The groundwater monitoring completed for the project is considered suitable to provide a baseline dataset to inform this assessment documented in this report.

Table 4-3 Summarised project groundwater monitoring bore testing

Groundwater level monitoring (dip meter)	Groundwater level monitoring (data logger) [2]	Groundwater quality sampling round (22-24/08/2018)	Slug tested to estimate hydraulic conductivity (August 2018)
• BH162 [1] (04/09/2018) • BH170 [1] (04/09/2018) • BH175 (04/09/2018)	• BH102 (15/02/2018 to 15/01/2019) • BH105 (18/02/2018 to 15/01/2019) • BH107 (12/05/2018 to 21/08/2018) • BH117 (12/05/2018 to 22/08/2018) • BH119 (16/02/2018 to 21/08/2018) • BH134 (16/02/2018 to 21/08/2018) • BH135 (18/02/2018 to 21/08/2018) • BH139 (dry) • BH144 (29/05/2018 to 22/08/2018) • BH150 (12/05/2018 to 27/08/2018) • BH155 (29/05/2018 to 27/08/2018) • BH204 (12/05/2018 to 21/08/2018) • BH211 (15/06/2018 to 21/08/2018) • BH215 (15/06/2018 to 21/08/2018)	• BH104 • BH112 • BH145 • BH202 • BH207 • BH209 • BH217 • BH223 • BH301 [3] • BH302 [3] Tested for: - Heavy metals (eight) - Total recoverable hydrocarbons	• BH104 • BH112 • BH145 • BH202 • BH217

Groundwater level monitoring (dip meter)	Groundwater level monitoring (data logger) [2]	Groundwater quality sampling round (22-24/08/2018)	Slug tested to estimate hydraulic conductivity (August 2018)
Additionally, dip meter measurements were also taken at all bores that were equipped with data loggers. Measurements were taken at the start and end dates of the data logger monitoring period documented in the adjacent column.	• BH219 (30/05/2018 to 21/08/2018) • BH221 (30/05/2018 to 21/08/2018) • BH227 (15/06/2018 to 22/08/2018) • BH104 (16/02/2018 to 15/01/2019) • BH112 (12/05/2018 to 21/08/2018) • BH145 (29/05/2018 to 22/08/2018) • BH202 (12/05/2018 to 21/08/2018) • BH207 (12/05/2018 to 21/08/2018) • BH209 (15/06/2018 to 21/08/2018) • BH217 (15/06/2018 to 21/08/2018) • BH223 (30/05/2018 to 22/08/2018)	- BTEXN - Ammonia - Nutrients - pH, EC, TDS, TSS, Turbidity - Major anions and cations	

Notes: [1] Equipped with data logger but data not downloaded at time of this report. [2] Data loggers are currently recording groundwater levels at all bores except BH301 and BH302. [3] Predominantly installed for the gas monitoring.

4.9.2 Project groundwater monitoring bore groundwater level data

Project groundwater monitoring bore details are summarised in **Table 4-4,** with locations provided in **Figure 3-2** and monitoring bore logs and hydrographs provided in **Annexure B** and **Annexure C** respectively.

Manual groundwater level measurements taken in August 2018 and continuous water level logger data are summarised in **Table 4-5**.

Groundwater level trends are summarised as follows:

- Excluding post purging trends, groundwater levels were stable or slowly decreasing throughout the monitoring period at BH104, BH105, BH107, BH112, BH117, BH119, BH134, BH135, BH144, BH202, BH204, BH207, BH209, BH211, BH215, BH217, BH219, BH221, BH223, BH227.
- Groundwater level at BH102 exhibited two gradual increasing trends during the monitoring period due to recovery from purging. Outside of the recovery periods, groundwater level was stable.
- BH145 and BH150 exhibited a gradual increasing trend throughout the data period, which is interpreted to represent slow post purging recovery due to low hydraulic conductivity. Towards the end of the available data period, groundwater level in BH150 is interpreted to have essentially recovered from purging. However, BH145 groundwater level is interpreted to not yet have recovered from purging. BH145 is a key bore for the project because it is in area of relatively deep cut. The groundwater level at BH145 at the end of the available data period represents the maximum level monitored by data logger and was 99.19 metres AHD. Whilst not having recovered to a representative groundwater level in the three month period since purging, once recovered, the representative groundwater level for this monitoring bore is expected to be well below the project’s design level of about 104.6 metres AHD in the vicinity of BH145.

The general stable or declining groundwater level trend exhibited at the majority of project monitoring bores is attributed to low rainfall over the monitoring period.

Table 4-4 Summarised project groundwater monitoring bore details

Location	Easting	Northing	Surface elevation (m AHD)	Screened interval (mBGL)	Target hydrogeological unit
BH102	287043	6251433	92.19	3.00-12.32	Sandstone and siltstone
BH104	287727	6251558	101.11	3.00-17.38	Siltstone and sandstone
BH105	288096	6251589	92.70	3.00-12.10	Sandstone and siltstone
BH107	288575	6251634	94.63	2.00-13.45	Sandstone and siltstone
BH112	289024	6251485	93.78	3.00-21.63	Sandstone and siltstone
BH117	291107	6251013	65.05	2.50-12.35	Silty clay, sandstone and siltstone
BH119	291372	6249710	54.00	2.50-12.05	Silty clay and siltstone
BH134	297252	6248876	57.94	1.50-18.07	Silty clay, siltstone and sandstone
BH135	297594	6248706	60.55	1.00-10.00	Silty clay, siltstone and sandstone
BH139	298273	6248770	101.10	2.00-14.95	Sandstone and siltstone
BH144	298657	6249024	113.50	3.00-20.65	Sandstone and siltstone
BH145	298880	6248989	116.30	3.00-20.00	Sandstone and siltstone
BH150	299108	6249308	109.50	2.00-10.20	Silty clay, siltstone and sandstone
BH155	299535	6249380	121.60	2.00-12.00	Silty clay, siltstone and sandstone
BH162	300514	6249490	118.62	3.00-18.43	Silty clay, sandstone and siltstone
BH170	300394	6248905	92.41	4.36-10.36	Siltstone and sandstone
BH175	299999	6248562	80.34	3.00-19.80	Siltstone and sandstone
BH202	290090	6251218	49.53	2.00-17.93	Silty sandy clay, sandstone and siltstone
BH204	290177	6251195	50.24	3.00-15.43	Gravelly clay, sandstone and siltstone
BH207	292342	6251217	40.03	2.00-17.90	Silty sandy clay, sandstone and siltstone
BH209	292587	6251246	39.36	0.40-18.15	Silty clay, siltstone and sandstone
BH211	293340	6251097	37.72	2.00-18.00	Gravelly clay, siltstone, sandstone
BH215	293615	6251030	37.77	2.00-18.41	Silty clay, siltstone and sandstone
BH217	293817	6251033	40.49	0.50-17.85	Silty clay, clayey silt, sandy clay, gravelly sandy clay, siltstone, sandstone
BH219	296088	6249516	44.46	2.00-18.33	Silty clay, sandstone, siltstone
BH221	296320	6249208	45.24	2.00-18.14	Sandy silt, silty sand, sandy gravel, siltstone and sandstone
BH223	296466	6249150	46.26	2.00-18.28	Silty clay, sandstone, siltstone
BH227	297056	6248945	55.85	2.00-18.11	Silty clay, siltstone and sandstone
BH301	292746	6251171	42.98	0.40-10.50	Silty clay, sandy clay, gravelly clay, siltstone
BH302	292935	6251154	40.54	0.30-10.50	Clayey silt (fill), silty clay, gravelly clay, siltstone

Table 4-5 Summarised project groundwater monitoring bore groundwater level data

Bore ID	Manual groundwater level m AHD (late August, 2018)	Data logger minimum groundwater level (m AHD)	Data logger mean groundwater level (m AHD)	Data logger maximum groundwater level (m AHD)	Data logger period used to derive minimum, mean and maximum groundwater levels
BH102	83.60	83.32	83.51	83.60	31/03/2018 to 24/09/2018, 09/11/2018 to 15/01/2019
BH104	91.72	90.97	91.50	91.84	03/03/2018 to 21/08/2018, 03/09/2018 to 15/01/2019
BH105	81.29	81.11	81.36	85.56	07/03/2018 to 15/01/2019
BH107	83.93	83.75	83.87	83.99	12/05/2018 to 21/08/2018
BH112	75.99	75.92	75.97	76.01	14/05/2018 to 21/08/2018
BH117	NA - no data	60.36	60.59	60.79	12/05/2018 to 22/08/2018
BH119	52.57	52.55	52.90	53.32	16/02/2018 to 21/08/2018
BH134	54.40	54.36	54.50	54.77	16/02/2018 to 21/08/2018
BH135	58.17	58.17	58.58	59.22	18/02/2018 to 21/08/2018
BH139	NA - dry	NA - dry	NA - dry	NA - dry	NA - dry
BH144	94.09	93.87	94.04	94.11	29/05/2018 to 22/08/2018
BH145	99.17	98.66	98.95	99.19	03/06/2018 to 22/08/2018
BH150	105.17	104.72	105.03	105.19	12/05/2018 to 27/08/2018
BH155	NA - no data	110.75	110.79	110.83	01/06/2018 to 27/08/2018
BH162	112.80 (04/09/2018)	NA – no data available at time of report	NA – no data available at time of report	NA – no data available at time of report	NA – no data available at time of report
BH170	87.94 (04/09/2018)	NA – no data available at time of report	NA – no data available at time of report	NA – no data available at time of report	NA – no data available at time of report
BH175	74.62 (04/09/2018)	NA – no data available at time of report	NA – no data available at time of report	NA – no data available at time of report	NA – no data available at time of report
BH202	47.27	47.21	47.36	47.79	12/05/2018 to 21/08/2018
BH204	48.02	47.99	48.20	48.33	12/05/2018 to 21/08/2018
BH207	35.59	35.57	35.68	35.80	12/05/2018 to 21/08/2018
BH209	35.75	35.73	35.79	35.85	18/06/2018 to 21/08/2018
BH211	35.47	35.46	35.51	35.55	18/06/2018 to 21/08/2018
BH215	34.30	34.29	34.36	34.41	18/06/2018 to 21/08/2018
BH217	35.10	35.09	35.13	35.21	18/06/2018 to 21/08/2018
BH219	41.88	41.87	42.04	42.15	30/05/2018 to 21/08/2018

Bore ID	Manual groundwater level m AHD (late August, 2018)	Data logger minimum groundwater level (m AHD)	Data logger mean groundwater level (m AHD)	Data logger maximum groundwater level (m AHD)	Data logger period used to derive minimum, mean and maximum groundwater levels
BH221	41.44	41.42	41.48	41.52	30/05/2018 to 21/08/2018
BH223	43.16	43.06	43.17	43.23	01/06/2018 to 22/08/2018
BH227	53.95	53.89	53.94	53.97	04/07/2018 to 22/08/2018
BH301 (primarily gas monitoring bore)	NA - no data	NA – no logger	NA – no logger	NA – no logger	NA – no logger
BH302 (primarily gas monitoring bore)	NA - no data	NA – no logger	NA – no logger	NA – no logger	NA – no logger

4.9.3 Registered groundwater bores

The Bureau of Meteorology's (BOM) Australian Groundwater Explorer (BOM, 2018a) was reviewed to investigate registered groundwater bores and associated groundwater level records in the region of the project. The review identified 38 registered groundwater bores (**Table 4-6**) within the study area. No water level records were available for the bores. Registered groundwater bores are shown in **Figure 4-3**, with available groundwater bore lithology logs provided in **Annexure D**.

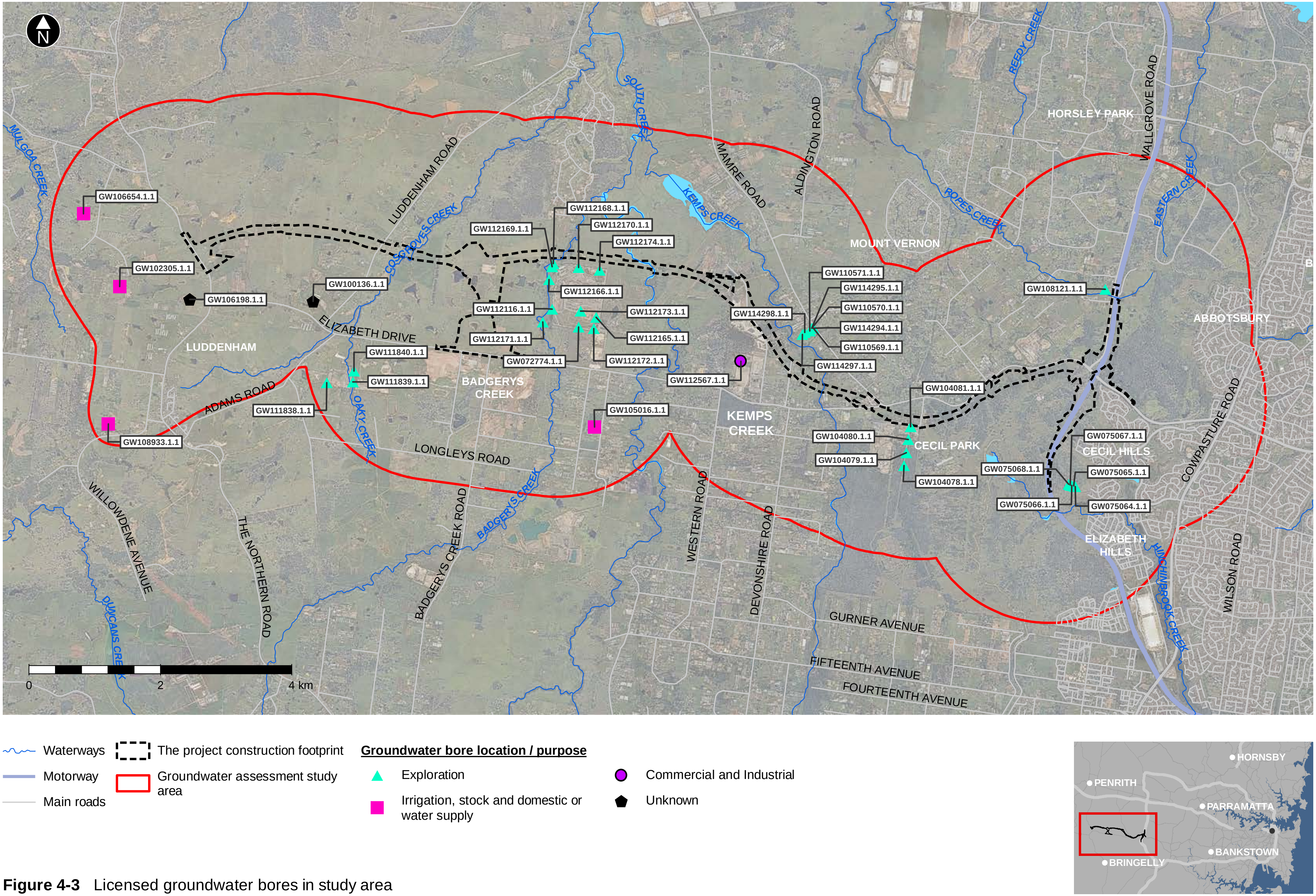
Five of the 38 bores had a purpose relating to water supply (ie irrigation, stock and domestic, water supply or commercial/industrial) and based on reported bore depth, three of these five bores are inferred to be accessing Hawkesbury Sandstone groundwater systems. The closest of these five bores relating to water supply is offset from the construction footprint by about 400 metres.

Table 4-6 Summary of registered groundwater bores in region of project (BOM, 2018a)

Bore ID	Purpose	Approximate surface level (m AHD)	Bore depth (m)	Standing water level m AHD (m BGL)
GW108933.1.1	Irrigation	82.5	268	ND
GW075068.1.1	Monitoring	69.0	10	ND
GW110571.1.1	Monitoring	45.4	12	ND
GW102305.1.1	Stock	78.0	61	ND
GW105016.1.1	Water supply	61.8	253	ND
GW072774.1.1	Exploration	54.6	30	ND
GW100136.1.1	Unknown	65.1	111	ND
GW110570.1.1	Monitoring	45.7	12	ND
GW110569.1.1	Monitoring	45.8	6	ND
GW075065.1.1	Monitoring	77.9	6	ND

Bore ID	Purpose	Approximate surface level (m AHD)	Bore depth (m)	Standing water level m AHD (m BGL)
GW075066.1.1	Monitoring	73.3	6	ND
GW075064.1.1	Monitoring	77.9	5	ND
GW108121.1.1	Monitoring	99.6	246	ND
GW106654.1.1	Irrigation	73.2	252	ND
GW104078.1.1	Monitoring	62.1	30	ND
GW075067.1.1	Monitoring	71.3	9	ND
GW104079.1.1	Monitoring	65.1	30	ND
GW104081.1.1	Monitoring	67.5	30	ND
GW104080.1.1	Monitoring	64.7	30	ND
GW106198.1.1	Unknown	86.9	268	ND
GW111838.1.1	Exploration	ND	30.0	ND
GW111839.1.1	Exploration	ND	30.4	ND
GW111840.1.1	Exploration	ND	30.7	ND
GW112168.1.1	Exploration	ND	26.5	ND
GW112169.1.1	Exploration	ND	16.6	ND
GW112166.1.1	Exploration	ND	32.3	ND
GW112116.1.1	Exploration	ND	23.4	ND
GW112171.1.1	Exploration	ND	32.0	ND
GW112170.1.1	Exploration	ND	26.9	ND
GW112173.1.1	Exploration	ND	24.0	ND
GW112174.1.1	Exploration	ND	22.0	ND
GW112165.1.1	Exploration	ND	35.0	ND
GW112172.1.1	Exploration	ND	36.5	ND
GW112567.1.1	Commercial and Industrial	ND	20.0	ND
GW114297.1.1	Exploration	ND	8.0	ND
GW114298.1.1	Exploration	ND	7.0	ND
GW114294.1.1	Exploration	ND	6.0	ND
GW114295.1.1	Exploration	ND	6.0	ND

Notes: [1] *ND = no data.*



Waterways	The project construction footprint	**Groundwater bore location / purpose**
Motorway	Groundwater assessment study area	▲ Exploration
Main roads		■ Irrigation, stock and domestic or water supply
		● Commercial and Industrial
		⬟ Unknown

Figure 4-3 Licensed groundwater bores in study area

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4.9.4 Main groundwater systems

Based on project geological conditions, project groundwater investigations and registered groundwater works, two main groundwater system types exist in the study area:

- Unconfined to semi confined alluvial groundwater systems associated with Cosgroves Creek, Badgerys Creek, South Creek and Kemps Creek, which the project alignment crosses
- Semi confined groundwater systems within the bedrock (Wianamatta Group Shale and Hawkesbury Sandstone).

These groundwater system types are described in the following sections.

Alluvial groundwater systems

As outlined in **Section 4.4**, with the exception of Ropes Creek, project boreholes adjacent to the project's creek crossings encountered alluvial clays, silts, sands and gravels above the bedrock, which occurred at depths ranging from about 2.5 to 7.0 metres BGL. Therefore, the alluvium deposits are relatively thin (ie less than seven metres) and predominantly clayey. Based on geological mapping (Geological Survey of NSW, 1991) within the study area, the widths of the alluvium deposits are of the order of 300 metres, 700 metres, one kilometre and 500 metres for Cosgroves Creek, Badgerys Creek, South Creek and Kemps Creek respectively.

The alluvial deposits are considered to be of insufficient thickness and hydraulic conductivity to be capable of providing a potential water supply. Flow directions are anticipated to be similar to a subdued reflection of the topographic surface. Therefore, it is likely that the alluvial groundwater systems are in some degree of hydraulic connection with the associated watercourses.

Current project groundwater monitoring bore data indicates that the water table depth in the area of the alluvial deposits ranges from about two metres BGL to five metres BGL.

Bedrock groundwater systems

The bedrock groundwater systems are characterised as semi confined dual porosity systems (granular flow and fracture flow). The upper major hydrostratigraphic unit comprises Wianamatta Shale which overlies a lower major hydrostratigraphic unit consisting of Hawkesbury Sandstone.

The Wianamatta Shale Group comprises Bringelly Shale, Minchinbury Sandstone and Ashfield Shale, which exist in that stratigraphic order. The base of the Wianamatta Group and top of the Hawkesbury Sandstone is anticipated to be at a level of the order of -40 metres AHD to -65 metres AHD in the study area.

Based on the project's maximum cut depth of about 15 metres BGL, the Wianamatta Group's upper formation of Bringelly Shale is the only rock formation anticipated to be encountered by project excavations. As such, and given the base of the Bringelly Shale formation is anticipated to be substantially lower than the project's vertical alignment, groundwater flow systems within the Bringelly Shale are considered to be the main bedrock groundwater flow systems relevant to the project.

Groundwater flow directions are anticipated to be similar to a subdued version of the topographic surface. Current project groundwater monitoring bore data indicates that the water table in the Bringelly Shale (including associated overlying residual clay) ranges from about one metre BGL to 19 metres BGL.

4.9.5 Groundwater quality

Groundwater quality has been assessed with respect to groundwater salinity mapping, project specific groundwater quality monitoring and groundwater contamination and is discussed below.

Salinity mapping and registered bore salinity

Sydney Basin groundwater salinity mapping (Russel et al., 2009) in the study area indicates that the Wianamatta Group groundwater systems have salinity concentrations of the order of 5000 to 10,000 mg/L, which is considered ‘unpalatable’ (NHMRC, 2011) for humans and generally likely to result in a decline in livestock production and condition (based on the upper 10,000 mg/L concentration). Salinity mapping (Russel et al., 2009) in the study area indicates that the Hawkesbury Sandstone groundwater systems have salinity concentrations of the order of 3000 to 5000 mg/L, which is considered ‘unpalatable’ (NHMRC, 2011) for humans and of a sufficiently low concentration such that most livestock types are able to adapt to this concentration without loss of production. At the upper end of the mapped concentration range (ie 5000 mg/L), dairy cattle production and condition would likely decline whilst poultry would likely not be able to tolerate this concentration, even if introduced gradually. Beyond the western extent of the study area, the mapped Hawkesbury Sandstone groundwater salinity decreases to 1000 to 3000 mg/L.

Of the 38 registered groundwater works, only three bores had reported salinity concentrations. Concentrations were 4200 mg/L (bore ID GW105016.1.1), 950 mg/L (bore ID GW108121.1.1) and 1500 mg/L (bore ID GW106654.1.1). These three bores had depths of 252.5 metres, 246 metres and 252 metres respectively and therefore are inferred to be accessing Hawkesbury Sandstone groundwater systems.

Project monitoring bore water quality data

Project groundwater monitoring bores were sampled once in August, 2018 and laboratory tested for a range of analytes. Ten bores were sampled, which included BH104, BH112, BH145, BH202, BH207, BH209, BH217, BH223, BH301 and BH301. Analytes included heavy metals, major cations and anions, nutrients, hydrocarbons, benzene toluene ethylbenzene xylenes and naphthalene (BTEXN) and polycyclic aromatic hydrocarbons (PAHs). Field parameters were taken using a water quality probe at the time of sampling.

Groundwater quality results are summarised in **Annexure F**, represented in a piper plot in Figure 2, **Annexure A** and documented in a laboratory certificate of analysis in **Annexure G**. The summary in **Annexure F** compares site analyte concentrations to the Australian Drinking Water Guidelines (ADWG) (NHMRC, 2015), the ANZECC Water Quality Guidelines trigger values for the protection of 95 per cent of freshwater species and ANZECC Water Quality Guidelines trigger values for lowland rivers.

Based on the data collected, the following general key points are noted:

- The piper plot indicates groundwater type is sodium chloride
- ADWG (2015) aesthetic criteria were exceeded for chloride, sodium and total dissolved solids
- Total dissolved solids ranged from 2650 mg/L to 19,500 mg/L, with an average value of 11,595 mg/L. These values correspond to saline to highly saline water.

Groundwater contamination

In relation to groundwater contamination and project groundwater quality laboratory results, the following summary points are noted:

- The majority of project groundwater bore copper and zinc concentrations exceeded the ANZECC Water Quality Guidelines for the protection of 95 per cent of freshwater species, with three locations either exceeding or equalling the trigger value for nickel
- Samples from three bores exceeded the ANZECC Water Quality Guidelines for the protection of 95 per cent of freshwater species for ammonia
- Samples from three bores exceeded the ANZECC Water Quality Guidelines trigger value for lowland rivers for total nitrogen
- ADWG (2015) health criteria were exceeded for arsenic at two bores and for nickel at one bore.

Appendix O of the EIS concludes that:

- The elevated heavy metal and nutrient concentrations in groundwater may be associated with the widespread agricultural land use in the area, the Elizabeth Drive landfill facility and potential areas of fill within the construction footprint, or alternatively represent background concentrations
- Contaminated groundwater has the potential to impact on construction activities such as bridge construction and excavations which reach depths to groundwater
- Releases of groundwater off site into the surrounding environments would also need to be managed through the CEMP to protect surrounding surface and groundwater environments.

4.9.6 Sensitive receiving environments

Sensitive receiving environments (SREs) relevant to this groundwater assessment include the potential aquatic and terrestrial GDEs (discussed in **Section 4.8**) plus the following waterways and/or waterbodies which were identified as SREs from a surface water perspective:

- Cosgroves Creek
- Badgerys Creek
- South Creek
- Kemps Creek
- Hinchinbrook Creek
- Unnamed tributary of Hinchinbrook Creek
- Doujon Lake
- SEPP Coastal Wetlands (ID113, ID114, ID117)
- Hinchinbrook Creek at the downstream SEPP coastal wetland ID276.

These SREs are relevant to the groundwater and hydrology assessment due to the potential for surface water/groundwater interactions. Further information about the classification of the SREs is available in Appendix M of the EIS.

4.9.7 Project bore hydraulic conductivity

Hydraulic testing results are summarised in **Table 4-7** with analysis plots provided in **Annexure E**. The following conclusions are made:

- The average and maximum hydraulic conductivity for bores screened in the Bringelly Shale was 0.002 m/d and 0.005 m/d respectively, which is within ranges cited in the literature (Hewitt, 2005) for Bringelly Shale.
- The average and maximum hydraulic conductivity for bores which had some of the screen interval within alluvial material was 0.017 m/d and 0.023 m/d respectively. The alluvial hydraulic conductivity values are an order of magnitude higher than the those from the bores screened in the Bringelly Shale.

Table 4-7 Summarised hydraulic testing results

Project groundwater monitoring bore ID	Screened material	Estimated hydraulic conductivity (m/d)	Analysis method
BH104	Below the water table, the screened material comprises sandstone	0.005	Rising head analysed using Hvorslev method
BH112	Below the water table, the screened material comprises siltstone and interbedded siltstone and sandstone	0.001	Rising head analysed using Hvorslev method
BH145	Below the water table, the screened material comprises interbedded siltstone and sandstone, siltstone and sandstone	5×10^{-5}	Rising head analysed using Hvorslev method
BH202	Below the water table, the screened material comprises silty sandy clay, interbedded siltstone and sandstone, siltstone and sandstone	0.010	Falling head analysed using Hvorslev method
BH217	Below the water table, the screened material comprises sandy clay, gravelly sandy clay, silty clay, siltstone and interbedded siltstone and sandstone	0.023	Rising head analysed using Hvorslev method

4.10 Cultural groundwater values

There are no high priority culturally significant sites listed in the schedule of the WSP. Historically, a natural spring fed watercourse located about 300 metres east of Badgerys Creek within the project construction and operational footprints may have been an important water source for past communities during the drier cycles of seasonal variation (Appendix I of the EIS). This natural spring has now been in-filled by land practices. Therefore, cultural values are not considered applicable to the project.

4.11 Conceptual hydrogeological model

The conceptual hydrogeological model for the alluvial groundwater systems is summarised as follows:

- Groundwater flow direction similar to broad topography trend
- Low hydraulic gradient of less than one per cent
- Unconfined to semi confined groundwater systems
- Low hydraulic conductivity predominantly clayey sediments, with areas of moderate hydraulic conductivity material comprising sands and gravels
- Variable specific yield (Sy) ranging from about 0.05 to 0.15
- Up to seven metres thickness
- Saline to highly saline
- Low recharge by rainfall and possible minor upward leakage from the underlying Bringelly Shale groundwater systems in the region of major drainage lines
- Underlain by a semi confined Bringelly Shale groundwater system
- Generally, not used as a water supply source
- Shallow water table depth of about two to five metres BGL.

The conceptual hydrogeological model for Bringelly Shale groundwater system is summarised as follows:

- Groundwater flow direction similar to broad topography trend
- Low hydraulic gradient of up to about three per cent
- Semi confined
- Low hydraulic conductivity material with hydraulic conductivity ultimately dependent on fracture/defect extent
- Specific yield (Sy) of the order of 0.01 to 0.04
- Underlain by Minchinbury Sandstone, Ashfield Shale and Hawkesbury Sandstone groundwater systems, with the latter expected to commence at about -40 metres AHD to -65 metres AHD
- Saline to highly saline
- Low recharge by rainfall
- Generally, not used as a water supply source, likely due to low anticipated yields in the order of 0.3 to one litre per second, and due to salinity
- Transmits minor leakage to underlying groundwater systems with localised areas of upward leakage where overlain by alluvium in the region of major drainage lines
- Variable water table depth of about one metre to 19 metres BGL, with depth to the water table generally greater than that for the alluvial groundwater systems.

A conceptual hydrogeological cross section is provided in **Figure 4-4**.

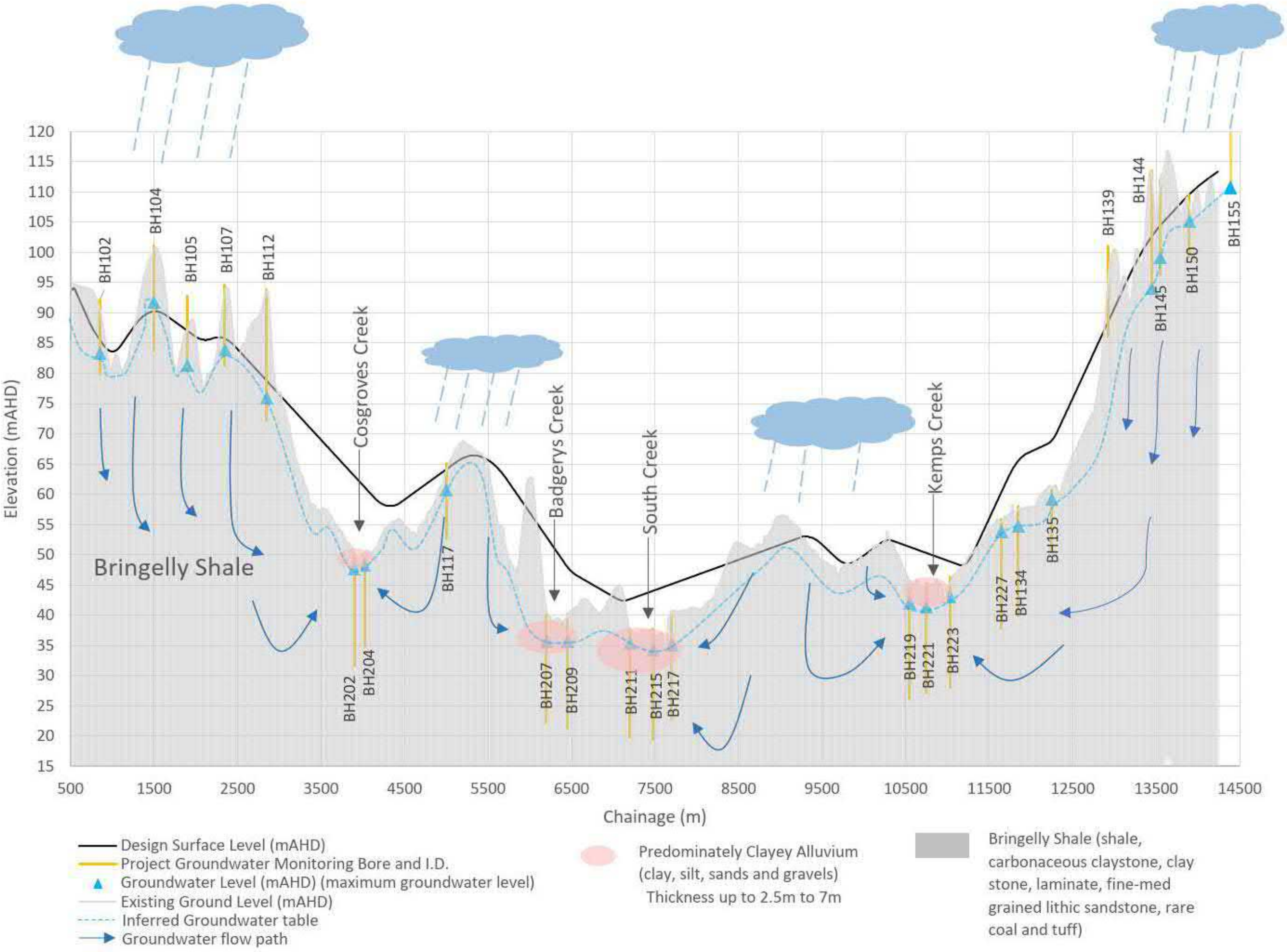

Figure 4-4 Conceptual hydrogeological cross section

5. Assessment of potential impacts

5.1 Construction impacts

The project would utilise a potable water supply during construction for a range of purposes including (but not limited to) dust suppression, earthworks compaction, wheel washing, machinery, concrete/asphalt batching plants, curing structures and onsite amenities. Groundwater would not be utilised for these purposes.

The project construction footprint is shown in **Figure 3-1**.

5.1.1 Groundwater inflows

Potential groundwater inflow zones

Review of plotted maximum observed groundwater levels relative to the project's road design levels (Figure 1, **Annexure A**) and inferred groundwater levels (**Figure 4-4**) indicates that there is one area of cut likely to intersect the water table. The area of cut is located approximately 1.5 kilometres east of The Northern Road and is hereafter referred to as the 'western cut' (**Figure 5-1**).

The western Cut is a focus of the assessment because data indicates this cut will likely intersect the water table. As demonstrated by **Figure 4-4**, there are areas where the inferred groundwater level is relatively close (ie about 0.5 metres to 1 metres) to the project's road design level, including between South Creek and Kemps Creek and between Cosgroves Creek and Badgerys Creek.

With respect to the area between South Creek and Kemps Creek, cut depth in the location where the inferred groundwater level is closest to the project's road design level is about five metres. For bores on ridges, such as BH104, BH105, BH107, BH112, BH144 and BH145, the average minimum depth to groundwater was 13.9 metres. This is well below the cut depth of five metres and therefore cuts in between South Creek and Kemps Creek are not anticipated to intersect the water table.

Maximum groundwater levels were relatively close (about 2.5 metres) to the existing ground level in the vicinity of BH134, BH135 and BH227. However, cut is not proposed in this area (fill is proposed) and therefore the water table won't be intersected.

Maximum groundwater level is relatively close (about 1.25 metres) to the project's road design level on the high point between Cosgroves Creek and Badgerys Creek. However, the proposed cut at this location is only about 3.5 metres and therefore intersection of the water table is unlikely.

The current quantity and distribution of project groundwater monitoring bores is considered suitable to assess impacts of the project on groundwater given the low value of the groundwater resource, low magnitude of potential drawdown and anticipated negligible impacts.

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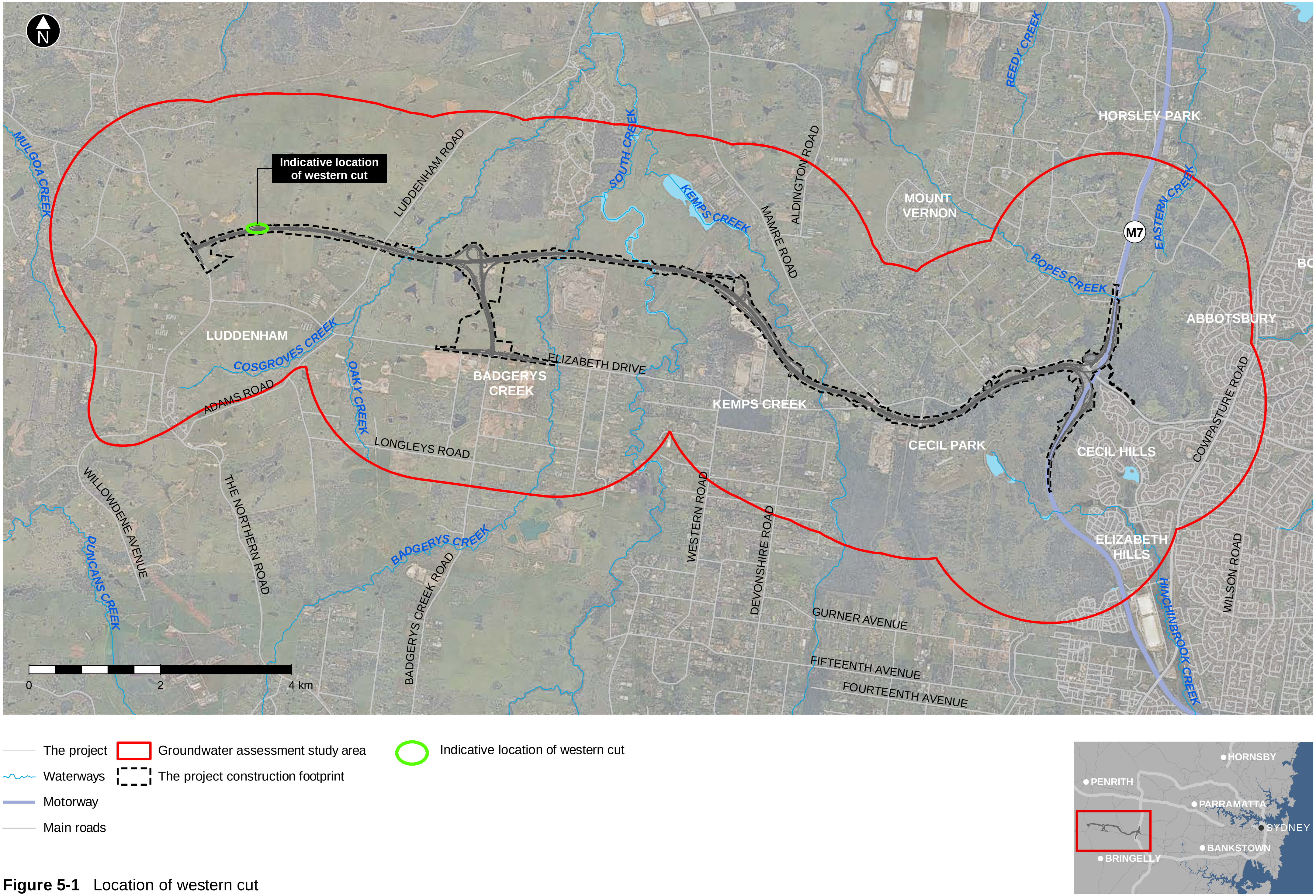

Figure 5-1 Location of western cut

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Created by : HK | QA by : AA

Western cut seepage face height and area

Prior to potential water table lowering due to groundwater seepage interception, the western cut base would be about 1.61 metres below the groundwater level. This is calculated by subtracting the road design level of 90.23 metres AHD from the maximum groundwater level monitored by data logger of 91.84 metres AHD at BH104. To account for long term drawdown at the cut face (due to drainage), for the purpose of inflow estimation, a long term seepage face height of 0.5 metres is adopted. This equates to 1.11 metres of drawdown at the cut face.

The western cut would potentially intersect the water table over a distance of about 250 metres on each side of the proposed motorway, giving a total cut length below the water table of about 500 metres.

Long-term seepage face cross sectional area is based on the total saturated cut length multiplied by the assumed long-term seepage face height. Therefore, long-term seepage face cross sectional area is 250 metres squared (500 x 0.50).

Western cut hydraulic conductivity

To account for uncertainty and incorporate sensitivity analysis into the assessment, three different hydraulic conductivity values were adopted to represent the Bringelly Shale in the region of the cut:

- The project's maximum Bringelly Shale hydraulic conductivity estimate from slug tests (0.005 m/d)
- Upper literature (Hewitt, 2005) bulk value for weathered Wianamatta Group Shale hydraulic conductivity (0.09 m/d)
- Mid-range literature (Hewitt, 2005) bulk value for weathered Wianamatta Group Shale hydraulic conductivity (0.04 m/d).

Western cut groundwater gradients

To account for uncertainty and incorporate sensitivity analysis into the assessment, three different groundwater gradients were applied in the region of the cut:

- Low gradient (0.04 m/m)
- Medium gradient (0.10 m/m)
- High gradient (0.30 m/m).

Western cut estimated groundwater inflows

Estimated groundwater inflows into the western cut for the full range of parameters that were adopted to account for uncertainty and incorporate sensitivity analysis are summarised in **Table 5-1**. The estimated maximum groundwater inflow from the total parameter set was 6.75 kilolitres per day.

Table 5-1 Estimated groundwater inflow scenarios

Location	Adopted hydraulic conductivity (m/d)	Adopted gradient (m/m)	Adopted long-term seepage face cross sectional area (m²)	Estimated groundwater inflow (kL/d)	Estimated groundwater inflow (ML/yr)
Western cut	0.04	0.04	250	0.40	0.15
Western cut	0.04	0.10	250	1.00	0.37
Western cut	0.04	0.30	250	3.00	1.10
Western cut	0.09	0.04	250	0.90	0.33
Western cut	0.09	0.10	250	2.25	0.82

Location	Adopted hydraulic conductivity (m/d)	Adopted gradient (m/m)	Adopted long-term seepage face cross sectional area (m²)	Estimated groundwater inflow (kL/d)	Estimated groundwater inflow (ML/yr)
Western cut	0.09	0.30	250	6.75	2.46
Western cut	0.005	0.04	250	0.05	0.02
Western cut	0.005	0.10	250	0.13	0.05
Western cut	0.005	0.30	250	0.38	0.14

Western cut potential groundwater inflow evaporation

If the western cut is exposed, based on the seepage face area plus allowance for a 0.5 metres wide strip at the base of the cut for drainage, the total evaporative surface area would be 500 square metres. Based on a mean daily evaporation rate of 2.9 millimetres, this would lead to evaporation of about 1.45 kL/d, which is greater than the majority of estimated groundwater inflows (Error! Reference source not found.). Therefore, large proportions of the estimated groundwater inflows are anticipated to readily evaporate.

Western cut groundwater inflow implications

Regardless of whether evaporation of groundwater inflow is considered, which is greater than the majority of estimated groundwater inflows, the estimated maximum groundwater inflow from the total parameter set is 6.75 kilolitres per day, which represents a very low groundwater inflow rate.

The rate of seepage through the face of the cut would decrease as the groundwater system reaches equilibrium. The time period until equilibrium conditions are achieved is anticipated to be in the range of months up to say a year. Groundwater inflow rates at any time during the construction and operation phases of the project would be sufficiently low such that there would be no impacts to environments that would receive the potential discharge. Groundwater licensing implications are discussed in **Section 5.1.8** whilst implications of discharging the intercepted groundwater are discussed in **Section 5.1.9**

5.1.2 Groundwater levels

Western cut

As outlined in **Section 5.1.1**, the western cut base is likely to be up to about 1.61 metres below the groundwater level. To provide a conservative groundwater drawdown impact assessment, if no long-term seepage face is assumed (ie water levels are drawn down to level of road), the maximum potential change to groundwater level is estimated to be a decrease of up to about 1.61 metres. This maximum change, if it eventuated, would occur at the base of the cut. Moving away from the cut, the magnitude of the change in groundwater level would reduce until groundwater levels were no longer being influenced by the cut.

This extent of influence is estimated using the Cooper-Jacob (1946) equation:

Radius of influence (m) = $(2.25Tt/S)^{0.5}$, where

T = transmissivity (m^2/d)
t = time (d)
S = storage

Transmissivity is assigned a value based on the full saturated cut height of 1.61 metres multiplied by the highest hydraulic conductivity scenario value of 0.09 m/d, which leads to conservative assessment.

Time is assigned a value of 365 days, which is considered sufficient time to enable steady state (ie equilibrium) conditions to be reached given the maximum drawdown is very small (1.61 metres). Seward et.al (2014) investigated a spatial approach to management of groundwater pumping wells using radius of influence and concluded that a five year period was appropriate for their study to determine a radius of influence. A reduced period of 365 days is chosen since the maximum drawdown caused by the project would be very small compared to drawdowns in pumping wells that Seward et.al (2014) investigated.

Storage is assigned a value of 0.03 to represent a specific yield (ie drainable porosity) for the Bringelly Shale.

Based on the above equation and associated parameter values, the extent of influence associated with the cut is determined to be about 60 metres. Based on regional experience, the maximum drawdown at the cut of 1.61 metres is considered within the bounds of natural variability that would occur in response to changing long-term climate conditions. Notwithstanding this, the implications of groundwater level drawdown within this zone of influence is assessed for GDEs, existing groundwater bores, surface water-groundwater interactions and surround land uses in **Section 5.1.4** to **Section 5.1.7**.

Areas of fill placement

There is a potential for the surcharge loading associated with fill placement and the resulting increase in effective stress to cause short-term increases to groundwater levels in areas of fill placement, and/or permanent increases to groundwater levels if the increased stress permanently alters the hydraulic conductivity of the underlying water-bearing ground.

This risk is applicable to relatively soft soils, and is not expected to occur in areas where the water table lies within the rock.

The potential increases in groundwater levels due to surcharge loading are expected to be very small, and limited to areas in the vicinity of fill placement.

Spring

Historically, a natural spring fed watercourse located about 300 metres east of Badgerys Creek within the project construction and operational footprints may have been an important water source for past communities during the drier cycles of seasonal variation (Appendix I of the EIS). This natural spring has now been in-filled by land practices. Despite being infilled, the location of the spring should be considered in the project’s detailed design due to the engineering and construction implications (eg potentially soft subgrades).

Other areas

Potential groundwater level changes in areas outside of the western cut’s extent of influence and areas of fill placement are anticipated to be negligible. Potential minor localised changes in the vicinity of bridge piles are discussed in **Section 5.1.6**.

5.1.3 Groundwater quality

There is minimal potential for groundwater quality to be impacted by the project during construction. Groundwater quality may be impacted during the construction phase by:

- Accidental spills or leakages of hazardous materials (such as fuels, lubricants and hydraulic oils) due to runoff and subsequent recharge, which is discussed in **Section 5.1.10**
- Recharge from project stormwater basin exfiltration, if the chemistry of the exfiltration water is different from that of the background recharge water quality
- Construction works that may mobilise contaminants (if present). This could occur due to locally altered flow directions due to dewatering of the western cut, or due to bridge piling excavations, which may increase the vertical connectivity between local groundwater systems, which is discussed in **Section 5.1.10**.

The above potential risks were assessed and determined to represent a low risk because:

- Potential impacts from accidental spills or leaks can be mitigated by measures identified in **Section 7**
- The chemistry of stormwater basin exfiltration water is not anticipated to be materially different from that of the background recharge water quality
- Changes to groundwater flow directions as a result of dewatering the western cut are estimated to be limited to within 60 metres of the cut, and groundwater quality in this location does not indicate a risk to human health
- Bridge piling is not anticipated to mobilise potential contaminants beyond the local vicinity of the pile because potential changes to groundwater levels are anticipated to be negligible, and because the pile bore would only be open temporarily before being filled with concrete.

The project is not anticipated to lower the beneficial use category of the groundwater system and is expected to have a neutral effect on groundwater quality.

5.1.4 Groundwater dependent ecosystems

The nearest mapped GDE to the western cut is about 240 metres away, which is outside the calculated extent of groundwater level reduction of about 60 metres (**Section 5.1.2**). Therefore, groundwater level changes caused by cut dewatering are not expected to occur in the areas of mapped GDEs.

5.1.5 Groundwater bores

The nearest registered groundwater bore used for water supply is about 1.9 kilometres from the western cut. This bore is outside the anticipated extent of influence of the western cut (**Section 5.1.2)** and therefore groundwater level impacts to surrounding groundwater supply bores would not occur.

The project is not anticipated to result in a change in groundwater quality which would lower the beneficial use category. Therefore, groundwater quality impacts to surrounding groundwater bores are not anticipated.

5.1.6 Surface water-groundwater interactions

As outlined in **Section 5.1.2**, groundwater level changes from potential western cut dewatering would be localised to within about 60 metres of the cut, which is sufficient distance from alluvial groundwater systems to avoid impacts. Additionally, negligible groundwater inflows are predicted and such flows would be subjected to high proportions of evaporative loss (**Section 5.1.1**). As a result, groundwater discharges are expected to be negligible. Therefore, potential cut dewatering would not impact alluvial systems and associated surface water-groundwater interactions.

The project has the potential to cause minor localised water table changes in areas where bridge footings extend beneath the water table. Deep footings which extend beneath the groundwater table in the alluvial material may lead to a minor, localised and short-term increase in groundwater level up-gradient of the footing due to flow obstruction. The reverse is expected to occur down-gradient of the footing. Such changes are not expected to affect the local groundwater flow system or alter groundwater-surface water exchange in the region of the creeks, as piled footings would readily accommodate local groundwater flow diversion around the pile. As such, no impacts regarding surface water-groundwater interactions are expected.

5.1.7 Surrounding land uses

No groundwater related impacts to surrounding land uses are expected. This is because changes to groundwater levels would be restricted to within about 60 metres of the western cut and even in this location, where the potential change in groundwater level would be highest, reduced groundwater levels are expected to still be within the bounds of natural variability. Additionally, the project is not anticipated to result in a change in groundwater quality which would lower the beneficial use category or exacerbate existing salinity (groundwater or soil) conditions.

5.1.8 Groundwater take and licensing

Permanent dewatering in the form of seepage collection from the western cut would ordinarily require a water use approval, a water supply work approval and a WAL. If the dewatering was temporary and occurred only during construction, then ordinarily a water supply work approval would be required. However, as discussed in **Section 2.1**, the project is exempt from the need for water use approval, a water supply work approval and a WAL.

For the purpose of assigning a volume for water accounting, a take of 2.46 ML/yr would be considered conservative since it accommodates the maximum estimated groundwater inflow calculated from the range of parameter set scenarios (**Table 5-1**). It is noted that the entire range of estimated groundwater inflows into the western cut are very low to negligible.

5.1.9 Soil and groundwater salinity

The main potential salinity risk is the project causing water table levels to rise, or project excavations resulting in a reduced depth to the water table. The project is not anticipated to raise water table levels during construction due to the following:

- The project construction footprint currently generally comprises grassland with extremely limited deep rooted vegetation. Therefore, evapotranspiration rates will not decrease due to removal of deep rooted vegetation during construction
- The construction footprint is generally compromised of low permeability material which has limited infiltration potential. Therefore, when exposed, and particularly after inadvertent and intentional compaction, increased infiltration is not anticipated

- Low lying areas, which based on mapping (**Section 4.6**) are likely to be relatively saline, will generally be filled with low permeability material, limiting infiltration potential in these areas
- Dust suppression water applied during construction would have low salinity and would be applied at rates which would not cause the water table to rise.

Areas where excavation during construction will lead to a reduced depth to groundwater are limited. In general, areas with an existing relatively shallow water table will be filled and therefore the depth to groundwater will be increased.

Based on the above, the project would have negligible impacts on soil and groundwater salinity during construction.

5.1.10 Groundwater contamination

Existing groundwater quality is discussed in **Section 4.9.5** with groundwater contamination implications discussed fully in Appendix O of the EIS and summarised below.

The following groundwater contamination related risks are considered potentially relevant to project construction works:

- Accidental spills or leakages of hazardous materials (such as fuels, lubricants and hydraulic oils) during the construction phase of the project have the potential to result in groundwater contamination (ie through runoff and subsequent recharge).
- If groundwater is contaminated, construction workers coming into contact with contaminated groundwater may be subjected to a human health risk.
- Construction works may mobilise contaminants towards SREs. This could occur through discharge of groundwater from the cut below the water table (ie the western cut) or through bridge piling excavations, which may increase the vertical connectivity between local groundwater systems.

The above potential risks were assessed and determined to represent a low risk.

Potential impacts from accidental spills or leaks can be mitigated by measures identified in **Section 7**.

Only one cut, the western cut, is expected to extend below the water table. The Discharge from this cut is estimated to be negligible, with substantial proportions of the discharge expected to evaporate (**Section 5.1.1**). For six out of nine parameter sets, the anticipated evaporation volume exceeds the estimated groundwater inflow rate. For the remaining three estimated inflow rates, the proportion of evaporation to the estimated groundwater inflow rates ranges from 21 per cent to 64 per cent.

Groundwater quality data from the bore (BH104) near this cut does not indicate a risk to human health. Potential discharge of groundwater from the cut below the water table is not anticipated to impact SREs.

Zinc concentration at BH104 (9 µg/L) was only 1 µg/L above the ANZECC Water Quality Guidelines freshwater 95 per cent protection value of 8 µg/L. Copper concentration at BH104 (10 µg/L) was only marginally above the ANZECC Water Quality Guidelines freshwater 95 per cent protection value of 1.4 µg/L. Whilst the zinc and copper concentrations exceeded the ANZECC Water Quality Guidelines freshwater 95 per cent level at BH104, so did most of the other tested project groundwater monitoring bores. Therefore, existing potential baseflow contributions from groundwater to surface water systems are likely currently elevated above the ANZECC Water Quality Guidelines. Appendix M of the EIS concluded that overall the existing water quality of creeks within the study area is poor due to low dissolved oxygen concentrations and elevated nutrients, and that some creeks had elevated metal concentrations.

Bridge piling is not anticipated to mobilise potential contaminants beyond the local vicinity of the pile because potential changes to groundwater levels are anticipated to be negligible, and because once the pile concrete is cured, potential hydraulic connection between different groundwater zones would be limited. Additionally, pile spoil comprising groundwater and soil/rock would be waste classified before being disposed offsite or reused onsite.

5.1.11 Utilities

Relocation of existing utilities and installation of additional utilities and services would be required for the project. Excavation depths for utilities would be confirmed during detailed design but are expected to typically be in the range of 0.3 metres to 1.2 metres for the project. Given that the minimum depth to groundwater is typically about two metres, such works are not anticipated to impact groundwater systems given the typical shallow depths of utilities.

5.2 Operational impacts

The project operational footprint is shown in **Figure 5-2**.

5.2.1 Groundwater inflows

Groundwater inflows during operation are not anticipated to differ from those likely to occur during construction (**Section 5.1.1**). If anything, operational inflows into the western cut would be less than during construction due to reduced hydraulic gradients.

5.2.2 Groundwater levels

Operational impacts to groundwater levels are not expected to differ from those which are likely to occur due to construction impacts (**Section 5.1**).

The most substantial changes to groundwater levels during operation are likely to occur in the area of the western cut, due to the cut intercepting and draining groundwater seepage. The maximum change to groundwater level would occur at the cut face and is anticipated to be about 1.61 metres, which is considered a minor change and likely within the bounds of variation caused by climate. No impacts are predicted as a consequence of this potential drawdown.

5.2.3 Groundwater quality

With the exception of recharge from project stormwater basin exfiltration, operational impacts to groundwater quality are not expected to differ from those which are likely to occur due to construction impacts (**Section 5.1.3**).

During operation, groundwater quality may be altered locally in the vicinity of stormwater basins. This may occur due to exfiltration from the stormwater basins resulting in groundwater recharge that has a different chemistry to that of the background groundwater recharge chemistry. If runoff from the road contains heavy metals, oil, grease or hydrocarbons from road use and/or accidental spills, the runoff would flow to stormwater basins and a small proportion may exfiltrate to the water table.

This is considered a low risk as potentially altered groundwater quality would be localised to the stormwater basins and the beneficial use category of the groundwater system is not anticipated to be degraded. Accordingly, the project would have a neutral effect on groundwater quality.

Figure 5-2 Project operational footprint

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5.2.4 Groundwater dependent ecosystems

Operational impacts to GDEs are not expected to differ from those which are likely to occur due to construction impacts (**Section 5.1.4**). During operation, reduced groundwater levels due to drainage of the western cut are estimated to be limited to within 60 metres of the cut. The nearest mapped GDE to the western cut is about 240 metres away. Therefore, groundwater level changes caused by cut dewatering are not expected to occur during operation of the project in the areas of mapped GDEs.

5.2.5 Groundwater bores

Operational impacts to groundwater bores are not expected to differ from those which are likely to occur due to construction impacts (**Section 5.1.5**).

Groundwater level and quality impacts to surrounding groundwater bores are not anticipated.

5.2.6 Surface water-groundwater interactions

Operational impacts to surface water-groundwater interactions are not expected to differ from those which are likely to occur due to construction impacts (**Section 5.1.6**).

As predicted for the construction phase, groundwater discharges from the western cut to surface water systems will be negligible during operation of the project. Additionally, groundwater level changes from potential western cut dewatering would be localised to within about 60 metres of the cut, which is sufficient distance from alluvial groundwater systems to avoid impacts.

The minor localised changes to groundwater levels due to pile construction that have been predicted to occur during the construction phase would be similar or less during the operation of the project.

No impacts to surface water-groundwater interactions are expected due to operation of the project.

5.2.7 Surrounding land uses

Groundwater related impacts to surrounding land uses are not anticipated. This is because changes to groundwater levels would be restricted to within about 60 m of the western cut and even at the cut where the potential change in groundwater level would be highest, reduced groundwater levels are expected to still be within the bounds of natural variability. Additionally, the project is not anticipated to result in a change in groundwater quality which would lower the beneficial use category or exacerbate existing salinity (groundwater or soil) conditions.

5.2.8 Groundwater take and licensing

Permanent dewatering in the form of seepage collection from the western cut would ordinarily require a water use approval, a water supply work approval and a WAL. However, as discussed in **Section 2.1**, the project is exempt from the need for water use approval, a water supply work approval and a WAL.

Operational groundwater take (ie inflow) is not expected to increase from that predicted to occur during construction (**Section 5.1.8**), if anything, the inflow rates would be lower.

For the purpose of assigning a volume for water accounting, a take of 2.46 ML/yr would be considered conservative since it accommodates the maximum estimated groundwater inflow calculated from the range of parameter set scenarios. It is noted that the entire range of estimated groundwater inflows are very low to negligible.

5.2.9 Soil and groundwater salinity

Soil and groundwater salinity impacts to surrounding land uses are not expected to occur as a result of the project operating.

5.2.10 Groundwater contamination

As discussed in **Section 5.2.3**, during operation, groundwater quality may be altered locally in the vicinity of stormwater basins due to exfiltration from the basins resulting in groundwater recharge. Such recharge is not anticipated to degrade the beneficial use category of the groundwater system.

Potential operational impacts associated with discharge of groundwater from the western cut would be the same as that applicable for construction impacts (**Section 5.1.10**). Therefore, potential operational discharge of groundwater is not anticipated to impact SREs.

With the implementation of the management measures outlined herein (**Section 7**) and in the EIS, impacts to groundwater quality during project operation are considered negligible and the beneficial use category of the groundwater system is not expected to be degraded.

5.3 Minimal impact considerations

As summarised in **Table 5-2**, the above potential construction and operational impacts meet the minimal impact considerations outlined in the NSW Aquifer Interference Policy (DPI NOW, 2012) and the project’s groundwater quality objective (**Section 3.5**). Therefore, potential project impacts to groundwater are considered acceptable.

Table 5-2 Minimal impact consideration demonstration

Minimal impact considerations	Response
Water table	
1. Less than or equal to 10 per cent cumulative variation in the water table, allowing for typical climatic "post-water sharing plan" variations, 40 m from any: a) High priority groundwater dependent ecosystem; or b) High priority culturally significant site; listed in the schedule of the relevant water sharing plan. A maximum of a two metre decline cumulatively at any water supply work.	Appendix 2 of the water sharing plan legislation indicated no High Priority GDEs (karst and wetlands) or culturally significant sites are mapped within about 10 kilometres of the study area. Water table decline is not predicted at water supply works.
2. If more than 10 per cent cumulative variation in the water table, allowing for typical climatic "post-water sharing plan" variations, 40 m from any: a) High priority groundwater dependent ecosystem; or b) High priority culturally significant site; listed in the schedule of the relevant water sharing plan if appropriate studies demonstrate to the Minister's satisfaction that the variation will not prevent the long-term viability of the dependent ecosystem or significant site. If more than a two metre decline cumulatively at any water supply work then make good provisions should apply.	As per above response.
Water pressure	
1. A cumulative pressure head decline of not more than a two metre decline, at any water supply work.	Pressure decline is not predicted at water supply works.
2. If the predicted pressure head decline is greater than requirement 1 above, then appropriate studies are required to demonstrate to the Minister's satisfaction that the decline will not prevent the long-term viability of the affected water supply works unless make good provisions apply.	As per above response.
Water quality	
1. Any change in the groundwater quality should not lower the beneficial use category of the groundwater source beyond 40 m from the activity.	The project is not anticipated to result in a change in groundwater quality which would lower the beneficial use category.
2. If condition 1 is not met then appropriate studies will need to demonstrate to the Minister's satisfaction that the change in groundwater quality will not prevent the long-term viability of the dependent ecosystem, significant site or affected water supply works.	Not applicable - see above response.

6. Cumulative impacts

Cumulative groundwater impacts may arise from the interaction of construction and operation activities of the project and other approved or proposed projects in the area. When considered in isolation, specific project impacts may be considered minor. These minor impacts may be more substantial, however, when the impact of multiple projects on the same receivers is considered. As such, the groundwater impacts discussed in **Section 5.1** and **Section 5.2**, are assessed in consideration of the recently completed, ongoing and proposed projects described in **Table 6-1**.

The identified projects are in varying stages of delivery and planning. This section provides an assessment of cumulative groundwater impacts based on the most current and publicly available information on the above. In many instances this is a high-level qualitative assessment. The assessment of cumulative impacts per project is discussed in the sections that follow.

Since potential groundwater drawdown impacts of the project are minor and localised (ie at the western cut), the project is expected to have a minor contribution to cumulative groundwater drawdown impacts. As the project is not expected to generate groundwater quality impacts during construction or operation, outside of the potential for accidental spills and localised negligible impacts at water quality basins, the M12 Motorway project would have a negligible contribution to cumulative groundwater quality and level impacts associated with the project and other identified projects in the vicinity.

Overall, given the minor impacts on groundwater generated by the project, which are also highly localised, the project would contribute only minor cumulative groundwater impacts associated with the construction and operation of the M12 Motorway project and other approved or known projects in the area.

Table 6-1 Assessment of potential cumulative impacts for relevant projects

Project	Relevance of the identified project to consideration of cumulative groundwater and hydrology impacts of the M12 project	Commentary
Western Sydney Airport (approved)	Temporal and spatial relevance, due to following characteristics: • Located directly adjacent to the project (overlapping areas of potential influence) • Within the same groundwater system • Likely to be some overlap in construction program, meaning likelihood of concurrent (simultaneous) construction and operation.	The Western Sydney Airport EIS groundwater assessment (GHD, 2016b) concluded that: • Impacts to surrounding bores are expected to be negligible • Impacts to artificial wetlands within the airport site are expected to be negligible • Drawdown impacts in areas of sensitive vegetation are expected to be minor • Drawdown associated with cuttings or building basements is expected to be very localised • Overall reliance on groundwater discharge by creeks is low and changes to groundwater discharge would have minor impacts • The underlying aquifer system is of low beneficial use • There is a low risk of the project impacting water quality at surrounding surface water features and sensitive groundwater-reliant vegetation, and in areas of groundwater infiltration. • The Western Sydney Airport EIS groundwater assessment (GHD, 2016b) indicated similar risks to groundwater are applicable during operation and construction. The precise magnitude of the cumulative impacts from the project and the Western Sydney Airport is not able to be determined as the specific level and extent of drawdown impacts from the Western Sydney Airport are subject to detailed design and further modelling. However, Western Sydney Airport EIS groundwater assessment (GHD, 2016b) concludes that it is likely to have minor drawdown impacts.
Sydney Metro Greater West	Temporal and spatial relevance, due to following characteristics: • Located directly adjacent to the project (overlapping areas of potential influence) • Within the same groundwater system • Likely to be some overlap in construction program, meaning likelihood of concurrent (simultaneous) construction and operation.	Construction of the Sydney Metro Greater West is likely to mean there will be both concurrent and consecutive activities with the construction of the M12 Motorway project. During timeframes where construction activities are concurrent, increased groundwater impacts may be possible. The magnitude of cumulative construction impacts will be dependent on the specific construction locations, activities and impacts which are yet to be determined for the Sydney Metro Greater West.

Project	Relevance of the identified project to consideration of cumulative groundwater and hydrology impacts of the M12 project	Commentary
The Northern Road Upgrade (approved) • Stage 5 (Littlefields Road to Glenmore Park) • Stage 6 (Eaton Road to Littlefields Road)	Temporal and spatial relevance, due to following characteristics: • Located directly adjacent to the project • Within the same groundwater system • Likely to be consecutive (back to back) construction and concurrent (simultaneous) operation.	Stages 1 through 4 of The Northern Road upgrade would be completed by the time construction of the project commences. Based on the existing EIS documentation prepared for The Northern Road upgrade, there is no expected drawdown to the regional shallow unconfined water table and no expected impact to groundwater users including water supply users, GDEs, riparian areas or wetlands during construction of the project (Roads and Maritime, 2017). The construction for Stage 5 has commenced and is scheduled for completion end of 2022. The construction for Stage 6 is scheduled for mid-2019 to end of 2021. Construction activities associated with Stage 5 and Stage 6 may overlap with the project construction.
Other existing road network upgrades and potential road projects, including: • Elizabeth Drive Upgrade • Mamre Road Upgrade • Outer Sydney Orbital	Temporal and spatial relevance, due to following characteristics: • Located directly adjacent to the project • Within the same groundwater system • Potential to be consecutive (back to back) construction and concurrent (simultaneous) operation.	The timing for construction of other road projects has not yet been announced. However, there is potential for overlaps in construction timing between the project and surrounding projects in the vicinity of the project. Based on current practice with ‘design’ of major roads, it would be expected that these projects are likely to generate similar impacts to that of the M12 Motorway – ie being localised and not expected to generate significant quality impacts beyond their respective footprints. Therefore, cumulative impacts are anticipated to be negligible.
Major land releases, including: • Western Sydney Aerotropolis • South West Growth Area • Western Sydney Employment Area.	Temporal and spatial relevance, due to following characteristics: • Located directly adjacent to the project • Within the same groundwater system • Potential future context of the M12 project (operation).	The timing for construction for surrounding urban development (growth areas) has not yet been announced. However, there is potential for overlaps in construction timing between the project and surrounding projects in the vicinity of the project. Urban and commercial development may impact on groundwater quality and levels. However, such impacts are anticipated to be minor based on the nature of the development and would be part of the analysis of constraints undertaken as part of strategic planning. The constraints analysis would also take into account major infrastructure such as the airport and road rail projects. If cumulative impacts to groundwater occurred, these impacts are anticipated to be minor and have limited consequences given the low value of the upper groundwater systems.

7. Environmental management measures

7.1 Overview

The environmental management measures that would be implemented to minimise groundwater and hydrology impacts of the project, along with the responsibility and timing for those measures, are presented in **Table 7-1**. These measures would be complimented by the environmental management measures outlines in Appendix M and Appendix O of the EIS. The environmental management measures include a groundwater monitoring program which will include collection of baseline groundwater data and groundwater monitoring during both construction and operation of the project as outlined in **Section 7.2**.

Based on the environmental management measures outlined in **Table 7-1**, it is considered that potential groundwater and hydrology impacts that may arise as a result of construction and operation of the project can be effectively managed.

Table 7-1 Environment management measures (groundwater and hydrology)

Impact	Reference	Environmental management measure	Responsibility	Timing
Impacts to Groundwater quality and flows	GW01	Groundwater monitoring will be undertaken as part of the construction water quality monitoring program for the project. The groundwater monitoring will be based on the water quality monitoring methodology, water quality indicators and the monitoring locations presented in the **Section 7.2.** Baseline groundwater monitoring will be undertaken at least monthly for at least six months prior to construction. Monitoring will also be undertaken at least monthly during construction and will continue for at least six months of operation to verify that there are no groundwater impacts, and that management measures are adequate.	Roads and Maritime/ Contractor	Prior to construction, and during construction
Alteration of groundwater flows and levels	GW02	Potential impacts to groundwater flows will be reconsidered as the detailed design for the project progresses, particularly in relation to the project's vertical alignment and extent of road cuttings. The aim of this will be to ensure that the groundwater controls proposed for the design as set out in the EIS, would remain effective in mitigating groundwater impacts. In the instance that, during detailed design it cannot be demonstrated that the groundwater controls would be effective in mitigating potential impacts, or if observed groundwater inflow rates into the western cut are higher than estimated, additional measures will be implemented to minimise potential impacts on groundwater flows due to road cuttings or other subsurface components of the project.	Contractor	Detailed design

7.2 Groundwater monitoring program

7.2.1 Purpose

A groundwater monitoring program will be implemented as an environmental management measure to observe any changes in groundwater quality and levels that may be attributable to the project and inform appropriate management responses.

The monitoring program will include collection of baseline data for comparison to construction and operational monitoring data to understand, and respond to, any impacts from the project. An outline of each stage of the monitoring program (baseline, construction, operational) is provided in **Sections 7.2.2**, **7.2.3** and **7.2.4** (respectively) and describes the location and frequency of monitoring during these periods.

The groundwater quality indicators to be monitored are common to all stages of the monitoring program and are outlined in **Section 7.2.5**. Project groundwater monitoring bore locations are shown in **Figure 3-2**.

The frequency, locations and indicators to be sampled would be confirmed during detailed design.

7.2.2 Baseline data

The baseline data collected to date is presented in **Section 4.9.2** and **Section 4.9.5**. Additional baseline groundwater quality and level data will be collected prior to commencement of construction.

Additional baseline groundwater quality sampling will be undertaken at a monthly interval for at least six months at BH104, BH107, BH112 and BH145.

These locations were chosen because they represent areas of relatively substantial road cuttings and therefore there is a relatively higher potential for groundwater interception by the project alignment in these areas.

Additional baseline groundwater level monitoring will be undertaken primarily through download of data loggers. Groundwater level monitoring by data logger is currently being undertaken and will continue at all existing project groundwater monitoring bores (except BH301 and BH302, which were installed primarily to monitor gas) until at least the commencement of construction. The specific timing for the conclusion of the baseline monitoring period at each bore will vary. This is because construction will not commence uniformly over the whole alignment. Therefore, bore data that is collected during the construction period at bores that are sufficiently separated from construction works will still represent baseline data.

To allow for this, the baseline monitoring period will end at a specific project monitoring bore once construction is within 200 metres of that bore. This distance is considered conservative and suitable to ensure data collected to inform baseline conditions is representative.

Downloading of the logger data will occur concurrently with the groundwater quality sampling at BH104, BH107, BH112 and BH145. At remaining project monitoring bores, downloading of the logger data will occur quarterly. The purpose of the routine logger data downloading is to verify logger operation and provide opportunities to change logger batteries and address logger failures. Manual groundwater level monitoring by dip meter will be undertaken concurrently with the data logger downloading.

The location of the project groundwater bores that would be used for baseline data collection is presented in **Figure 7-1**.

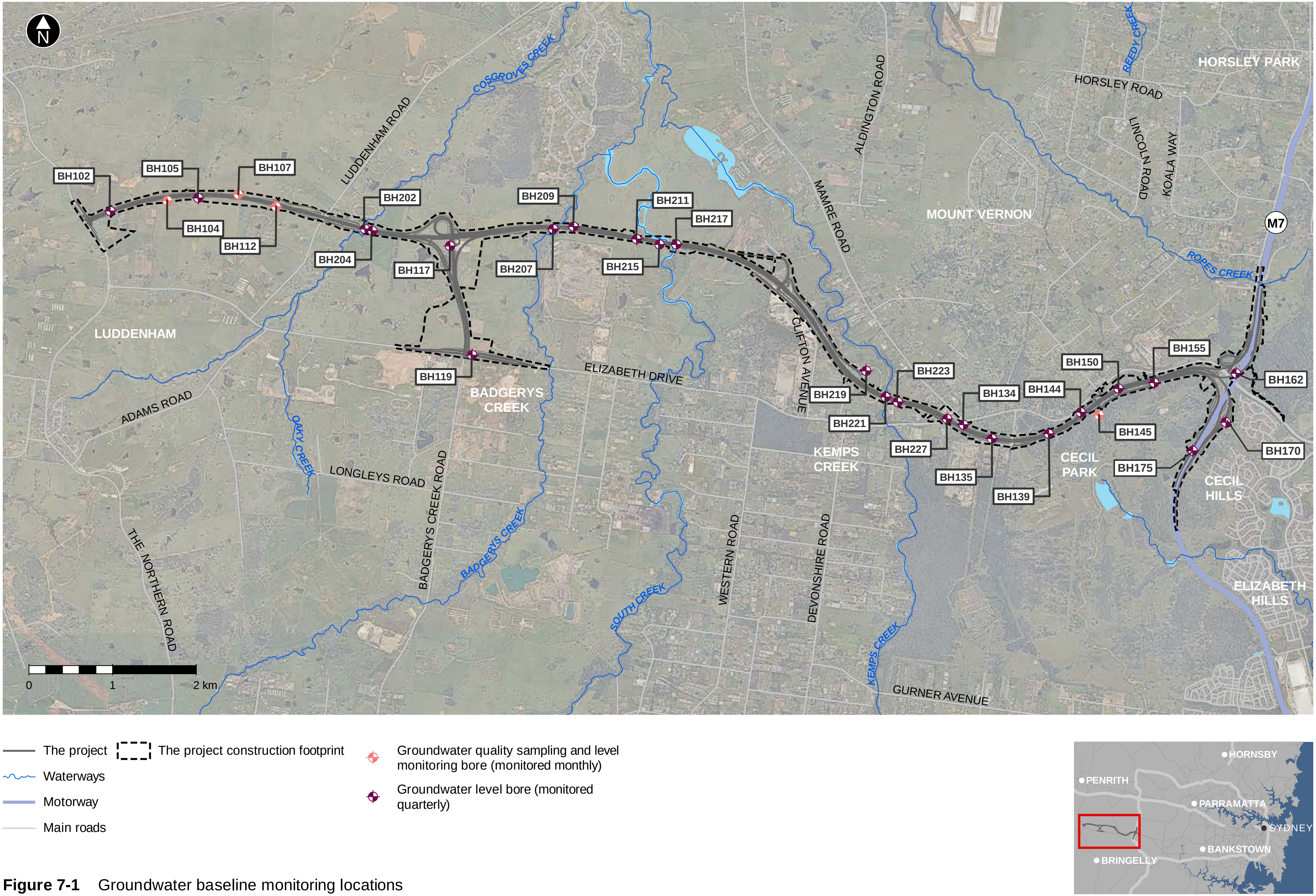

Figure 7-1 Groundwater baseline monitoring locations

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7.2.3 Construction phase groundwater monitoring

During construction, groundwater quality sampling will be undertaken monthly at BH104, BH107, BH112 and BH145.

Groundwater level data loggers will be downloaded at BH104, BH107, BH112 and BH145 concurrently with the groundwater quality sampling, and bi-monthly at all other project bores (except BH301 and BH302, which were installed primarily to monitor gas).

Manual groundwater level monitoring by dip meter will be undertaken concurrently with the data logger downloading.

With the exception of BH145, all of the project bores are within the construction footprint and will therefore be decommissioned during construction. Bores BH104, BH107, BH112 and BH145 will be replaced with newly drilled and constructed bores. The replacement bores are to be completed such that monthly groundwater quality sampling during construction can continue without a gap in the data record. All other bores will not be replaced unless data collected during the construction phase indicates this is required.

Groundwater quality monitoring indicators for the construction phase monitoring period are listed in the ‘Groundwater monitoring indicators’ section below.

7.2.4 Operational phase groundwater monitoring

Groundwater monitoring will continue for at least the first six months of operation to verify that operational impacts to groundwater are not occurring, or alternatively, inform appropriate mitigation measures. The operational phase groundwater level monitoring will be undertaken at the bores that replace BH104, BH107, BH112 and BH145 and will comprise:

- Monthly groundwater quality sampling for the indicators listed in in the ‘Groundwater monitoring indicators’ section below
- Monthly (concurrent with groundwater quality sampling) groundwater level data logger download and manual groundwater level measurement.

7.2.5 Groundwater monitoring indicators

The groundwater monitoring program will include monitoring of groundwater levels (data logger download and manual dipping at key locations) and sampling of the following indicators:

- Field parameters (electrical conductivity, pH, turbidity, dissolved oxygen, temperature and redox conditions)
- Heavy metals (arsenic, cadmium, chromium, copper, lead, mercury, nickel, zinc, iron and manganese)
- Total recoverable hydrocarbons
- Nutrients (including ammonia, nitrate, nitrite, total nitrogen, total phosphorus)
- Major ions (chloride, sulphate, sodium, potassium, magnesium, calcium, carbonate and bicarbonate)
- Benzene, toluene, ethylbenzene, xylene and naphthalene (BTEXN)
- Total dissolved solids (TDS)
- Total suspended solids (TSS).

8. Conclusions

8.1 Summary

Based on a detailed review of background groundwater level and quality data, along with an analysis of the existing environmental setting and an assessment of the proposed alignment, with the exception of groundwater cultural values, the project is expected to generate negligible impacts on groundwater. As such, the project would have a negligible contribution to potential cumulative impacts associated with other projects in the surrounding area (ie Western Sydney Airport, Sydney Metro Greater West or major subdivisions and land releases).

Risks associated with accidental spills or leakages of hazardous materials (such as fuels, lubricants and hydraulic oils) during the construction phase of the project will be managed through the CEMP and during operation will be managed by surface water quality management measures outlined in Appendix M of the EIS.

Baseline groundwater level and quality monitoring has been undertaken and will be supplemented prior to construction, which in conjunction with construction and operational phase groundwater level and quality monitoring, will enable impacts to be identified and addressed with targeted response measures.

The project has minimal potential to directly interact with groundwater systems, with direct potential interaction expected to be limited to:

- A single cut in the west (about 1.5 kilometres east of The Northern Road) of the alignment, which may intersect the water table by up to about 1.6 metres over a distance of about 250 metres. This cut is referred to as the ‘western cut’ in this report.
- Bridge footings, where piles are drilled below the water table.

The assessment presented in this document is based on the design outlined in the M12 Motorway EIS. If the project is approved, a further detailed design process would follow, which may include variations to the design. Any subsequent changes to the design may alter the impacts outlined herein would be considered during the detailed design stage of the project.

8.2 Western cut

Potential groundwater inflows from the western cut were assessed to be very low. The maximum estimated groundwater inflow rate was 6.75 kilolitre per day. However, the majority of parameter sets adopted for sensitivity analysis generated groundwater inflow rates ≤1.00 kilolitre per day, and if the cut is exposed, evaporation would be about 1.45 kilolitre per day. The project is exempt from the need for a WAL. For the purpose of assigning a volume for water accounting, a take of 2.46 ML/yr is considered conservative since it accommodates the maximum estimated groundwater inflow calculated from a range of parameter set scenarios. It is noted that the entire range of estimated groundwater inflows were very low to negligible.

Groundwater quality at the bore (BH104) representative of this location had copper and zinc concentrations above the ANZECC Water Quality Guidelines trigger values for the protection of 95 per cent of freshwater species. However, the water quality at this location does not indicate a risk to human health, nor are impacts anticipated to occur due to intercepted groundwater from the cut being discharged to surface water.

8.3 Bridge footings

The project has the potential to cause minor localised water table changes in areas where bridge footings extend beneath the water table. Deep footings which extend beneath the groundwater table in alluvial material may lead to a minor, localised and short-term increase in groundwater level up-gradient of the footing due to flow obstruction. The reverse is expected to occur down-gradient of the footing. Such changes are not expected to affect the local groundwater flow system or alter groundwater-surface water exchange in the region of the creeks, as piled footings would readily accommodate local groundwater flow diversion around the pile.

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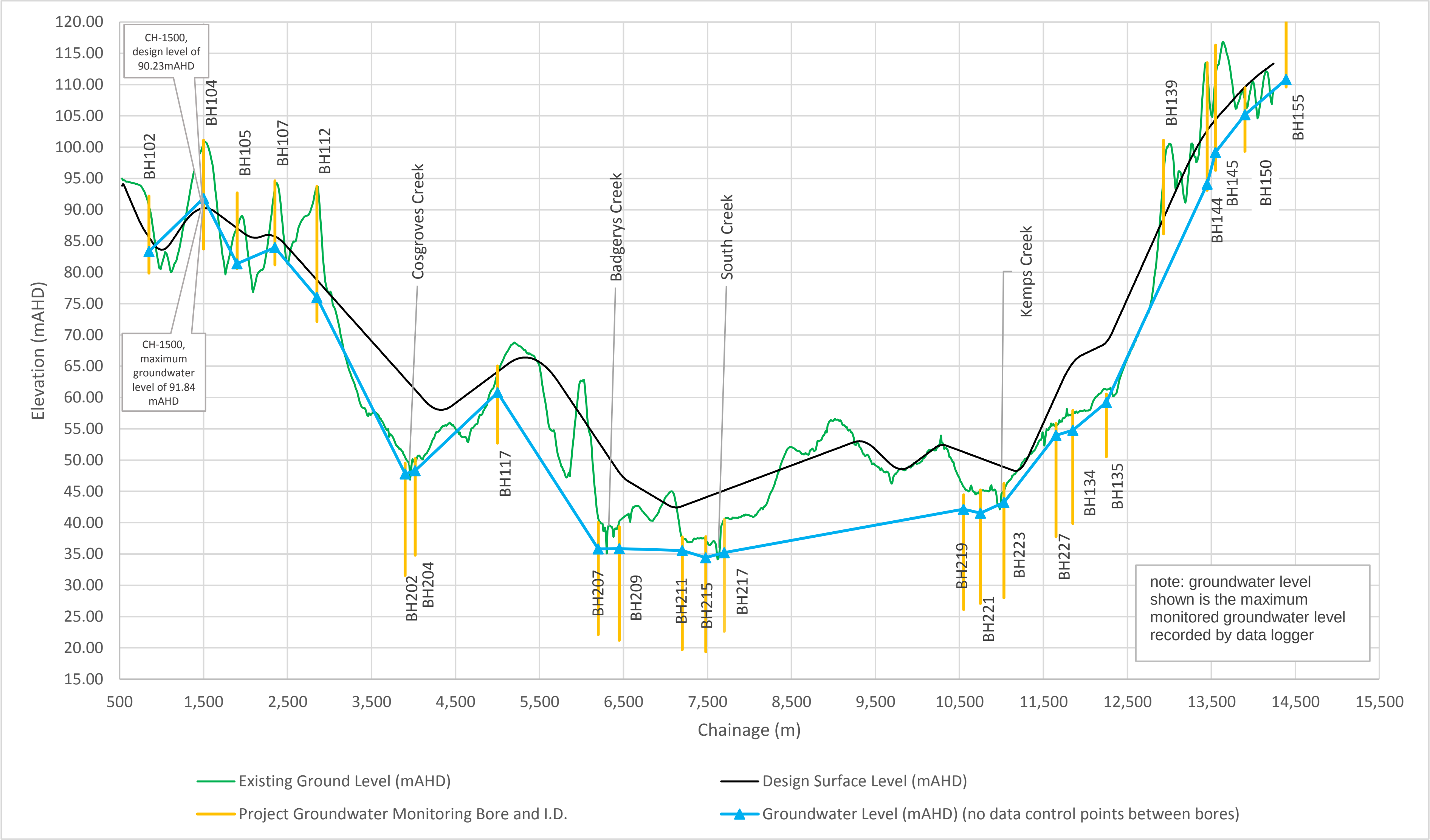
Annexure A

Figures



CH-1500, design level of 90.23mAHD

CH-1500, maximum groundwater level of 91.84 mAHD

note: groundwater level shown is the maximum monitored groundwater level recorded by data logger

M12 Motorway Groundwater Monitoring Bore Long Section - Figure 1

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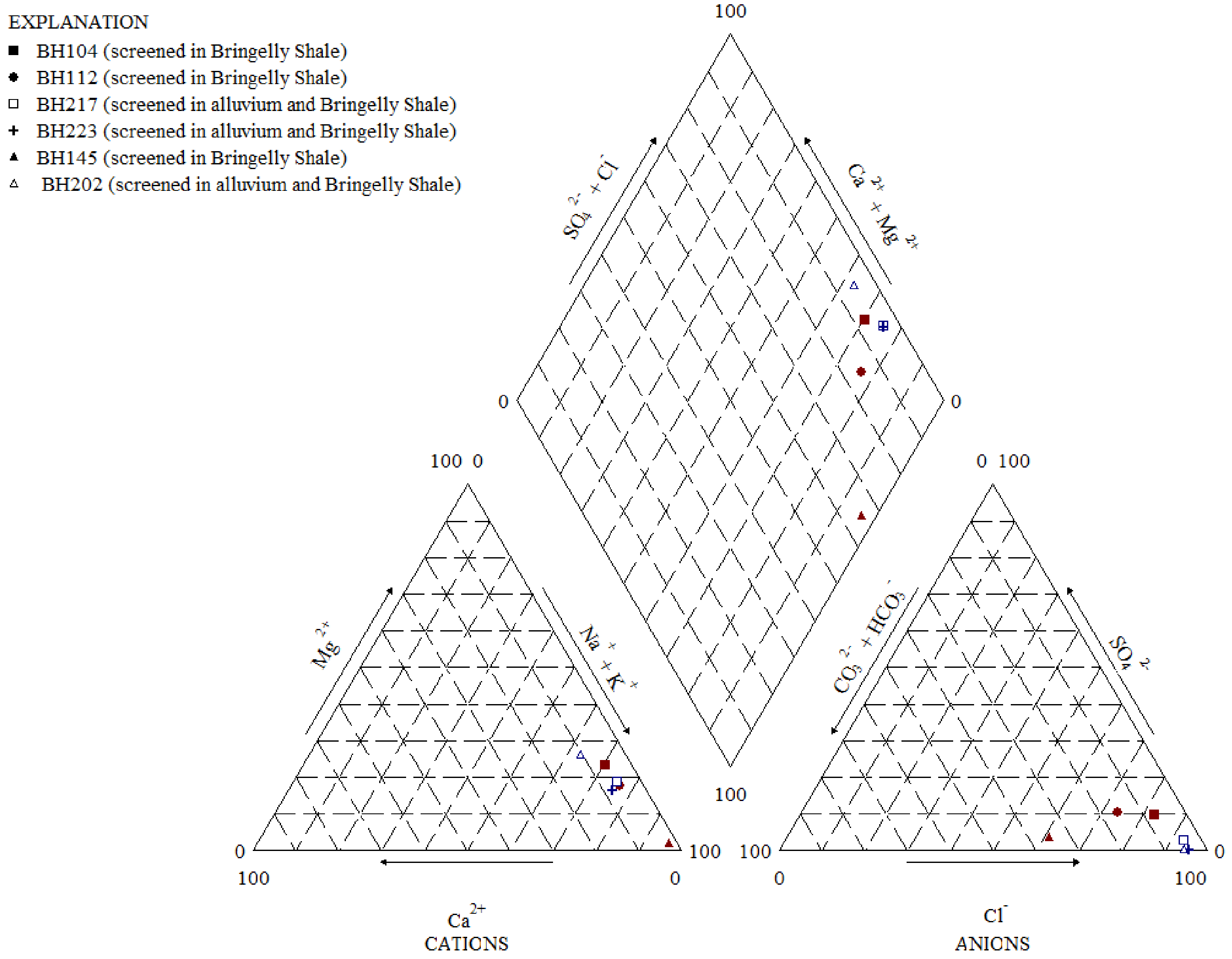

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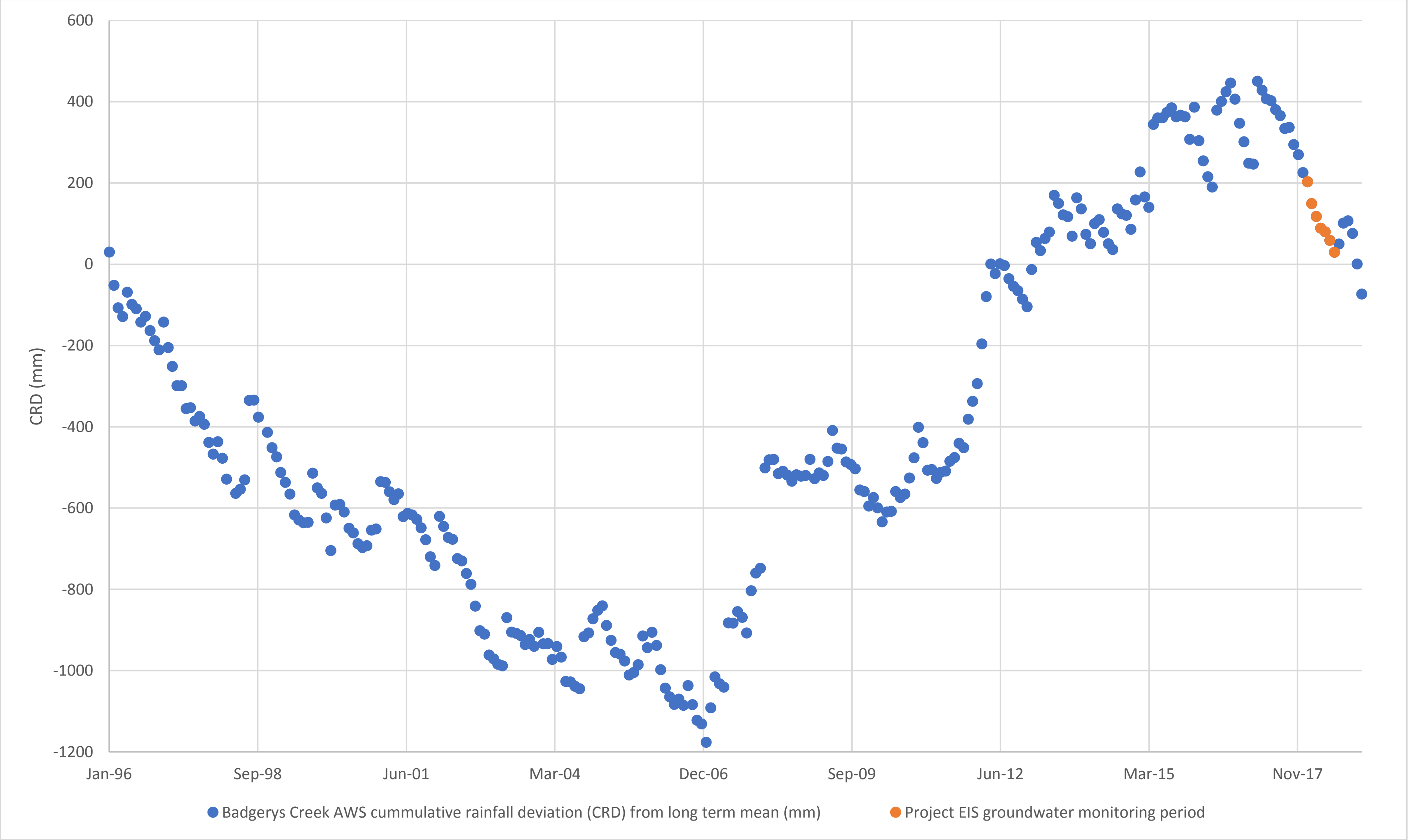
M12 Motorway Groundwater Monitoring Bore Piper Plot for BH104, BH112, BH145, BH202, BH2017 and BH223 - Figure 2

C:\Users\rosebj\Desktop\M12\[GW level data logger analysis.xlsx]Piper plot



JACOBS

Badgerys Creek AWS BOM station cummulative rainfall deviation (CRD) and project EIS groundwater monitoring period - Figure 3

\\Jacobs.com\ANZ\IE\Projects\04_Eastern\IA145100\09 Environmental\Surface and Ground Water\Groundwater\[observed pan evap during mon period.xlsx]long section figure

Annexure B

Project monitoring bore logs

JACOBS Piezometer Installation Details

BH102

Project:	M12 Motorway Concept Design			**Page:**	1 of 2
Client:	Roads and Maritime Services	**Location:**	The Northern Rd, Luddenham, NSW	**Project No:**	IA145100

Contractor:	Terratest	**Easting:**	287043.5	**Elevation:**	92.19	**Started:**	04/12/2017
Plant:	HydraScout	**Northing:**	6251432.9	**Datum:**	AHD	**Finished:**	05/12/2017
Logged by: JC	**Checked by:**	**Grid:**	MGA94 Zone 56	**Inclination:**	-90°	**Orientation:**	

DRILLING | MATERIAL SUBSTANCE | INSTALLATION DETAILS

Method & Support | Water | RL (m) | Depth (m) | Graphic Log

Description of Strata

ROCK TYPE : Colour, Grain size, Structure (texture, fabric, mineral composition, hardness alteration, cementation, major defect type)

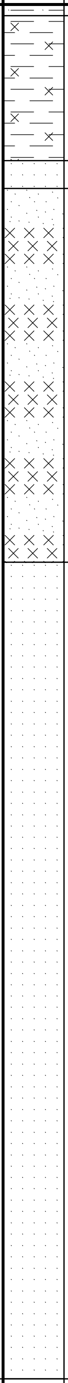
ID	Type	Stick Up & RL	Tip Depth & RL
BH102	Standpipe Piezometer		12.32 m 79.87 m

Method & Support: AD/V (0 – approx. 0.4 m); HQ3 (to 12.32 m)

Water: 15/02/18

RL (m): 92, 90, 88, 86, 84, 82, 80

Depth (m): 2, 4, 6, 8, 10, 12



Sandy CLAY: Low plasticity, brown, trace rootlets.

Silty CLAY: High plasticity, yellow-brown, orange-brown.

SANDSTONE: Yellow-brown, fine grained, extremely weathered, very low strength.

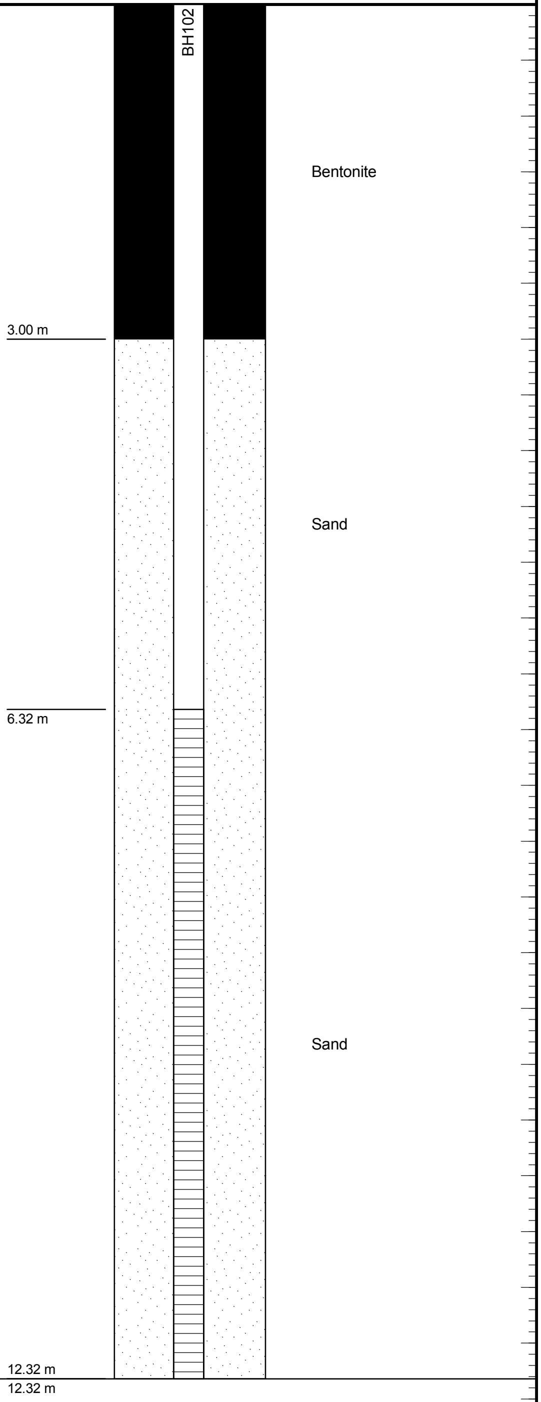
Interbedded SANDSTONE and SILTSTONE: Brown and orange-brown, sandstone is fine grained, beds are approximately 100-200mm thick, distinctly sub-horizontal bedding.

4.92m: Pebbly band 50mm thick.

SANDSTONE: Grey with a trace of thin orange brown bands, medium grained, indistinct sub-horizontal bedding.
5.47m: As above but with a trace of dark grey carbonaceous laminations to 5.90m.

9.22m: Carbonaceous siltstone band 80mm thick.

Hole Terminated at 12.32 m



DRILLING

NMLC	NMLC Coring	HQ	HQ Coring	TCR	% core run recovered
NQ	NQ Coring	PQ	PQ Coring	RQD	% core run > 100mm long (rock fraction only measured)

GROUNDWATER SYMBOLS

▼ = Water level (static) ▽ = Water level (during drilling)

Piezometer Installation Details

BH104

Project:	M12 Motorway Concept Design			**Page:**	1 of 2
Client:	Roads and Maritime Services	**Location:**	Luddenham, NSW	**Project No:**	IA145100

Contractor:	Terratest	**Easting:**	287726.9	**Elevation:**	101.11	**Started:**	30/11/2017
Plant:	HydraScout	**Northing:**	6251557.9	**Datum:**	AHD	**Finished:**	01/12/2017
Logged by:	JC **Checked by:**	**Grid:**	MGA94 Zone 56	**Inclination:**	-90°	**Orientation:**	

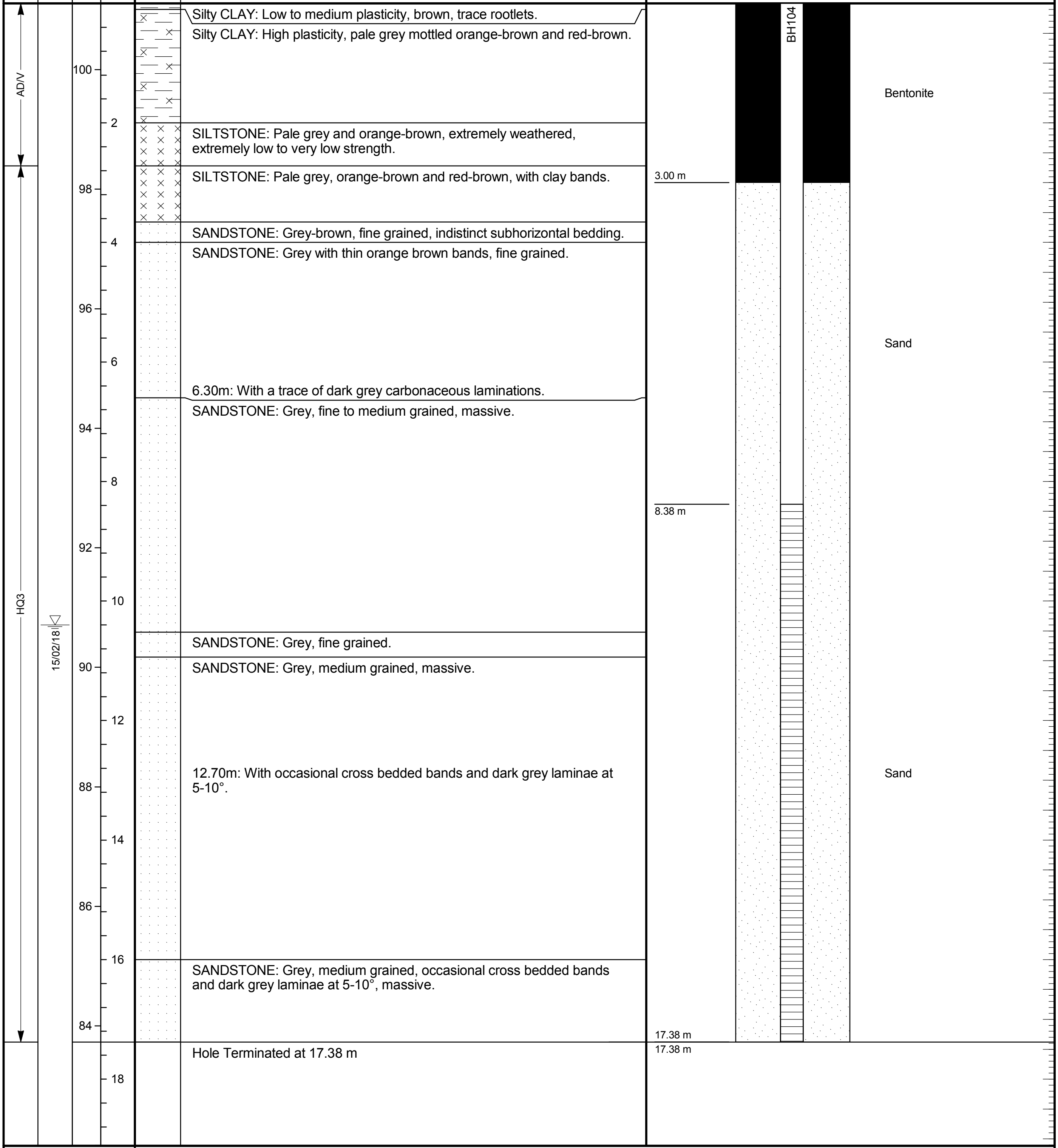
DRILLING | MATERIAL SUBSTANCE | INSTALLATION DETAILS

Method & Support | Water | RL (m) | Depth (m) | Graphic Log

Description of Strata

ROCK TYPE : Colour, Grain size, Structure
(texture, fabric, mineral composition, hardness
alteration, cementation, major defect type)

ID	Type	Stick Up & RL	Tip Depth & RL
BH104	Standpipe Piezometer		17.38 m 83.73 m



Silty CLAY: Low to medium plasticity, brown, trace rootlets.

Silty CLAY: High plasticity, pale grey mottled orange-brown and red-brown.

SILTSTONE: Pale grey and orange-brown, extremely weathered, extremely low to very low strength.

SILTSTONE: Pale grey, orange-brown and red-brown, with clay bands.

SANDSTONE: Grey-brown, fine grained, indistinct subhorizontal bedding.

SANDSTONE: Grey with thin orange brown bands, fine grained.

6.30m: With a trace of dark grey carbonaceous laminations.

SANDSTONE: Grey, fine to medium grained, massive.

SANDSTONE: Grey, fine grained.

SANDSTONE: Grey, medium grained, massive.

12.70m: With occasional cross bedded bands and dark grey laminae at 5-10°.

SANDSTONE: Grey, medium grained, occasional cross bedded bands and dark grey laminae at 5-10°, massive.

Hole Terminated at 17.38 m

DRILLING

NMLC	NMLC Coring	HQ	HQ Coring	TCR	% core run recovered
NQ	NQ Coring	PQ	PQ Coring	RQD	% core run > 100mm long (rock fraction only measured)

GROUNDWATER SYMBOLS

▼ = Water level (static)   ▽ = Water level (during drilling)

Piezometer Installation Details

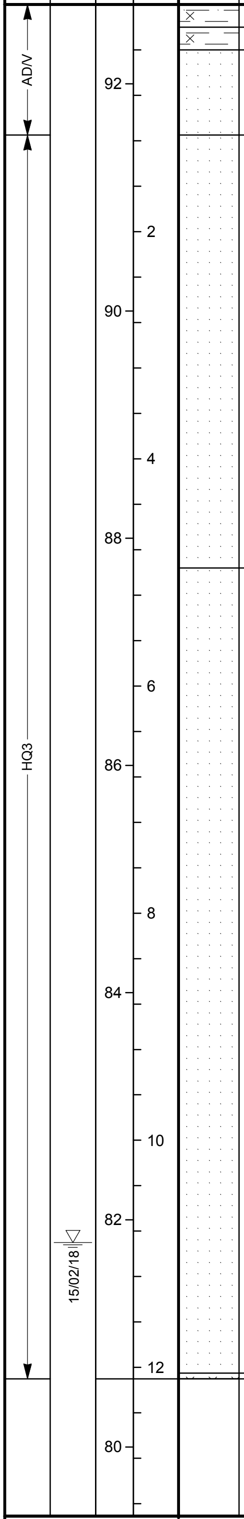
BH105

Project: M12 Motorway Concept Design
Page: 1 of 2
Client: Roads and Maritime Services
Location: Luddenham, NSW
Project No: IA145100

Contractor: Terratest
Easting: 288096.0
Elevation: 92.70
Started: 01/12/2017
Plant: HydraScout
Northing: 6251588.9
Datum: AHD
Finished: 04/12/2017
Logged by: JC
Checked by:
Grid: MGA94 Zone 56
Inclination: -90°
Orientation:

DRILLING | MATERIAL SUBSTANCE | INSTALLATION DETAILS

ID	Type	Stick Up & RL	Tip Depth & RL
BH105	Standpipe Piezometer		12.10 m 80.60 m



Description of Strata

ROCK TYPE : Colour, Grain size, Structure
(texture, fabric, mineral composition, hardness
alteration, cementation, major defect type)

Sandy Silty CLAY: Low plasticity, brown, trace rootlets.

Silty CLAY: Medium plasticity, orange-brown, pale grey, with a trace of sand.

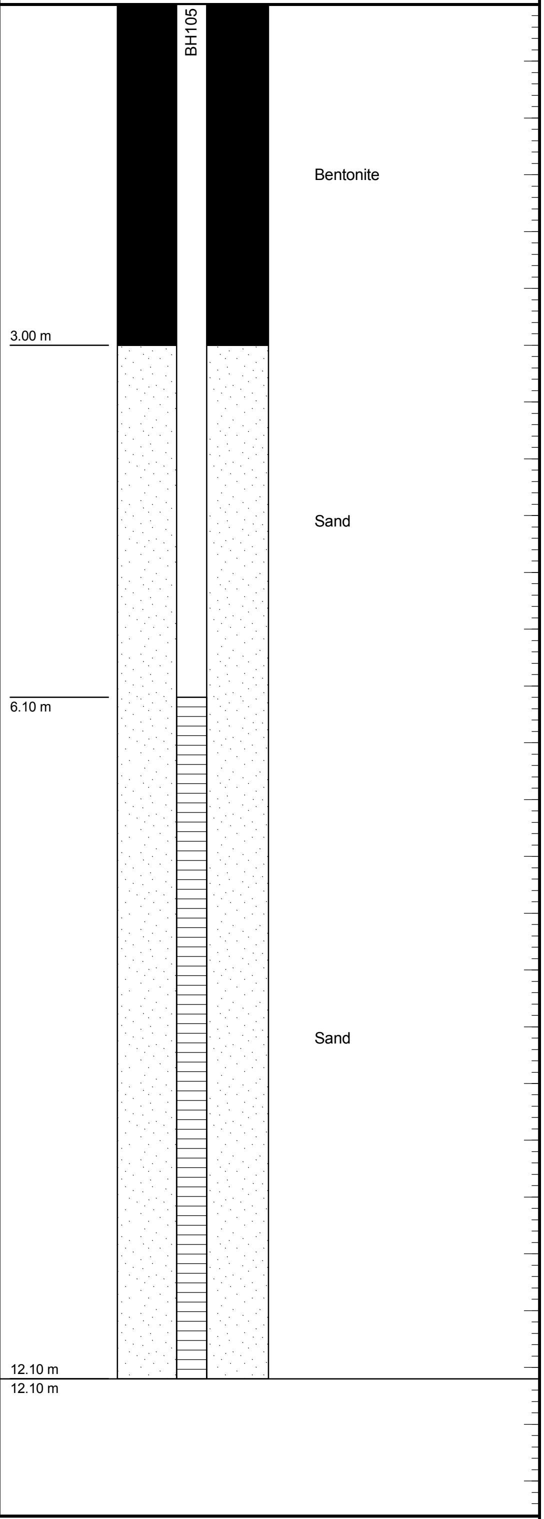
SANDSTONE: Brown, orange-brown, extremely weathered, very low strength.

SANDSTONE: Brown, fine to medium grained, indistinctly bedded.

SANDSTONE: Grey with brown bands, fine to medium grained, indistinctly bedded.

8.50m: With band of carbonaceous laminations at 0-5°.

SILTSTONE: Dark grey.
Hole Terminated at 12.10 m



DRILLING

NMLC NMLC Coring
NQ NQ Coring
HQ HQ Coring
PQ PQ Coring
TCR % core run recovered
RQD % core run > 100mm long
(rock fraction only measured)

GROUNDWATER SYMBOLS

▼ = Water level (static)
▽ = Water level (during drilling)

Piezometer Installation Details

BH107

Project:	M12 Motorway Concept Design			**Page:**	1 of 2
Client:	Roads and Maritime Services	**Location:**	Luddenham, NSW	**Project No:**	IA145100

Contractor:	Terratest	**Easting:**	288574.6	**Elevation:**	94.63	**Started:**	10/04/2018
Plant:	Comacchio 205	**Northing:**	6251634.4	**Datum:**	AHD	**Finished:**	11/04/2018
Logged by:	JC **Checked by:**	**Grid:**	MGA94 Zone 56	**Inclination:**	-90°	**Orientation:**	

DRILLING

Method & Support: AD/T; AD/V; HQ3

Water: Not Encountered; 11/05/18

MATERIAL SUBSTANCE

Description of Strata

ROCK TYPE : Colour, Grain size, Structure (texture, fabric, mineral composition, hardness alteration, cementation, major defect type)

Silty Sandy CLAY: Low to medium plasticity, red-brown mottled yellow-brown, sand is fine grained.

SANDSTONE: Mottled brown and red-brown, fine grained, extremely weathered, extremely low strength.

1.50m: V-bit Refusal

SANDSTONE: Brown, fine grained, massive.
1.70m: As above, but with some dark grey carbonaceous laminations at 5°.

5.36m: As above, but becoming medium grained.

SANDSTONE: Grey and orange-brown, fine grained, with some coarse subrounded pebbles.

SILTSTONE: Grey, with dark grey carbonaceous laminations at 0°.

9.07-9.14m: Sandstone band, 70mm.
9.14m: As above, but dark grey with orange-brown staining.

SANDSTONE: Dark grey, fine grained.

SILTSTONE: Dark grey with orange-brown staining, laminated at 0°.

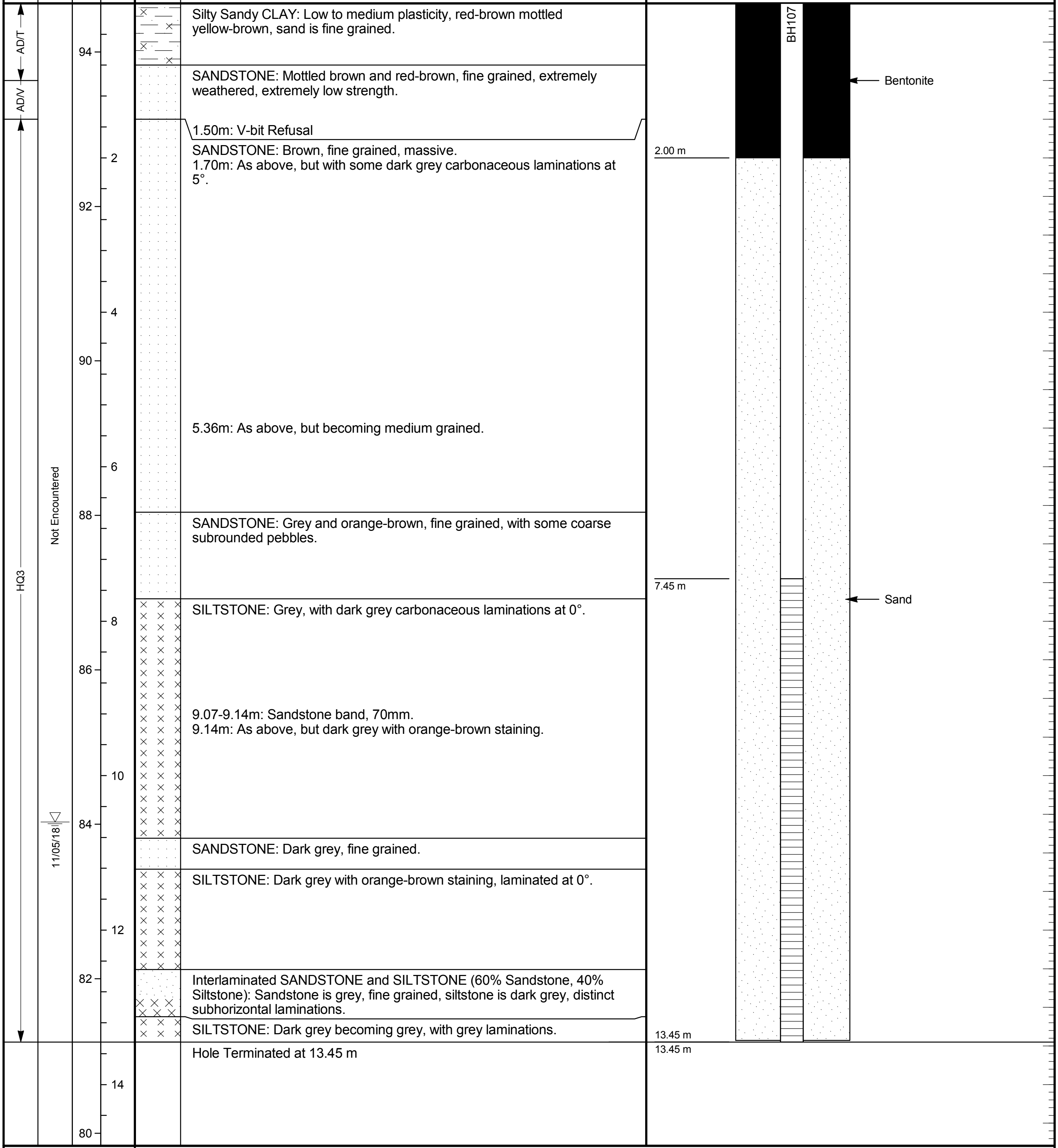
Interlaminated SANDSTONE and SILTSTONE (60% Sandstone, 40% Siltstone): Sandstone is grey, fine grained, siltstone is dark grey, distinct subhorizontal laminations.

SILTSTONE: Dark grey becoming grey, with grey laminations.

Hole Terminated at 13.45 m

INSTALLATION DETAILS

ID	Type	Stick Up & RL	Tip Depth & RL
BH107	Standpipe Piezometer		13.45 m 81.18 m



DRILLING

NMLC	NMLC Coring	HQ	HQ Coring	TCR	% core run recovered
NQ	NQ Coring	PQ	PQ Coring	RQD	% core run > 100mm long (rock fraction only measured)

GROUNDWATER SYMBOLS

▼ = Water level (static) ▽ = Water level (during drilling)

JACOBS Piezometer Installation Details

BH112

Project: M12 Motorway Concept Design
Page: 1 of 2
Client: Roads and Maritime Services
Location: Luddenham, NSW
Project No: IA145100

Contractor:	Terratest	**Easting:**	289024.5	**Elevation:**	93.78
Plant:	Comacchio 205	**Northing:**	6251485.3	**Datum:**	AHD
Logged by:	JC	**Grid:**	MGA94 Zone 56	**Inclination:**	-90°
Checked by:		**Started:**	03/04/2018	**Finished:**	04/04/2018
Orientation:					

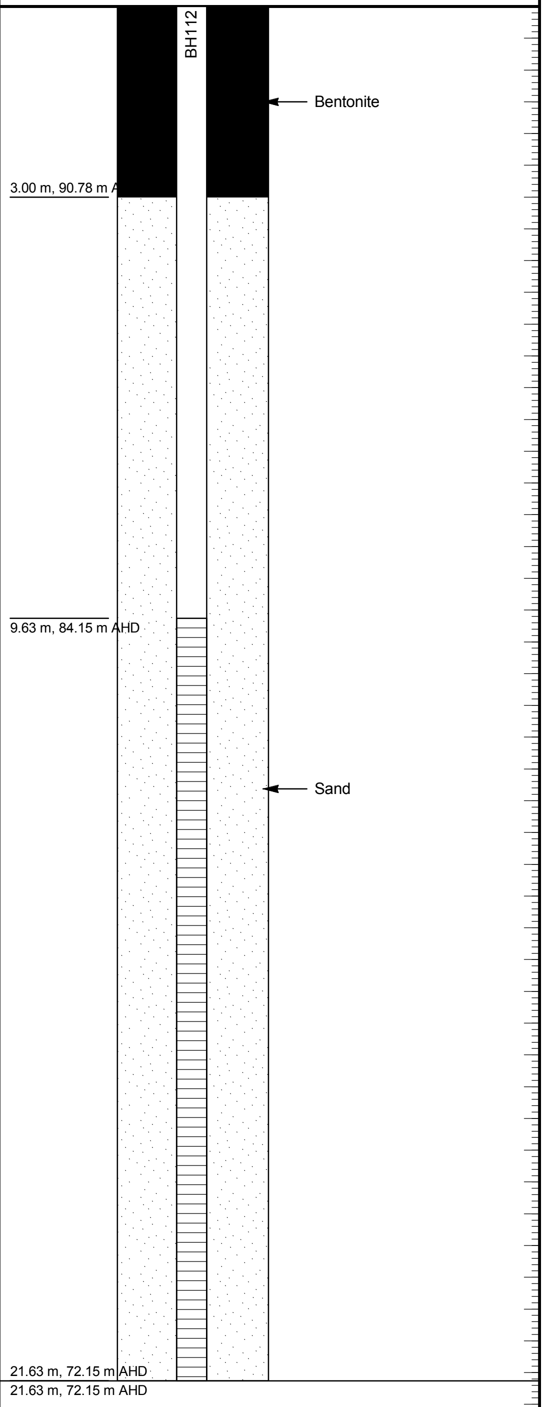
DRILLING / MATERIAL SUBSTANCE

Method & Support	Water	Description of Strata ROCK TYPE : Colour, Grain size, Structure (texture, fabric, mineral composition, hardness alteration, cementation, major defect type)
AD/T	Not Encountered	Silty Sandy CLAY: Medium plasticity, red-brown trace fine grained sand.
AD/V		SANDSTONE: Pale grey mottled yellow-brown and orange-brown, fine grained, extremely weathered, very low strength.
		SILTSTONE: Dark grey mottled orange-brown, extremely weathered, very low strength.
HQ3		SILTSTONE: Pale grey and dark grey stained orange-brown.
		Interlaminated SILTSTONE and SANDSTONE (70% Siltstone, 30% Sandstone): Dark grey stained brown and orange-brown, sandstone is fine grained, subhorizontal laminations.
		Silty CLAY: Medium plasticity, pale grey, grey and yellow-brown.
		SILTSTONE: Dark grey with orange-brown staining, indistinctly laminated. 7.35-7.66m: As above, but with iron indurated clasts.
		SANDSTONE: Grey, fine grained.
		SILTSTONE: Grey and dark grey, distorted laminations.
		SANDSTONE: Dark grey, fine grained.
		SILTSTONE: Dark grey becoming pale grey, indistinctly laminated.
		Interbedded SILTSTONE and SANDSTONE (60% Siltstone, 40% Sandstone): Siltstone is dark grey, sandstone is grey, fine grained, subhorizontal bedding.
	▽ 15/05/18	SILTSTONE: Dark grey, indistinctly laminated, with occasional fine grained sandstone bands approximately 100-200mm thick.
		Interbedded SILTSTONE and SANDSTONE (60% Siltstone, 40% Sandstone): Siltstone is dark grey, sandstone is grey, fine grained, distinct subhorizontal laminations. 17.90m: As above, but becoming 70% Sandstone, 30% Siltstone.
		SILTSTONE: Dark grey, distinctly laminated, with occasional grey laminations. 20.72m: Sandstone band, fine to medium grained, 140mm thick. 20.98m: As above, but with some fine grained Sandstone laminations.
		Hole Terminated at 21.63 m Target depth

RL (m)	Depth (m)
92	2
90	4
88	6
86	8
84	10
82	12
80	14
78	16
76	18
74	20
72	22

INSTALLATION DETAILS

ID	Type	Stick Up & RL	Tip Depth & RL
BH112	Standpipe Piezometer		21.63 m 72.15 m



DRILLING

NMLC	NMLC Coring	HQ	HQ Coring	TCR	% core run recovered
NQ	NQ Coring	PQ	PQ Coring	RQD	% core run > 100mm long (rock fraction only measured)

GROUNDWATER SYMBOLS

▼ = Water level (static)
▽ = Water level (during drilling)

Piezometer Installation Details

BH117

Project: M12 Motorway Concept Design
Page: 1 of 2
Client: Roads and Maritime Services
Location: Badgery's Creek, NSW
Project No: IA145100

Contractor:	Terratest	**Easting:**	291107.2	**Elevation:**	65.05	**Started:**	06/12/2017
Plant:	Comacchio 205	**Northing:**	6251013.3	**Datum:**	AHD	**Finished:**	07/12/2017
Logged by:	OC **Checked by:**	**Grid:**	MGA94 Zone 56	**Inclination:**	-90°	**Orientation:**	

DRILLING | MATERIAL SUBSTANCE | INSTALLATION DETAILS

Method & Support | Water | RL (m) | Depth (m) | Graphic Log

Description of Strata

ROCK TYPE : Colour, Grain size, Structure (texture, fabric, mineral composition, hardness alteration, cementation, major defect type)

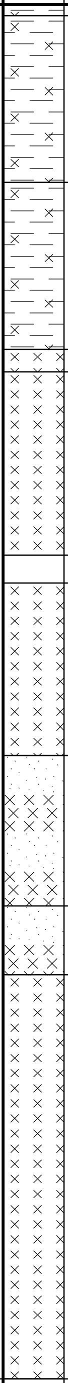
ID	Type	Stick Up & RL	Tip Depth & RL
BH117	Standpipe Piezometer		12.35 m 52.70 m

Method & Support: AD/V (0 to 3.0 m); HQ3 (3.0 to 12.35 m)

Water: 15/02/18

RL (m): 64, 62, 60, 58, 56, 54, 52

Depth (m): 2, 4, 6, 8, 10, 12



Silty CLAY: Medium plasticity, brown, trace rootlets.

Silty CLAY: Medium to high plasticity, brown grey, with some fine to coarse sand and fine grained ironstone gravel.

1.00m: Iron indurated bands.

Silty CLAY: High plasticity, grey mottled red-brown.

2.70m: Some iron indurated bands.

SILTSTONE: Red brown.

SILTSTONE: Grey with some red brown mottle, thinly laminated 5-10°.

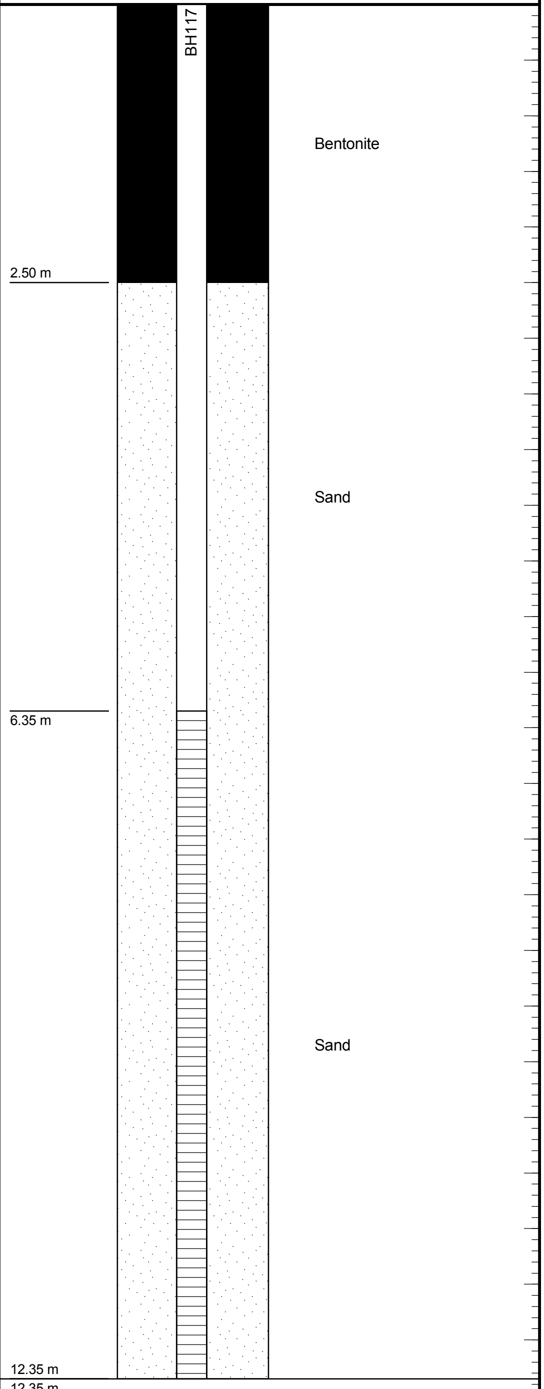
SILTSTONE: Grey brown and red brown, thinly laminated 5-10°.

Interbedded SILTSTONE and SANDSTONE (70%/30%): Grey and dark grey, sandstone is fine grained, bedded at 0-10°.

Interlaminated SILTSTONE and SANDSTONE (50%/50%): Grey and dark grey, sandstone is fine grained, laminated at 0-10°.

SILTSTONE: Dark grey with some thin sandstone bands, grey, fine grained.

Hole Terminated at 12.35 m



DRILLING

NMLC NMLC Coring
NQ NQ Coring
HQ HQ Coring
PQ PQ Coring
TCR % core run recovered
RQD % core run > 100mm long (rock fraction only measured)

GROUNDWATER SYMBOLS

▼ = Water level (static)
▽ = Water level (during drilling)

JACOBS

Piezometer Installation Details

BH119

Project: M12 Motorway Concept Design
Client: Roads and Maritime Services
Location: Elizabeth Dr, Badgery's Creek, NSW
Page: 1 of 2
Project No: IA145100

Contractor: Terratest	**Easting:** 291372.4	**Elevation:** 54.00	**Started:** 30/11/2017
Plant: Comacchio 205	**Northing:** 6249710.5	**Datum:** AHD	**Finished:** 30/11/2017
Logged by: OC **Checked by:**	**Grid:** MGA94 Zone 56	**Inclination:** -90°	**Orientation:**

DRILLING | MATERIAL SUBSTANCE | INSTALLATION DETAILS

Method & Support | Water | RL (m) | Depth (m) | Graphic Log | **Description of Strata**

ROCK TYPE : Colour, Grain size, Structure
(texture, fabric, mineral composition, hardness
alteration, cementation, major defect type)

ID	Type	Stick Up & RL	Tip Depth & RL
BH119	Standpipe Piezometer		12.05 m 41.95 m

Method & Support: AD/V (0 – approx. 3.0 m); HQ3 (approx. 3.0 – 12.05 m)

Water: 15/02/18

RL (m) / Depth (m): 52 – 2; 50 – 4; 48 – 6; 46 – 8; 44 – 10; 42 – 12

Silty CLAY: Medium to high plasticity, brown, trace of fine sand and rootlets.

Silty CLAY: Medium to high plasticity, mottled orange-brown and grey brown, trace of fine grained sand and fine grained subangular ironstone gravel.

Silty CLAY: Medium to high plasticity, mottled grey and red brown, with some iron indurated bands.

SILTSTONE: Grey brown, extremely weathered, very low strength.

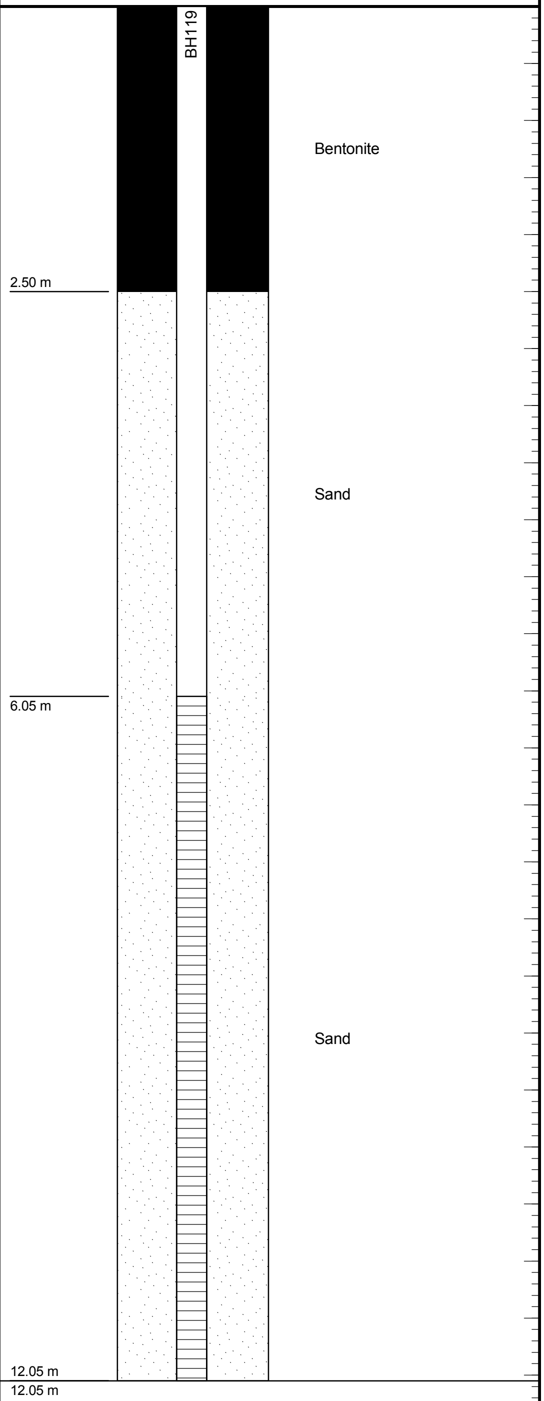
SILTSTONE: Grey.

SILTSTONE: Grey and dark grey, with some thin sandstone bands, grey, fine grained.

SILTSTONE: Dark grey.

SILTSTONE: Dark grey with thin sandstone and carbonaceous siltstone bands, laminated at 0-5°.

Hole Terminated at 12.05 m



DRILLING

NMLC NMLC Coring	HQ HQ Coring	TCR % core run recovered	
NQ NQ Coring	PQ PQ Coring	RQD % core run > 100mm long (rock fraction only measured)	

GROUNDWATER SYMBOLS

▼ = Water level (static)   ▽ = Water level (during drilling)

Piezometer Installation Details

BH129

Project: M12 Concept Design
Client: Roads and Maritime Services
Location: Clifton Ave, Kemps Creek, NSW
Page: 1 of 2
Project No: IA145100

Contractor: Terratest
Plant: Comacchio 205
Logged by: MG **Checked by:** STP
Easting: 295498.5
Northing: 6250051.9
Grid: MGA94 Zone 56
Elevation: 49.12
Datum: AHD
Inclination: -90°
Started: 27/06/2018
Finished: 27/06/2018
Orientation:

DRILLING — Method & Support: AD/T; AD/V — CASING; HQ3
Water: Not Encountered

MATERIAL SUBSTANCE

Description of Strata

ROCK TYPE : Colour, Grain size, Structure
(texture, fabric, mineral composition, hardness
alteration, cementation, major defect type)

CLAYEY GRAVELLY SAND: fine to coarse grained sand, brown and dark brown, gravel is fine to medium, subangular to angular, with a trace of rootlets.; moist, very stiff - hard

SILTY SANDY CLAY: medium to high plasticity, brown, with a trace of fine gravel; moist, very stiff to hard

SILTY CLAY: high plasticity, red-brown and grey, with some fine to medium, subangular ironstone gravel; moist, hard

2.00m: Becoming pale grey mottled red-brown and orange-brown, with some ironstone bands.

SILTY CLAY: high plasticity, pale grey mottled red-brown, with some ironstone gravel, (RESIDUAL SOIL)

SILTSTONE: grey and brown, with some pale grey clay seams and some sandy laminations, massive.; highly weathered, extremely low to low strength

SILTSTONE: massive, grey-brown and dark grey.; extremely weathered to highly weathered, extremely low to very low strength

5.84-5.89m: Carbonaceous siltstone band.

6.21-6.26m: Carbonaceous siltstone band.

CARBONACEOUS SILTSTONE: dark grey., distinct sub-horizontal laminations.; highly weathered to moderately weathered, very low and medium strength

SILTSTONE: dark grey and grey., indistinctly bedded, sub-horizontal.; moderately weathered, low to medium strength

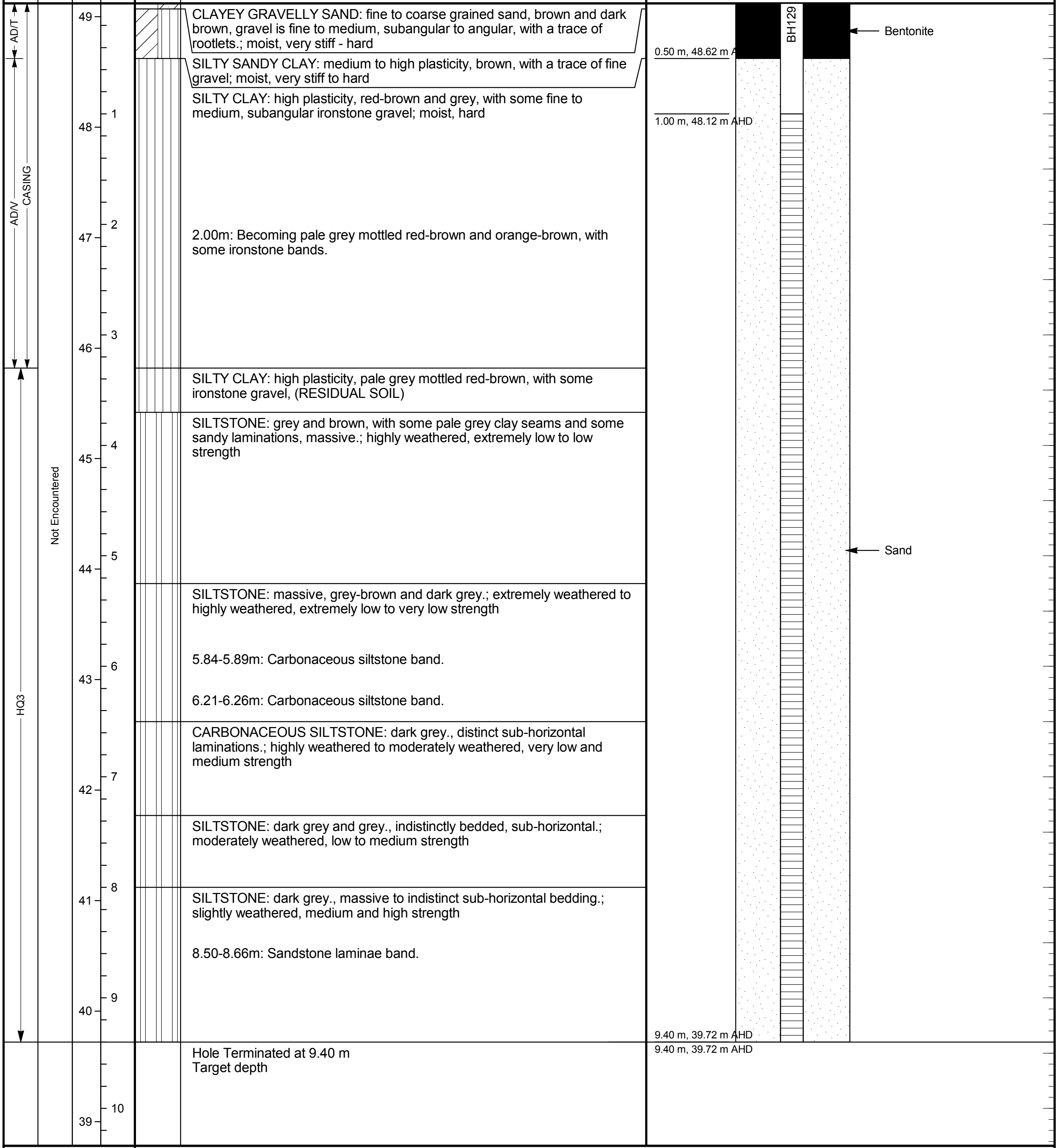
SILTSTONE: dark grey., massive to indistinct sub-horizontal bedding.; slightly weathered, medium and high strength

8.50-8.66m: Sandstone laminae band.

Hole Terminated at 9.40 m
Target depth

INSTALLATION DETAILS

ID	Type	Stick Up & RL	Tip Depth & RL
BH129	Standpipe Piezometer		9.40 m 39.72 m



DRILLING

NMLC NMLC Coring
NQ NQ Coring
HQ HQ Coring
PQ PQ Coring
TCR % core run recovered
RQD % core run > 100mm long
(rock fraction only measured)

GROUNDWATER SYMBOLS

▼ = Water level (static)
▽ = Water level (during drilling)

Piezometer Installation Details

BH134

Project:	M12 Motorway Concept Design			**Page:**	1 of 2
Client:	Roads and Maritime Services	**Location:**	Elizabeth Dr, Cecil Park, NSW	**Project No:**	IA145100

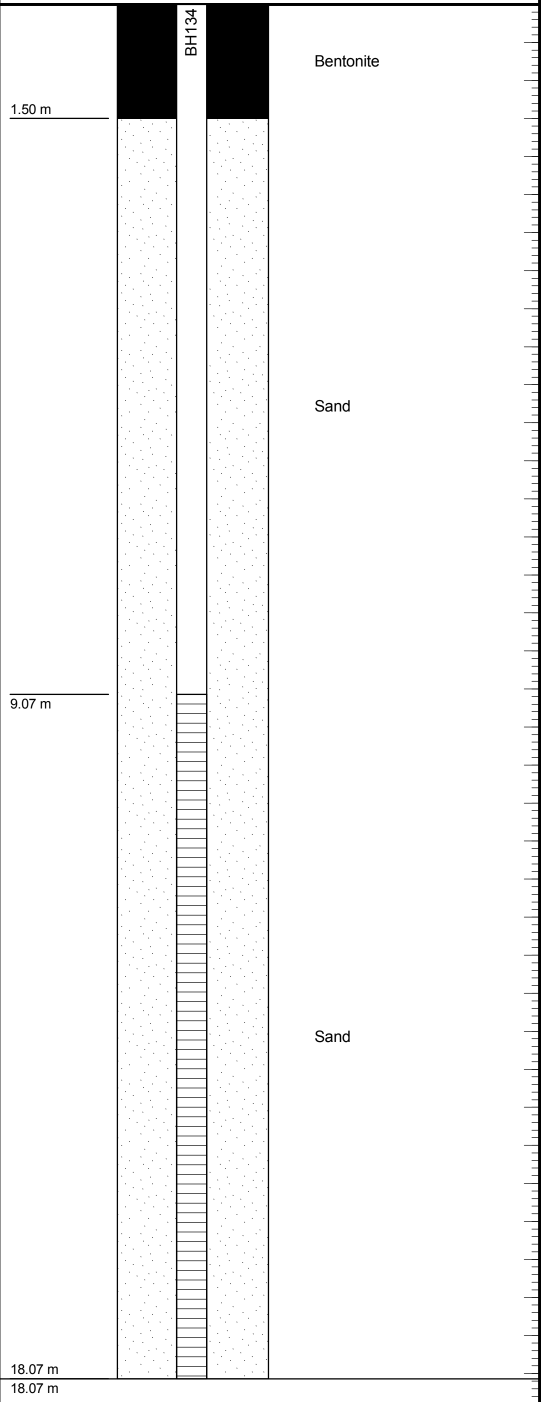
Contractor:	Terratest	**Easting:**	297251.6	**Elevation:**	57.94	**Started:**	07/12/2017
Plant:	HydraScout	**Northing:**	6248876.4	**Datum:**	AHD	**Finished:**	08/12/2017
Logged by:	JC **Checked by:**	**Grid:**	MGA94 Zone 56	**Inclination:**	-90°	**Orientation:**	

DRILLING / MATERIAL SUBSTANCE

Method & Support	Water	RL (m)	Depth (m)	Description of Strata ROCK TYPE : Colour, Grain size, Structure (texture, fabric, mineral composition, hardness alteration, cementation, major defect type)
AD/V				Silty Sandy CLAY: Low to medium plasticity, brown, trace of rootlets.
				Silty CLAY: High plasticity, yellow-brown mottled red-brown, trace of sand.
	▽ 15/02/18	56	2	
				2.50m: Colour becomes pale grey mottled orange-brown.
		54	4	4.00m: With a trace of fine to coarse subrounded gravel.
		52	6	
				SANDSTONE: Pale grey and orange-brown, extremely weathered, very low strength.
HQ3				SANDSTONE: Orange-brown, fine grained.
		50	8	
				9.00m: Siltstone band 40mm.
				SILTSTONE: Pale grey and orange brown.
				Interbedded SILTSTONE and SANDSTONE (70%/30%): Siltstone is dark grey, sandstone is grey, fine grained, distinctly bedded at 0-5°.
		48	10	
		46	12	
				12.66m: Approximately 30% siltstone and 70% sandstone.
		44	14	
		42	16	Interbedded SILTSTONE and SANDSTONE (30%/70%): Siltstone is dark grey, sandstone is grey, fine grained, distinctly bedded at 0-5°.
		40	18	
				Hole Terminated at 18.07 m

INSTALLATION DETAILS

ID	Type	Stick Up & RL	Tip Depth & RL
BH134	Standpipe Piezometer		18.07 m 39.87 m



DRILLING

NMLC	NMLC Coring	HQ	HQ Coring	TCR	% core run recovered
NQ	NQ Coring	PQ	PQ Coring	RQD	% core run > 100mm long (rock fraction only measured)

GROUNDWATER SYMBOLS

▼ = Water level (static) ▽ = Water level (during drilling)

Piezometer Installation Details

BH135

Project:	M12 Motorway Concept Design			**Page:**	1 of 2
Client:	Roads and Maritime Services	**Location:**	Range Rd, Cecil Park, NSW	**Project No:**	IA145100

Contractor:	Terratest	**Easting:**	297594.0	**Elevation:**	60.55	**Started:**	07/12/2017
Plant:	HydraScout	**Northing:**	6248705.9	**Datum:**	AHD	**Finished:**	07/12/2017
Logged by:	JC **Checked by:**	**Grid:**	MGA94 Zone 56	**Inclination:**	-90°	**Orientation:**	

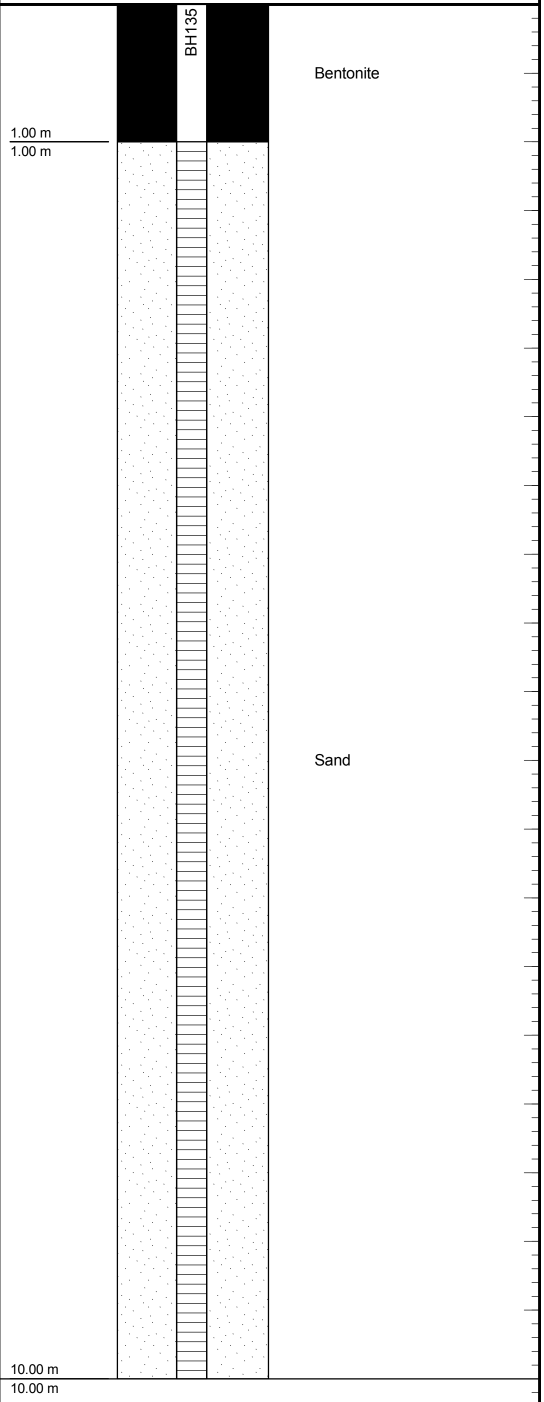
DRILLING — MATERIAL SUBSTANCE — INSTALLATION DETAILS

Method & Support: AD/V; HQ3

Water: 15/02/18

Description of Strata ROCK TYPE : Colour, Grain size, Structure (texture, fabric, mineral composition, hardness alteration, cementation, major defect type)
Silty Clayey SAND: Fine to medium grained, dark brown, trace of rootlets.
Silty CLAY: High plasticity, yellow-brown and orange-brown, trace sand.
Silty CLAY: High plasticity, pale grey mottled red-brown.
SILTSTONE: Pale grey and orange-brown, extremely weathered, very low strength.
SILTSTONE: Brown and grey, with occasional thin bands of sandstone 50-100mm, and thin clay bands.
SILTSTONE: Grey, indistinctly laminated at 0-5°.
INTERLAMINATED SILTSTONE and SANDSTONE: Sandstone is grey, fine grained, siltstone is dark grey.
SANDSTONE: Grey with dark flecks, fine grained.
Hole Terminated at 10.00 m

ID	Type	Stick Up & RL	Tip Depth & RL
BH135	Standpipe Piezometer		10.00 m 50.55 m



DRILLING

NMLC NMLC Coring
NQ NQ Coring

HQ HQ Coring
PQ PQ Coring

TCR % core run recovered
RQD % core run > 100mm long (rock fraction only measured)

GROUNDWATER SYMBOLS

▼ = Water level (static)

▽ = Water level (during drilling)

Piezometer Installation Details

BH139

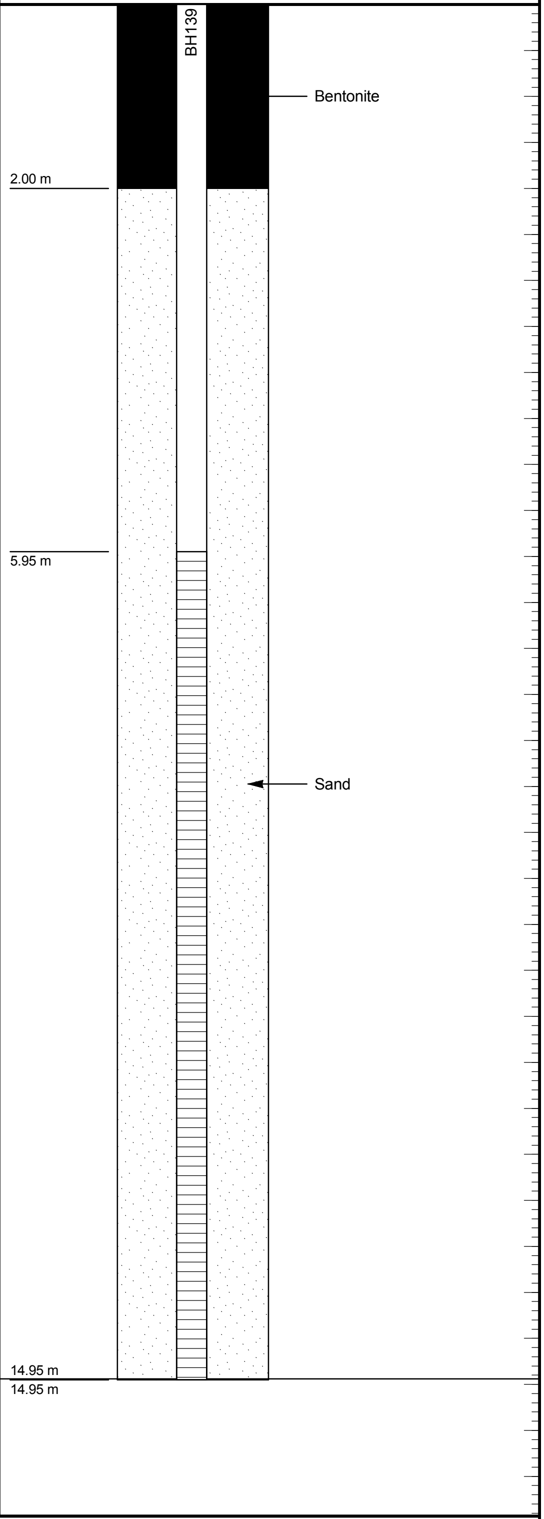
Project: M12 Motorway Concept Design
Page: 1 of 2
Client: Roads and Maritime Services
Location: Western Sydney Parklands, NSW
Project No: IA145100

Contractor:	Terratest	**Easting:**	298273.1	**Elevation:**	101.10	**Started:**	16/04/2018
Plant:	Comacchio 205	**Northing:**	6248769.7	**Datum:**	AHD	**Finished:**	17/04/2018
Logged by:	JC **Checked by:**	**Grid:**	MGA94 Zone 56	**Inclination:**	-90°	**Orientation:**	

DRILLING | MATERIAL SUBSTANCE | INSTALLATION DETAILS

Method & Support	Water	RL (m)	Depth (m)	Graphic Log	Description of Strata ROCK TYPE : Colour, Grain size, Structure (texture, fabric, mineral composition, hardness alteration, cementation, major defect type)
AD/V	Not Encountered				Silty CLAY: Medium to high plasticity, red-brown, trace fine grained sand.
					SANDSTONE: Brown and red-brown, fine grained, extremely weathered, very low strength.
		100			
HQ3					SANDSTONE: Brown, fine grained, massive.
			2		
					2.45m: As above, but becomes distinctly horizontally bedded.
		98			
					3.05m: As above, but colour becomes grey and brown.
			4		
		96			
			6		SANDSTONE: Brown and grey, fine grained, with siltstone bands.
		94			
					SANDSTONE: Brown and grey, fine to medium grained, with siltstone breccia/nodules, dark grey.
			8		
		92			
			10		SILTSTONE: Dark grey with orange-brown staining, indistinctly laminated.
		90			
			12		
		88			
			14		13.85m: Sandstone band, grey, fine grained, 150mm thick.
					SANDSTONE: Grey, fine grained, with dark grey laminae.
		86			Hole Terminated at 14.94 m
			16		

ID	Type	Stick Up & RL	Tip Depth & RL
BH139	Standpipe Piezometer		14.95 m 86.15 m



DRILLING

NMLC NMLC Coring
NQ NQ Coring
HQ HQ Coring
PQ PQ Coring
TCR % core run recovered
RQD % core run > 100mm long (rock fraction only measured)

GROUNDWATER SYMBOLS

▼ = Water level (static)
▽ = Water level (during drilling)

Piezometer Installation Details

BH144

Project: M12 Motorway Concept Design
Page: 1 of 2
Client: Roads and Maritime Services
Location: Western Sydney Parklands, NSW
Project No: IA145100

Contractor:	Terratest	**Easting:**	298656.6	**Elevation:**	113.50	**Started:**	04/04/2018
Plant:	Comacchio 305	**Northing:**	6249024.3	**Datum:**	AHD	**Finished:**	05/04/2018
Logged by:	MG **Checked by:**	**Grid:**	MGA94 Zone 56	**Inclination:**	-90°	**Orientation:**	

DRILLING

MATERIAL SUBSTANCE

INSTALLATION DETAILS

Method & Support | Water | RL (m) | Depth (m) | Graphic Log

Description of Strata

ROCK TYPE : Colour, Grain size, Structure
(texture, fabric, mineral composition, hardness
alteration, cementation, major defect type)

ID	Type	Stick Up & RL	Tip Depth & RL
BH144	Standpipe Piezometer		20.65 m 92.85 m

Method & Support: AD/T; HQ3

Water: Not Encountered; 29/05/18

RL (m): 112, 110, 108, 106, 104, 102, 100, 98, 96, 94, 92

Depth (m): 2, 4, 6, 8, 10, 12, 14, 16, 18, 20, 22

Silty CLAY: Medium plasticity, brown, with a trace of root fibres in top 50mm.

SILTSTONE: Brown and dark grey, highly weathered, very low strength.

Interbedded SILTSTONE and SANDSTONE (70% Siltstone, 30% Sandstone): Brown and grey, sandstone is fine grained, with iron staining in defects, thinly bedded.

5.50m: Becoming more grey.

Interbedded SILTSTONE and SANDSTONE (50% Siltstone, 50% Sandstone): Grey and dark grey, sandstone is fine grained.

SANDSTONE: Pale grey with dark grey flecks and laminae, fine grained.

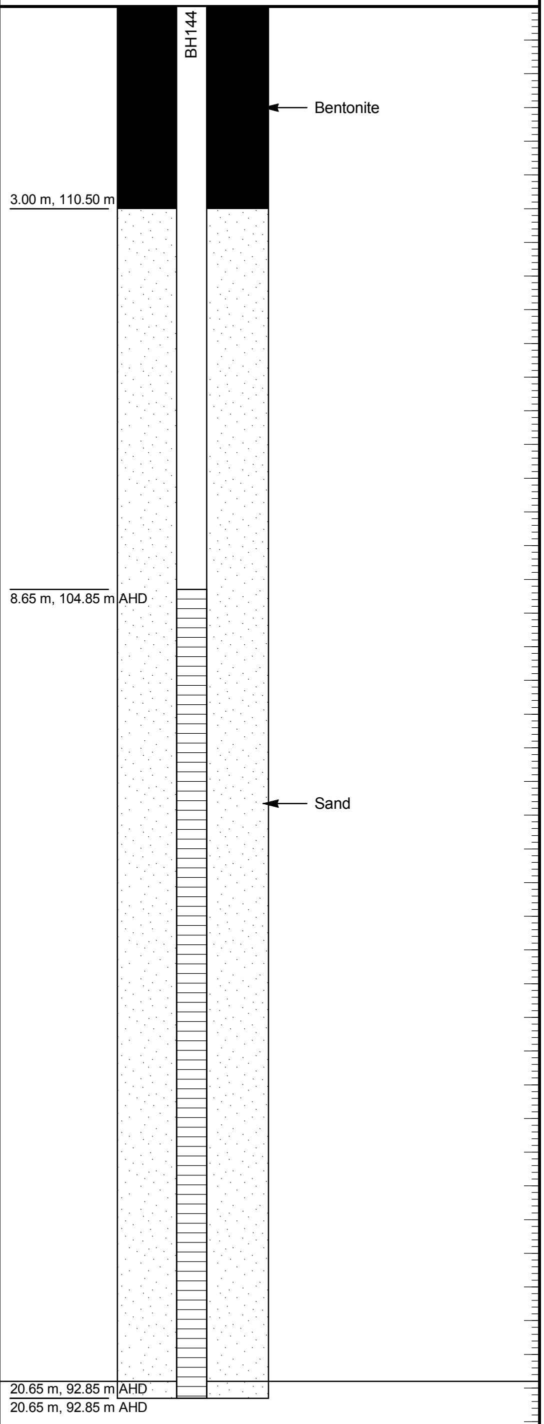
Interlaminated SILTSTONE and SANDSTONE (50% Siltstone, 50% Sandstone): Grey and dark grey, sandstone is fine grained, distinctly laminated.

Interbedded SILTSTONE and SANDSTONE (50% Siltstone, 50% Sandstone): Grey and dark grey, sandstone is fine grained.

Interlaminated SILTSTONE and SANDSTONE (50% Siltstone, 50% Sandstone): Siltstone is dark grey, sandstone is grey, fine grained.

SILTSTONE: Dark grey with some thin sandstone bands and laminae, distinctly laminated.

Hole Terminated at 20.40 m



DRILLING

NMLC	NMLC Coring	HQ	HQ Coring	TCR	% core run recovered
NQ	NQ Coring	PQ	PQ Coring	RQD	% core run > 100mm long (rock fraction only measured)

GROUNDWATER SYMBOLS

▼ = Water level (static)
▽ = Water level (during drilling)

Piezometer Installation Details

BH145

Project: M12 Motorway Concept Design
Client: Roads and Maritime Services
Location: Western Sydney Parklands, NSW
Page: 1 of 2
Project No: IA145100

Contractor:	Terratest	**Easting:**	298879.9	**Elevation:**	116.30
Plant:	Comacchio 305	**Northing:**	6248988.6	**Datum:**	AHD
Logged by:	MG	**Checked by:**		**Grid:**	MGA94 Zone 56
Inclination:	-90°	**Started:**	05/04/2018	**Finished:**	06/04/2018
Orientation:					

DRILLING | MATERIAL SUBSTANCE | INSTALLATION DETAILS

Method & Support | Water | RL (m) | Depth (m) | Graphic Log | **Description of Strata**

ROCK TYPE : Colour, Grain size, Structure (texture, fabric, mineral composition, hardness alteration, cementation, major defect type)

ID	Type	Stick Up & RL	Tip Depth & RL
BH145	Standpipe Piezometer		20.00 m 96.30 m

Method & Support: AD/V; HQ3

Water: Not Encountered 29/05/18

RL (m): 116, 114, 112, 110, 108, 106, 104, 102, 100, 98, 96

Depth (m): 2, 4, 6, 8, 10, 12, 14, 16, 18, 20

Silty Sandy CLAY: Medium plasticity, brown and yellow-brown, with some root fibres in the top 50mm.

Silty CLAY: Medium plasticity, grey and orange-brown.

SILTSTONE: Dark grey and orange brown, extremely weathered, very low strength.

SILTSTONE: Dark grey with some red-brown

Interbedded SILTSTONE and SANDSTONE (70% Siltstone, 30% Sandstone): Grey-brown, sandstone is fine grained, subhorizontal bedding.

7.60m: Increasing in Sandstone (40%) and becoming more grey.

Interbedded SILTSTONE and SANDSTONE (60% Siltstone, 40% Sandstone): Grey and dark grey, with iron stained defects, sandstone is fine grained, thin to medium subhorizontal bedding.

9.50m: Increasing in Siltstone (70%), indistinctly bedded.

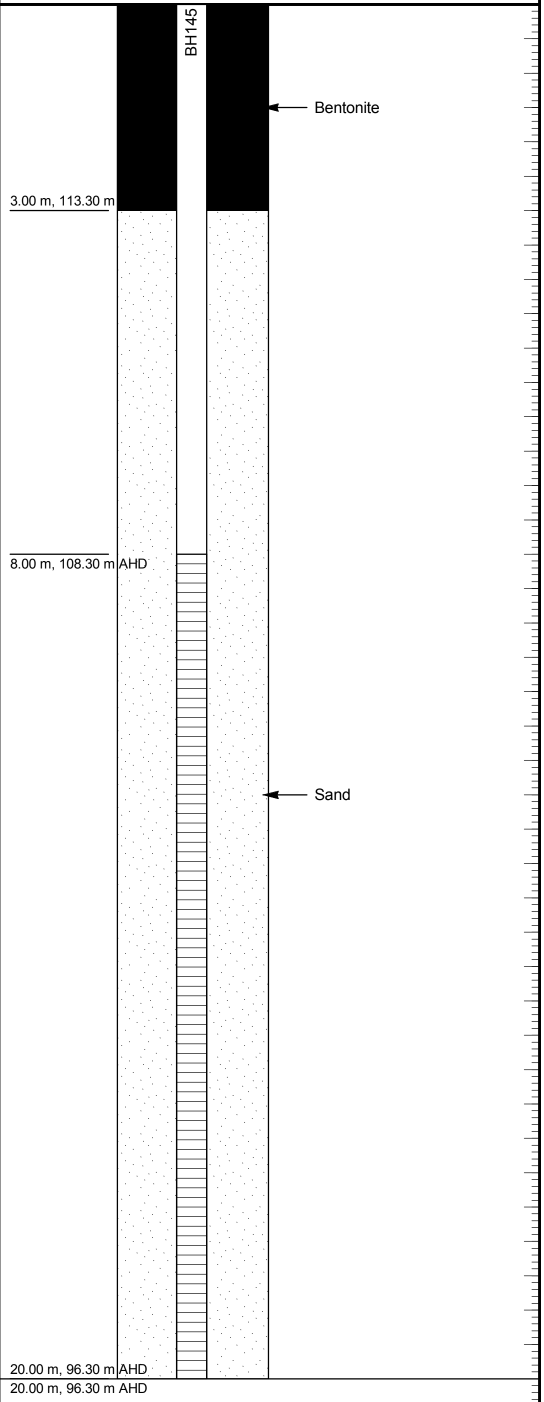
Carbonaceous SILTSTONE: Dark Grey.

Interlaminated SILTSTONE and SANDSTONE (50% Siltstone, 50% Sandstone): Dark grey and grey, sandstone is fine grained, indistinct subhorizontal laminations.

SANDSTONE: Grey, fine grained, with some dark grey laminae.

Interbedded SILTSTONE and SANDSTONE (50% Siltstone, 50% Sandstone): Dark grey, sandstone is fine grained, thin subhorizontal bedding.

Hole Terminated at 20.00 m



DRILLING

NMLC	NMLC Coring	HQ	HQ Coring	TCR	% core run recovered
NQ	NQ Coring	PQ	PQ Coring	RQD	% core run > 100mm long (rock fraction only measured)

GROUNDWATER SYMBOLS

▼ = Water level (static)
▽ = Water level (during drilling)

Piezometer Installation Details

BH150

Project: M12 Motorway Concept Design
Client: Roads and Maritime Services
Location: Western Sydney Parklands, NSW
Page: 1 of 2
Project No: IA145100

Contractor:	Terratest	**Easting:**	299108.0	**Elevation:**	109.50	**Started:**	10/04/2018
Plant:	Comacchio 305	**Northing:**	6249307.6	**Datum:**	AHD	**Finished:**	10/04/2018
Logged by:	MG **Checked by:**	**Grid:**	MGA94 Zone 56	**Inclination:**	-90°	**Orientation:**	

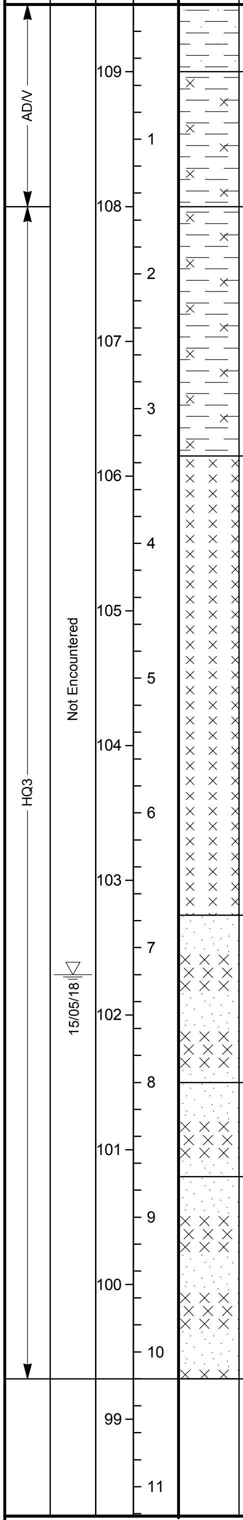
DRILLING | MATERIAL SUBSTANCE | INSTALLATION DETAILS

Method & Support | Water | RL (m) | Depth (m) | Graphic Log

Description of Strata

ROCK TYPE : Colour, Grain size, Structure (texture, fabric, mineral composition, hardness alteration, cementation, major defect type)

ID	Type	Stick Up & RL	Tip Depth & RL
BH150	Standpipe Piezometer		10.20 m 99.30 m



Sandy Silty CLAY: Low to medium plasticity, brown, with root fibres in the top 50mm.

Silty CLAY: Medium plasticity, orange-brown.

1.00m: Becoming dark grey and brown.

Silty CLAY: Medium plasticity, pale grey mottled brown and red, hard, with some ironstone and shale gravel.

SILTSTONE: Grey-brown and dark grey, highly fractured.

4.20m: As above, but with some bands of sandstone approximately 10-20mm thick.

6.00-6.20m: Carbonaceous siltstone band.

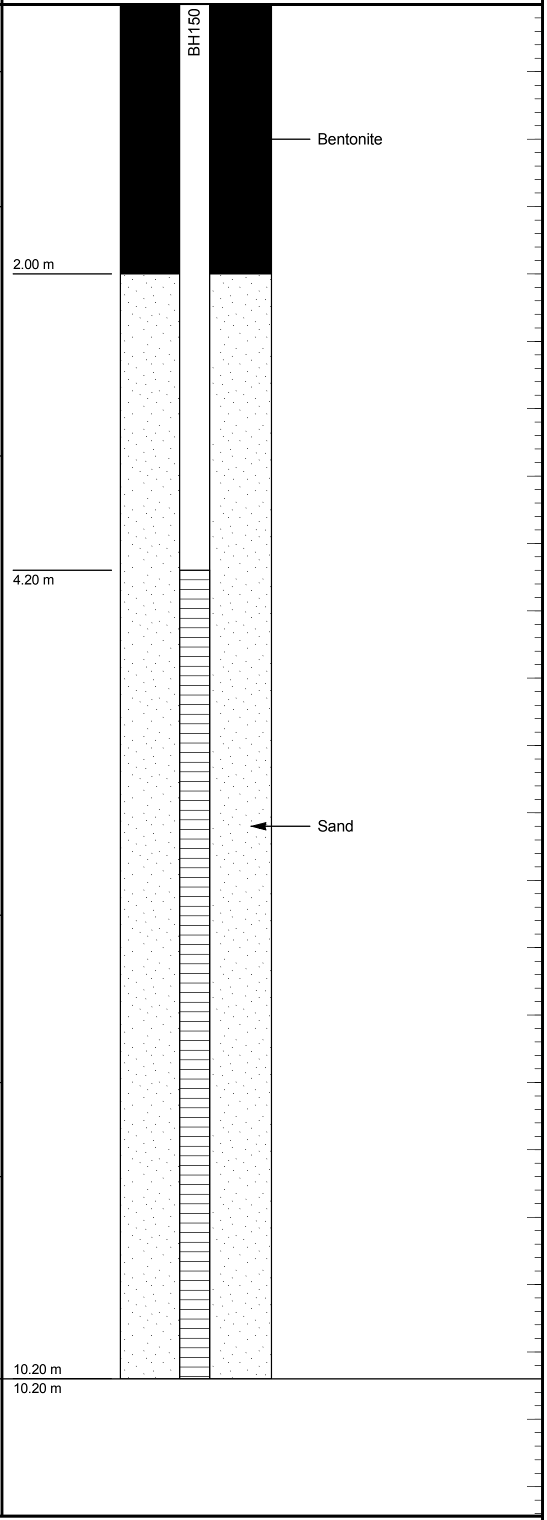
6.63-6.76m: Sandstone band.

Interbedded SILTSTONE and SANDSTONE (60% Siltstone, 40% Sandstone): Dark grey, sandstone is fine grained.

Interbedded SILTSTONE and SANDSTONE (50% Siltstone, 50% Sandstone): Dark grey, sandstone is fine grained, thinly to medium bedded, with iron staining in defects.

Interlaminated SILTSTONE and SANDSTONE (50% Siltstone, 50% Sandstone): Dark grey, sandstone is fine grained, grey.

Hole Terminated at 10.20 m



DRILLING

NMLC NMLC Coring
NQ NQ Coring
HQ HQ Coring
PQ PQ Coring
TCR % core run recovered
RQD % core run > 100mm long (rock fraction only measured)

GROUNDWATER SYMBOLS

▼ = Water level (static)
▽ = Water level (during drilling)

Piezometer Installation Details

BH155

Project:	M12 Motorway Concept Design			**Page:**	1 of 2
Client:	Roads and Maritime Services	**Location:**	Western Sydney Parklands, NSW	**Project No:**	IA145100

Contractor:	Terratest	**Easting:**	299535.5	**Elevation:**	121.60	**Started:**	16/04/2018
Plant:	Comacchio 405	**Northing:**	6249379.5	**Datum:**	AHD	**Finished:**	16/04/2018
Logged by:	MG **Checked by:**	**Grid:**	MGA94 Zone 56	**Inclination:**	-90°	**Orientation:**	

DRILLING — MATERIAL SUBSTANCE — INSTALLATION DETAILS

Method & Support: HA; AD/V; HQ3

Water: Not Encountered; 29/05/18

Description of Strata

ROCK TYPE : Colour, Grain size, Structure (texture, fabric, mineral composition, hardness alteration, cementation, major defect type)

ID	Type	Stick Up & RL	Tip Depth & RL
BH155	Standpipe Piezometer		12.00 m 109.60 m

Silty Sandy CLAY: Low plasticity, brown, with root fibres in top 50mm.

Silty CLAY: Low to medium plasticity, pale brown and red-brown.

Silty CLAY: Medium plasticity, brown and red-brown, with some extremely weathered bands of siltstone.

1.90m: As above, but becoming pale grey mottled red-brown.

Interbedded SILTSTONE and SANDSTONE (75% Siltstone, 25% Sandstone): Brown and grey-brown, sandstone is fine grained, medium bedded.

NO CORE: 200mm

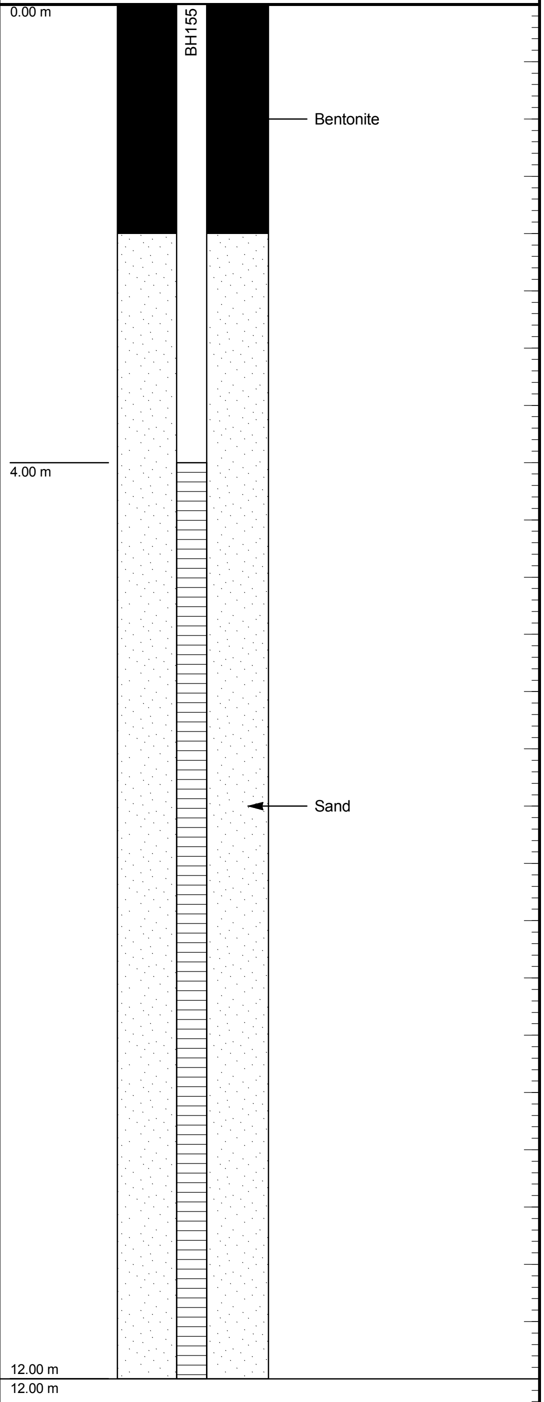
SILTSTONE: Dark grey, with sandstone bands and laminae, grey, fine grained.

Interbedded SILTSTONE and SANDSTONE (60% Siltstone, 40% Sandstone): Grey-brown and grey, sandstone is fine grained, thinly to medium bedded.

SILTSTONE: Dark grey, subhorizontal laminations.

11.60m: As above, but with some sandstone bands.

Hole Terminated at 12.00 m



DRILLING

NMLC NMLC Coring
NQ NQ Coring
HQ HQ Coring
PQ PQ Coring
TCR % core run recovered
RQD % core run > 100mm long (rock fraction only measured)

GROUNDWATER SYMBOLS

▼ = Water level (static)
▽ = Water level (during drilling)

Piezometer Installation Details

BH202

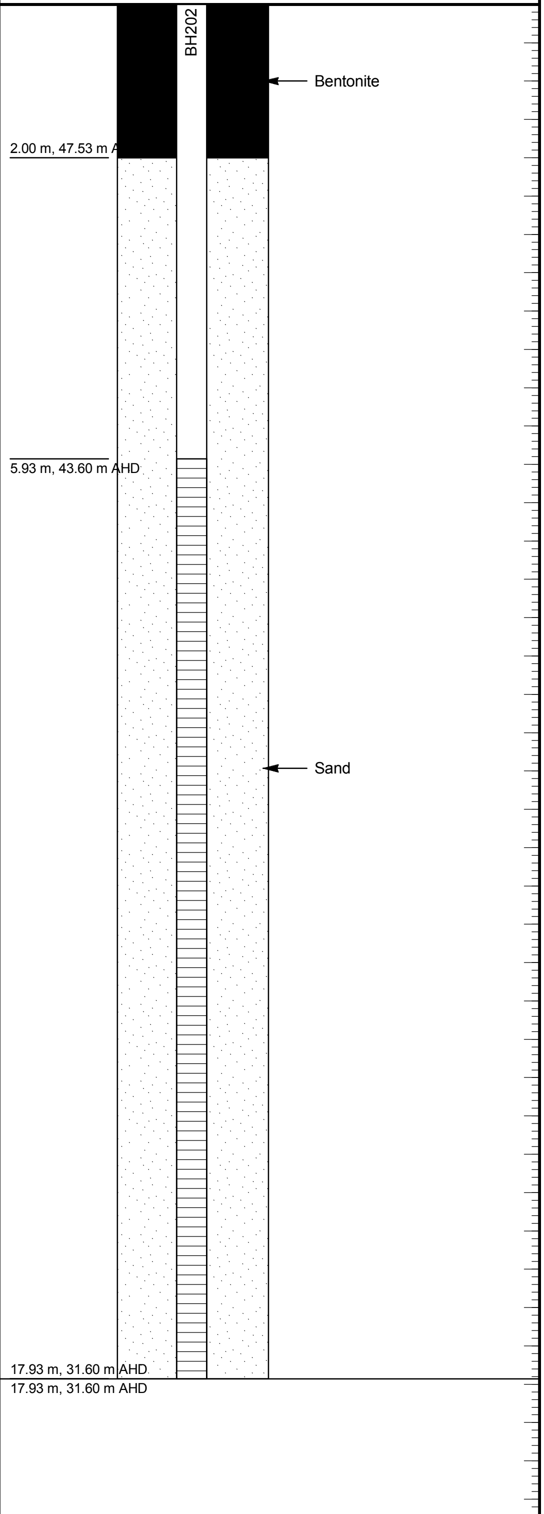
Project:	M12 Motorway Concept Design			**Page:**	1 of 2
Client:	Roads and Maritime Services	**Location:**	Cosgroves Creek, Luddenham. NSW	**Project No:**	IA145100

Contractor:	Terratest	**Easting:**	290089.9	**Elevation:**	49.53	**Started:**	02/05/2018
Plant:	Comacchio 405	**Northing:**	6251218.3	**Datum:**	AHD	**Finished:**	03/05/2018
Logged by:	JC **Checked by:**	**Grid:**	MGA94 Zone 56	**Inclination:**	-90°	**Orientation:**	

DRILLING | MATERIAL SUBSTANCE | INSTALLATION DETAILS

Method & Support	Water	RL (m)	Depth (m)	Graphic Log	Description of Strata ROCK TYPE : Colour, Grain size, Structure (texture, fabric, mineral composition, hardness alteration, cementation, major defect type)
AD/V	15/05/18				Silty SAND: Fine grained, brown, trace of rootlets and fine subrounded gravel.
		48	2		Silty Sandy CLAY: High plasticity, orange-brown, mottled pale grey, sand is fine grained, with a trace of rootlets.
					SANDSTONE: Pale grey mottled orange-brown, extremely weathered, very low strength.
HQ3	Not Encountered	46			SANDSTONE: Orange-brown and yellow-brown, fine grained, with dark grey carbonaceous laminations.
			4		SILTSTONE: Dark grey, distinctly laminated, with fine grained sandstone laminations and bands.
		44	6		SANDSTONE: Grey, fine grained.
					Carbonaceous SILTSTONE: Dark grey.
		42	8		SILTSTONE: Dark grey, with pale grey bands, indistinct laminations. 8.39m: As above, but with bands of Carbonaceous Siltstone. 8.76-8.89m: Sandstone band, fine grained, 130mm.
		40	10		Interlaminated SILTSTONE and SANDSTONE (60% Siltstone/ 40% Sandstone): Siltstone is dark grey, sandstone is grey, fine grained, distinct subhorizontal laminations.
		38	12		SILTSTONE: Dark grey and grey, subhorizontal laminations with some sandstone laminae, pale grey.
		36	14		Interlaminated SANDSTONE and SILTSTONE (70% Sandstone/ 30% Siltstone): Sandstone is grey, fine grained, siltstone is dark grey, distinct subhorizontal laminations.
		34	16		Carbonaceous SILTSTONE: Dark grey, indistinctly laminated.
					SANDSTONE: Grey and dark grey, fine grained with siltstone laminations.
		32	18		Interlaminated SILTSTONE and SANDSTONE (70% Siltstone/ 30% Sandstone): Siltstone is dark grey, sandstone is grey, fine grained, distinct subhorizontal laminations.
		30			Hole Terminated at 17.93 m Target depth

ID	Type	Stick Up & RL	Tip Depth & RL
BH202	Standpipe Piezometer		17.93 m 31.60 m



DRILLING

NMLC	NMLC Coring	HQ	HQ Coring	TCR	% core run recovered
NQ	NQ Coring	PQ	PQ Coring	RQD	% core run > 100mm long (rock fraction only measured)

GROUNDWATER SYMBOLS

▼ = Water level (static)   ▽ = Water level (during drilling)

Piezometer Installation Details

BH204

Project: M12 Motorway Concept Design
Client: Roads and Maritime Services
Location: Cosgroves Creek, Luddenham. NSW
Page: 1 of 2
Project No: IA145100

Contractor:	Terratest	**Easting:**	290177.3	**Elevation:**	50.24
Plant:	Comacchio 405	**Northing:**	6251195.2	**Datum:**	AHD
Logged by:	JC	**Grid:**	MGA94 Zone 56	**Inclination:**	-90°
Checked by:		**Started:**	19/04/2018	**Finished:**	20/04/2018
Orientation:					

DRILLING

Method & Support: AD/V (0 – approx. 4.6 m); HQ3 (to 15.43 m)

Water: 15/05/18 (water level during drilling); Not Encountered

RL (m): 50, 48, 46, 44, 42, 40, 38, 36, 34

Depth (m): 2, 4, 6, 8, 10, 12, 14, 16

MATERIAL SUBSTANCE

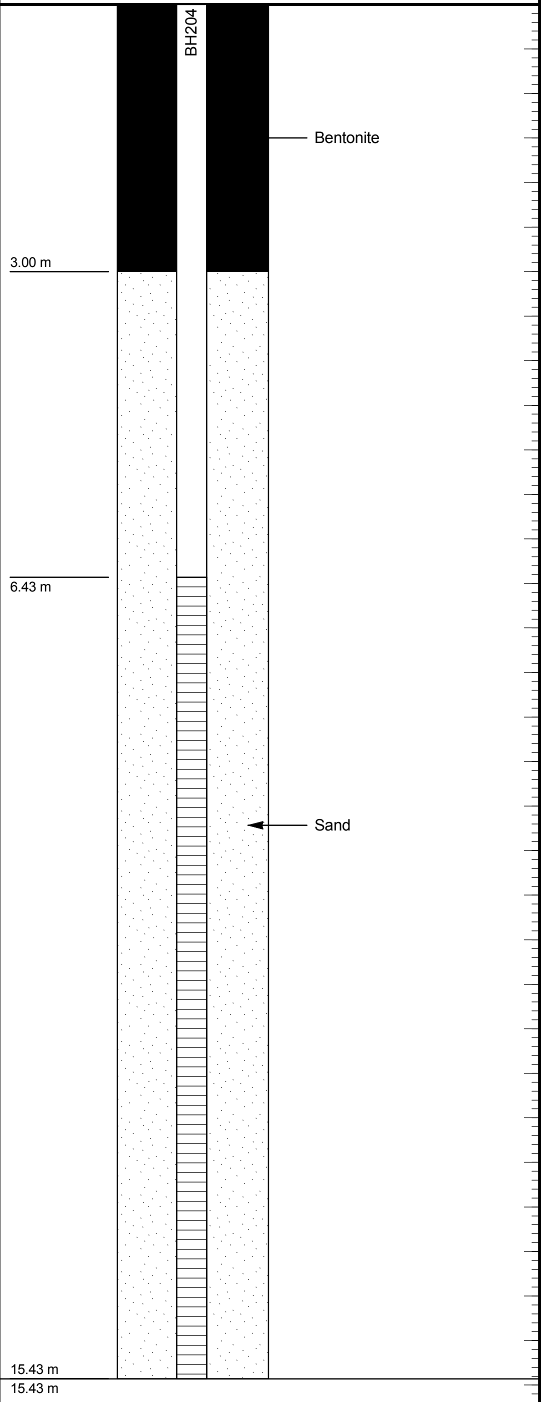
Description of Strata

ROCK TYPE : Colour, Grain size, Structure (texture, fabric, mineral composition, hardness alteration, cementation, major defect type)

Description of Strata
Silty SAND: Fine grained, brown, trace rootlets.
Sandy CLAY: High plasticity, yellow-brown mottled grey, sand is fine to medium grained, trace fine sub-rounded to rounded gravel, trace rootlets.
Gravelly CLAY: Low to medium plasticity, mottled red-brown, orange-brown and yellow-brown, gravel is fine to coarse sub-rounded ironstone, with fine to coarse grained sand.
SANDSTONE: Grey, fine grained, extremely weathered, very low strength.
SANDSTONE: Grey stained orange-brown becoming grey, fine grained, with dark grey laminations.
SILTSTONE: Dark grey with occasional grey sandstone and black carbonaceous siltstone bands. 6.00m: As above, but trace fine to medium sub-rounded pebbles.
SANDSTONE: Grey, fine grained.
SILTSTONE: Grey.
SANDSTONE: Grey, fine grained.
SILTSTONE: Grey.
SANDSTONE: Grey, fine grained.
SILTSTONE: Dark grey.
CARBONACEOUS SILTSTONE: Dark grey, with some coal laminae.
SILTSTONE: Dark grey, indistinctly laminated.
Interlaminated SANDSTONE and SILTSTONE (60% Sandstone, 40% Siltstone): Sandstone is grey, fine grained, siltstone is dark grey, distinct subhorizontal laminations.
Interbedded SILTSTONE and SANDSTONE (60% Siltstone, 40% Sandstone): Siltstone is dark grey, sandstone is grey, fine grained, subhorizontal bands with some pebble bands.
Interlaminated SILTSTONE and SANDSTONE (70% Siltstone, 30% Sandstone): Siltstone is dark grey, sandstone is grey, fine grained, distinctly laminated.
Carbonaceous SILTSTONE: Dark grey.
Interlaminated SANDSTONE and SILTSTONE (70%, 30% Siltstone): Grey and dark grey, sandstone is fine grained, subhorizontal laminations.
Hole Terminated at 15.43 m

INSTALLATION DETAILS

ID	Type	Stick Up & RL	Tip Depth & RL
BH204	Standpipe Piezometer		15.43 m 34.81 m



DRILLING

NMLC	NMLC Coring	HQ	HQ Coring	TCR	% core run recovered
NQ	NQ Coring	PQ	PQ Coring	RQD	% core run > 100mm long (rock fraction only measured)

GROUNDWATER SYMBOLS

▼ = Water level (static)
▽ = Water level (during drilling)

Piezometer Installation Details

BH207

Project: M12 Motorway Concept Design
Client: Roads and Maritime Services
Location: Badgery's Creek, NSW
Page: 1 of 2
Project No: IA145100

Contractor: Terratest	**Easting:** 292341.6	**Elevation:** 40.03	**Started:** 02/05/2018		
Plant: Comacchio 205	**Northing:** 6251217.1	**Datum:** AHD	**Finished:** 03/05/2018		
Logged by: MG	**Checked by:**	**Grid:** MGA94 Zone 56	**Inclination:** -90°	**Orientation:**	

DRILLING

Method & Support: AD/T; AD/V; HQ3

Water: 15/05/18; Not Encountered

RL (m)	Depth (m)
38	2
36	4
34	6
32	8
30	10
28	12
26	14
24	16
22	18

MATERIAL SUBSTANCE

Description of Strata

ROCK TYPE : Colour, Grain size, Structure (texture, fabric, mineral composition, hardness alteration, cementation, major defect type)

Silty CLAY: Medium to high plasticity, brown, with rootlets in top 50mm.

Silty CLAY: High plasticity, brown, yellow-brown and grey.

NO CORE: 850mm

Silty Sandy CLAY: High plasticity, orange-brown and grey, w < PL, Vst.

NO CORE: 500mm

SANDSTONE: Yellow-brown and pale grey, fine to medium grained.

SILTSTONE: Dark grey, pale grey and yellow-brown.

Carbonaceous SILTSTONE: Dark grey and grey, with some fine grained sandy laminations.

6.60-6.90m: Siltstone band, 300mm.

7.50m: Sandstone band, fine grained, 40mm thick.

Interlaminated SILTSTONE and SANDSTONE (50% Siltstone/ 50% Sandstone): Dark grey and grey, sandstone is fine grained, distinctly laminated at 0-5°.

10.50m: Increasing in sandstone (60%)

11.50m: Increasing in sandstone (75%), with some bands up to 100mm thick.

13.20-13.40m: Sandstone band, 20mm

SILTSTONE: Dark grey.
14.00m: Pebble band, 50mm.

Carbonaceous SILTSTONE: Dark grey.

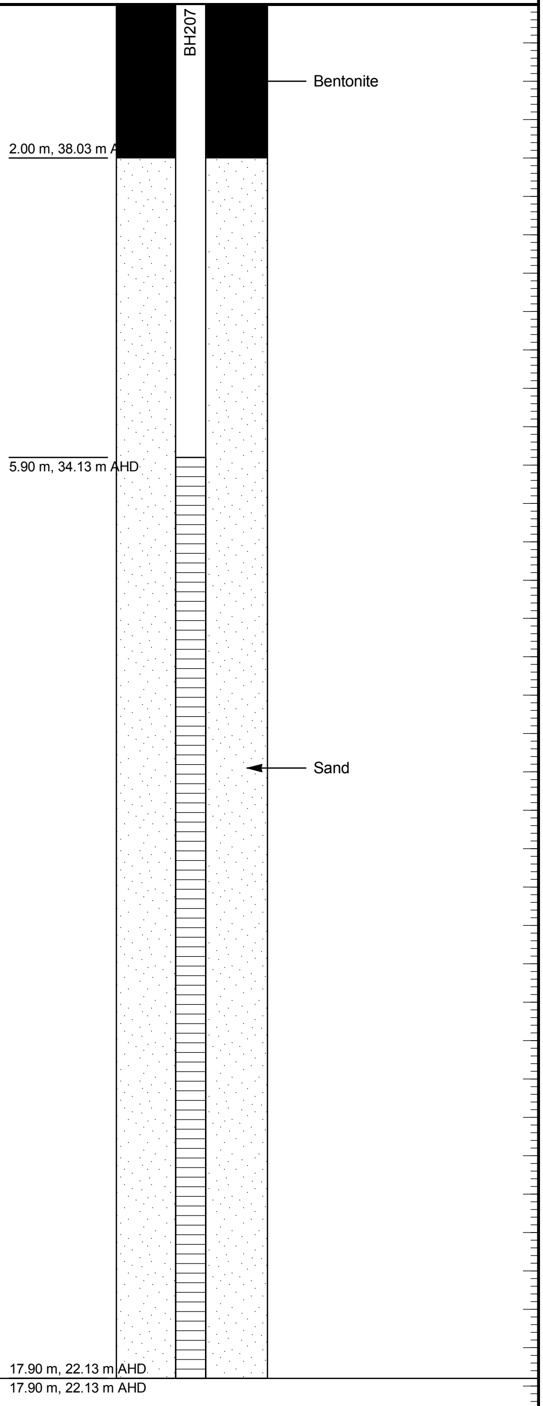
Interlaminated SILTSTONE and SANDSTONE (60% Siltstone/ 40% Sandstone): Dark grey and grey, sandstone is fine grained, distinctly laminated at 0-5°.

Interlaminated SILTSTONE and SANDSTONE (65% Siltstone/ 35% Sandstone): Dark grey and grey, sandstone is fine grained, indistinctly laminated at 0-5°.

Hole Terminated at 17.90 m
Target depth

INSTALLATION DETAILS

ID	Type	Stick Up & RL	Tip Depth & RL
BH207	Standpipe Piezometer		17.90 m 22.13 m



DRILLING

NMLC	NMLC Coring	HQ	HQ Coring	TCR	% core run recovered
NQ	NQ Coring	PQ	PQ Coring	RQD	% core run > 100mm long (rock fraction only measured)

GROUNDWATER SYMBOLS

▼ = Water level (static)

▽ = Water level (during drilling)

Piezometer Installation Details

BH209

Project: M12 Motorway Concept Design
Client: Roads and Maritime Services
Location: Badgery's Creek, NSW
Page: 1 of 2
Project No: IA145100

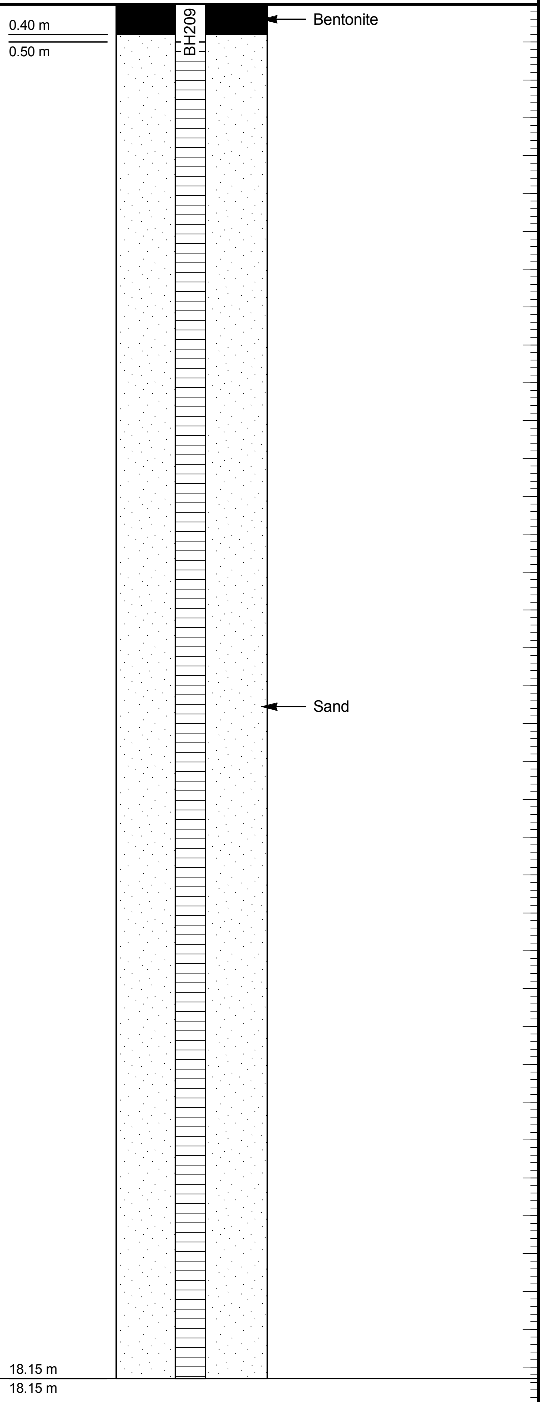
Contractor: Terratest
Plant: Comacchio 405
Logged by: GC **Checked by:**
Easting:
Northing:
Grid: MGA94 Zone 56
Elevation:
Datum: AHD
Inclination: -90°
Started: 06/06/2018
Finished: 06/06/2018
Orientation:

DRILLING | MATERIAL SUBSTANCE

Method & Support	Water	RL (m)	Depth (m)	Graphic Log	Description of Strata ROCK TYPE : Colour, Grain size, Structure (texture, fabric, mineral composition, hardness alteration, cementation, major defect type)
AD/V					Silty CLAY: Medium plasticity, mottled red-brown. orange-brown and grey, trace subrounded to rounded fine ironstone gravel, trace of fine grained sand.
	▽ 15/06/18		2		Silty CLAY: Medium plasticity, grey and orange, trace subangular fine ironstone gravel.
WB			4		SILTSTONE: Grey and dark grey, extremely weathered, very low strength.
HQ3	Not Encountered		6		SILTSTONE: Dark grey and brown, indistinctly laminated. 6.30m: With some fine grained sandstone laminations. 6.90m: As above, but with trace carbonaceous nodules.
					SILTSTONE: Grey. 7.96m: With some grey, fine grained sandstone laminations.
			8		SILTSTONE: Grey, with some grey, fine grained sandstone laminations.
					SILTSTONE: Dark grey and grey, with trace carbonaceous bands and laminations. 9.20-9.30m: With some grey, fine grained sandstone laminations.
			10 12		SILTSTONE: Dark grey and grey, with some carbonaceous laminae up to 2mm thick. 11.13-11.29m: WIth some subangular to subrounded pebbles. 11.42-11.58m: Grey and dark grey sandstone band, fine grained. 12.52m: Becoming distinctly laminated.
			14		SILTSTONE: Dark grey, with some light grey, fine grained sandstone laminations.
			16		Interlaminated SANDSTONE and SILTSTONE (70% Sandstone, 30% Siltstone): Sandstone is grey, fine grained, siltstone is dark grey, distinctly laminated at 0-5°.
			18		SANDSTONE: Grey, fine grained, with some dark grey laminae and thin bands.
					Hole Terminated at 18.15 m Target depth

INSTALLATION DETAILS

ID	Type	Stick Up & RL	Tip Depth & RL
BH209	Standpipe Piezometer		18.15 m



DRILLING

NMLC NMLC Coring
NQ NQ Coring
HQ HQ Coring
PQ PQ Coring
TCR % core run recovered
RQD % core run > 100mm long (rock fraction only measured)

GROUNDWATER SYMBOLS

▼ = Water level (static)
▽ = Water level (during drilling)

Piezometer Installation Details

BH211

Project: M12 Motorway Concept Design
Client: Roads and Maritime Services **Location:** South Creek, NSW
Page: 1 of 2
Project No: IA145100

Contractor:	Terratest	**Easting:**		**Elevation:**	
Plant:	Comacchio 405	**Northing:**		**Datum:**	AHD
Logged by:	GC **Checked by:**	**Grid:**	MGA94 Zone 56	**Inclination:**	-90°

Started: 05/06/2018
Finished: 05/06/2018
Orientation:

DRILLING | MATERIAL SUBSTANCE | INSTALLATION DETAILS

Method & Support | Water | RL (m) | Depth (m) | Graphic Log | **Description of Strata**

ROCK TYPE : Colour, Grain size, Structure
(texture, fabric, mineral composition, hardness
alteration, cementation, major defect type)

ID	Type	Stick Up & RL	Tip Depth & RL
BH211	Standpipe Piezometer		18.00 m

Method & Support: AD/V (0 – 2.5 m); WB (2.5 – 5.5 m); HQ3 (5.5 – 18.0 m)

Water: 15/06/18 (at 2 m); Not Encountered

Depth (m): 2, 4, 6, 8, 10, 12, 14, 16, 18

Silty Sandy CLAY: Medium plasticity, orange-brown mottled red-brown, sand is fine grained.

Gravelly CLAY: High plasticity, mottled pale grey, red-brown, orange-brown and grey, with some fine to coarse sand and fine gravel.

SILTSTONE: Brown, extremely weathered, very low strength.

SILTSTONE: Dark grey.

NO CORE 110mm

SILTSTONE: Dark grey.

Interlaminated SILTSTONE and SANDSTONE (50% Siltstone, 50% Sandstone): Siltstone is dark grey, sandstone is grey, fine grained, distinctly laminated at 0-10°.

SILTSTONE: Grey and dark grey, indistinctly laminated.

SANDSTONE: Grey, fine grained, with occasional dark grey laminations.

9.45-9.65m: Interlaminated band of sandstone and siltstone.

SILTSTONE: Dark grey, with some sandstone laminations.

SILTSTONE: Dark grey, with some thin bands of sandstone laminae.

13.33-13.70m: Band of grey siltstone.

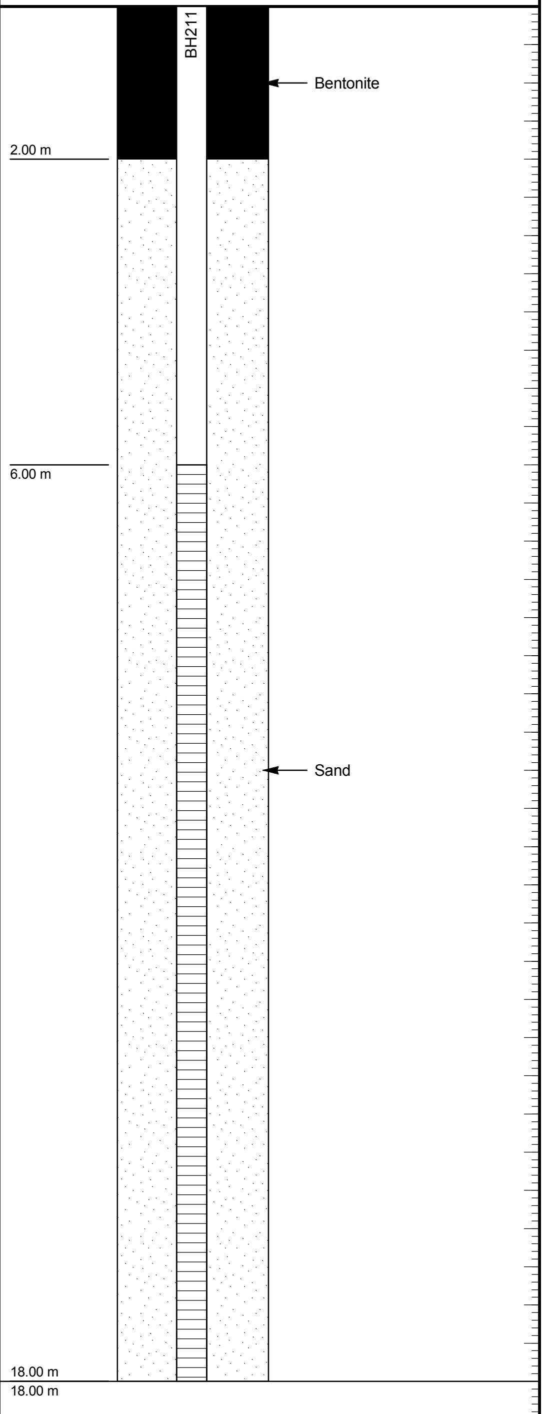
Interlaminated SILTSTONE and SANDSTONE (50% Siltstone, 50% Sandstone): Siltstone is dark grey, sandstone is grey, fine grained, distinctly laminated at 0-5°.

SILTSTONE: Dark grey and brown.

16.53m: With some pebbles.

Interlaminated SILTSTONE and SANDSTONE (60% Siltstone, 40% Sandstone): Siltstone is dark grey, sandstone is pale grey, fine grained, distinctly laminated at 0-5°.

Hole Terminated at 18.00 m
Target depth



DRILLING

NMLC	NMLC Coring	HQ	HQ Coring	TCR	% core run recovered
NQ	NQ Coring	PQ	PQ Coring	RQD	% core run > 100mm long (rock fraction only measured)

GROUNDWATER SYMBOLS

▼ = Water level (static) ▽ = Water level (during drilling)

Piezometer Installation Details

BH215

Project:	M12 Motorway Concept Design			**Page:**	1 of 2
Client:	Roads and Maritime Services	**Location:**	South Creek, NSW	**Project No:**	IA145100

Contractor:	Terratest	**Easting:**		**Elevation:**		**Started:**	29/05/2018
Plant:	Comacchio 405	**Northing:**		**Datum:**	AHD	**Finished:**	29/05/2018
Logged by:	GC **Checked by:**	**Grid:**	MGA94 Zone 56	**Inclination:**	-90°	**Orientation:**	

DRILLING | MATERIAL SUBSTANCE | INSTALLATION DETAILS

ID	Type	Stick Up & RL	Tip Depth & RL
BH215	Standpipe Piezometer		18.41 m

Method & Support: AD/V; WB; HQ3

Water: 15/06/18; Not Encountered

Depth (m): 2, 4, 6, 8, 10, 12, 14, 16, 18, 20

Description of Strata

ROCK TYPE : Colour, Grain size, Structure (texture, fabric, mineral composition, hardness alteration, cementation, major defect type)

Silty CLAY: Low to medium plasticity, orange-brown mottled grey, with some fine grained sand, with trace organic matter.

Silty CLAY: Medium plasticity, brown and grey and orange-brown, trace fine grained sand.

Silty CLAY: Medium to high plasticity, brown and grey, trace fine to coarse grained sand and fine ironstone gravel.

SILTSTONE: Grey and brown, extremely weathered, very low strength.

NO CORE 110mm

SILTSTONE: Dark grey and brown-orange, indistinctly laminated.

NO CORE 50mm

SILTSTONE: Grey with orange bands, indistinctly laminated.

SILTSTONE: Dark grey, indistinctly laminated.

SANDSTONE: Grey, fine grained, with occasional dark grey laminations.

Interbedded SILTSTONE and SANDSTONE (50% Siltstone, 50% Sandstone): Siltstone is dark grey, sandstone is grey, fine grained

9.61m: Becoming subhorizontaly interlaminated

SILTSTONE: Dark grey

10.80-10.98m: With some sandstone laminations.

SILTSTONE: Grey.

SILTSTONE: Dark grey, with trace rounded pebbles.

NO CORE 120mm

SILTSTONE: Dark grey, with trace pebbles and sandstone laminae.

NO CORE 70mm

SILTSTONE: Dark grey, with trace pebbles.

Interlaminated SANDSTONE and SILTSTONE (70% Sandstone, 30% Siltstone): Sandstone is grey, fine grained, siltstone is dark grey, disturbed laminae.

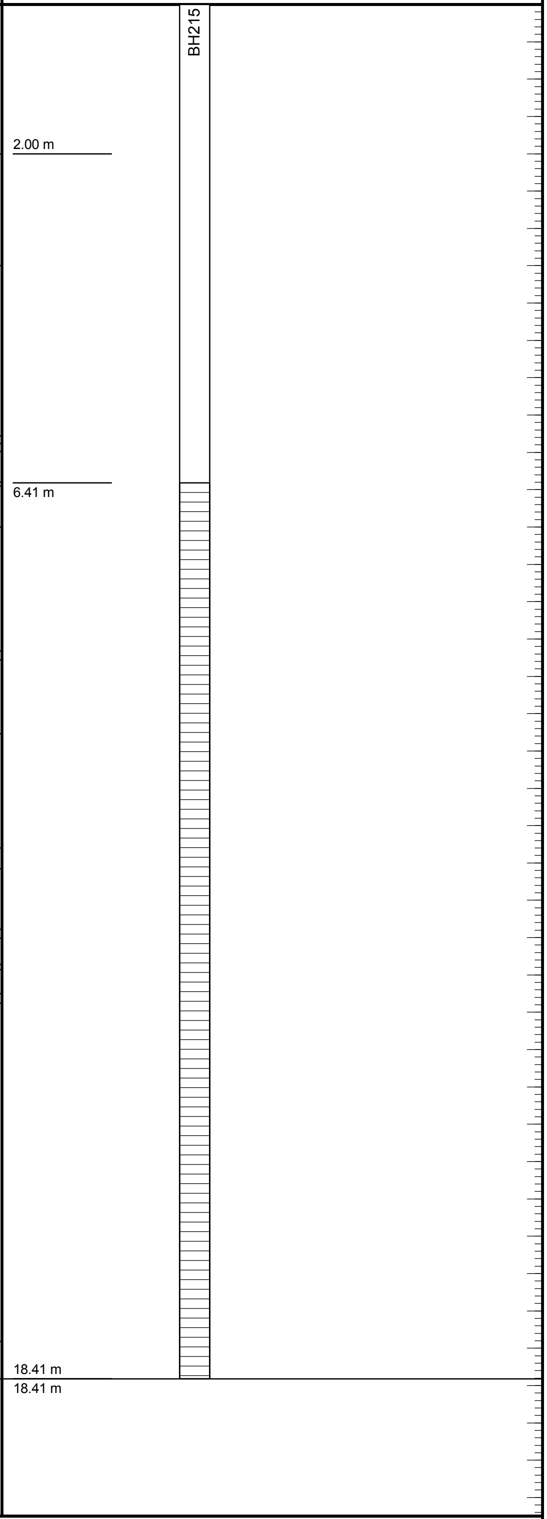
SILTSTONE: Dark grey
13.87-14.16m: Grey band.
14.85-14.95m: Pebble band.

15.72-15.78m: Grey, fine to medium grained sandstone band.

17.39m: Pebble band, 50mm.

Interlaminated SILTSTONE and SANDSTONE (80% Siltstone, 20% Sandstone): Siltstone is dark grey, sandstone is pale grey, fine grained, distinctly laminated at 0-5°.

Hole Terminated at 18.41 m
Target depth



DRILLING

NMLC	NMLC Coring	HQ	HQ Coring	TCR	% core run recovered
NQ	NQ Coring	PQ	PQ Coring	RQD	% core run > 100mm long (rock fraction only measured)

GROUNDWATER SYMBOLS

▼ = Water level (static)　▽ = Water level (during drilling)

Piezometer Installation Details

BH217

Project: M12 Motorway Concept Design
Client: Roads and Maritime Services **Location:** South Creek, NSW
Page: 1 of 2
Project No: IA145100

Contractor:	Terratest	**Easting:**		**Elevation:**	
Plant:	Hanjin DB8	**Northing:**		**Datum:**	AHD
Logged by:	MG **Checked by:**	**Grid:**	MGA94 Zone 56	**Inclination:**	-90°
Started:	12/06/2018	**Finished:**	13/06/2018	**Orientation:**	

DRILLING | MATERIAL SUBSTANCE | INSTALLATION DETAILS

Method & Support: AD/V (0 to approx. 2.7 m); HQ3 (approx. 2.7 to 17.85 m)

Water: 15/06/18 ▽; Not Encountered

Description of Strata

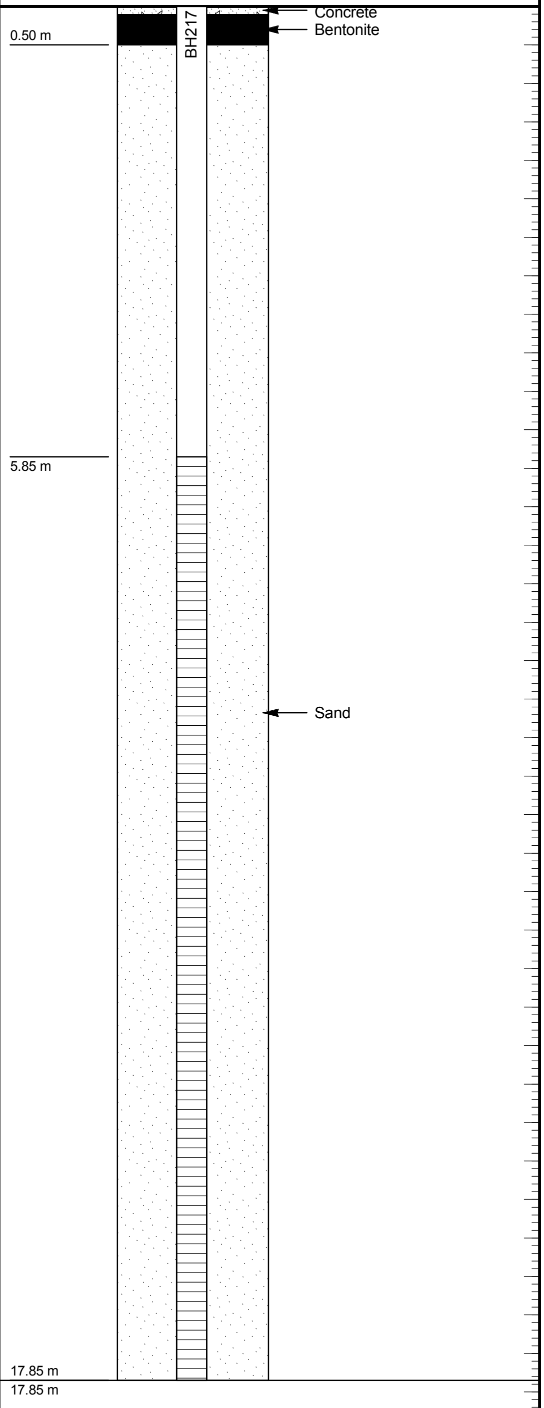
ROCK TYPE : Colour, Grain size, Structure
(texture, fabric, mineral composition, hardness
alteration, cementation, major defect type)

- Clayey SILT: Brown, with some rootlets and a trace of sand.
- Silty CLAY: High plasticity, yellow-brown.
- Clayey SILT: Low plasticity, brown, yellow-brown mottled grey, with dark grey flecks.
- Sandy CLAY: Medium plasticity, yellow-brown, brown and grey, with a trace of fine gravel.
- Sandy CLAY: Medium plasticity, yellow-brown and pale grey, w> PL, Vst.
- NO CORE: 200mm
- Sandy CLAY: Medium plasticity, pale grey, yellow-brown, with ironstone gravel, w> PL, Vst.
- NO CORE: 250mm
- Gravelly Sandy CLAY: Medium plasticity, orange-brown, fine to coarse grained sand, gravel is fine to medium subangular ironstone gravel.
- NO CORE: 1000mm
- Gravelly Sandy CLAY: Medium plasticity, yellow-brown, pale grey, dark grey, sand is fine to coarse grained, gravel is fine to medium, subangular ironstone, w > PL, Vst.
- Silty CLAY: High plasticity, pale grey, w> PL, hard.
- SILTSTONE: Dark grey and grey.
- Interbedded SANDSTONE and SILTSTONE (65% Sandstone, 35% Siltstone): Dark grey, sandstone is fine grained, thinly bedded at 0-5°.
- SILTSTONE: Dark grey and grey.
- Carbonaceous SILTSTONE: Dark grey.
- SILTSTONE: Grey and dark grey.
  9.20m: With some sandy laminations.
  9.75-9.85m: Sandstone, band.
  10.30-10.60m: Carbonaceous Siltstone.
- Carbonaceous SILTSTONE: Dark grey.
- Interlaminated SANDSTONE and SILTSTONE (65% Sandstone, 35% Siltstone): Grey and dark grey, sandstone is fine grained, indistinctly laminated at 0-5°.
- SILTSTONE: Grey and dark grey.
  12.80-12.92m: Interlaminated Siltstone and Sandstone.
  13.30m: With some sandy laminations.
- Interlaminated SANDSTONE and SILTSTONE (60% Sandstone, 40% Siltstone): Grey and dark grey, sandstone is fine grained, indistinctly laminated at 0-5°.
  14.40m: Increasing in Siltstone (60% Siltstone, 40% Sandstone).
- SILTSTONE: Dark grey and grey.
- SILTSTONE: Grey, with a trace of sandy laminations.
- Carbonaceous SILTSTONE: Dark grey, with some sandy laminations up to 10mm thick.
- Interlaminated SANDSTONE and SILTSTONE (70% Sandstone, 30% Siltstone): Grey and dark grey, sandstone is fine grained, indistinctly laminated at 0-5°.
- SANDSTONE: Grey, fine to medium grained.

Hole Terminated at 17.85 m

Depth (m): 2, 4, 6, 8, 10, 12, 14, 16, 18

ID	Type	Stick Up & RL	Tip Depth & RL
BH217	Standpipe Piezometer		17.85 m



DRILLING

NMLC	NMLC Coring	HQ	HQ Coring	TCR	% core run recovered
NQ	NQ Coring	PQ	PQ Coring	RQD	% core run > 100mm long (rock fraction only measured)

GROUNDWATER SYMBOLS

▼ = Water level (static) ▽ = Water level (during drilling)

Piezometer Installation Details

BH219

Project:	M12 Motorway Concept Design			**Page:**	1 of 2
Client:	Roads and Maritime Services	**Location:**	Kemps Creek, NSW	**Project No:**	IA145100

Contractor:	Terratest	**Easting:**	296088.3	**Elevation:**	44.46	**Started:**	23/05/2018
Plant:	Comacchio 405	**Northing:**	6249516.1	**Datum:**	AHD	**Finished:**	23/05/2018
Logged by:	GC **Checked by:**	**Grid:**	MGA94 Zone 56	**Inclination:**	-90°	**Orientation:**	

DRILLING | MATERIAL SUBSTANCE | INSTALLATION DETAILS

Method & Support | Water | RL (m) | Depth (m) | Graphic Log

Description of Strata

ROCK TYPE : Colour, Grain size, Structure
(texture, fabric, mineral composition, hardness
alteration, cementation, major defect type)

ID	Type	Stick Up & RL	Tip Depth & RL
BH219	Standpipe Piezometer		18.33 m 26.13 m

Method & Support: AD/V; WB; HQ3

Water: 30/05/18; 23/05/18

RL (m): 44, 42, 40, 38, 36, 34, 32, 30, 28, 26

Depth (m): 2, 4, 6, 8, 10, 12, 14, 16, 18, 20

Silty CLAY: Medium to high plasticity, grey and orange-brown mottled red-brown, some fine grained sand, trace fine, subrounded ironstone gravel and rootlets.

2.00m: As above, mottled grey and orange-brown with some red-brown staining.

Silty CLAY: Medium to high plasticity, grey and brown, with some inferred thin bands of very low strength.

NO CORE: 150mm

SANDSTONE: Grey, fine grained, with some dark grey subhorizontal laminations.

Interbedded SANDSTONE and SILTSTONE (50% Sandstone, 50% Siltstone): Sandstone is grey, fine grained, siltstone is dark grey, distinctly bedded at 0-5°, bands up to 100mm thick.

SILTSTONE: Dark grey and grey.

7.20-7.40m: Pebbly band.

SILTSTONE: Dark grey, indistinctly laminated.

SANDSTONE: Grey, fine grained, with some dark grey laminae.

SILTSTONE: Dark grey, indistinctly laminated.

NO CORE: 50mm

SILTSTONE: Dark grey, indistinctly laminated.

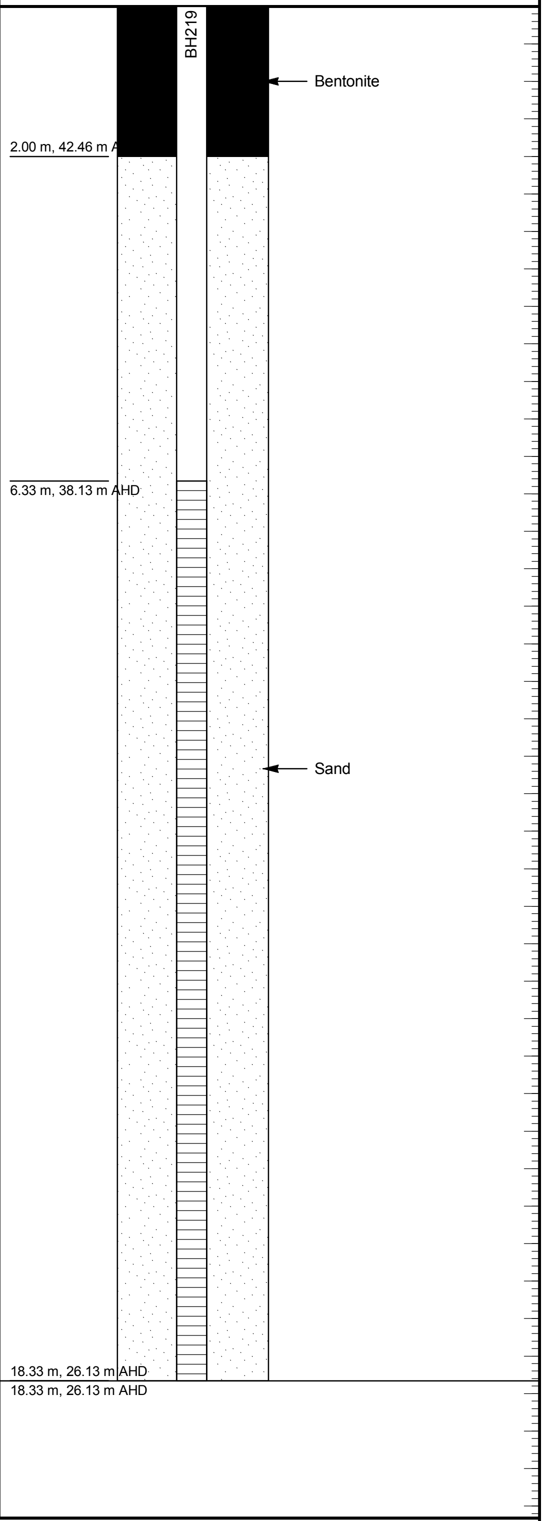
15.39m: As above, but grey.

Interlaminated SILTSTONE and SANDSTONE (75% Siltstone, 25% Sandstone): Siltstone is dark grey, sandstone is grey, fine grained.

SILTSTONE: Dark grey, indistinct.

Interlaminated SANDSTONE and SILTSTONE (50% Sandstone, 50% Siltstone): Sandstone is grey, fine grained, siltstone is dark grey, distinct laminations at 0-5°.

Hole Terminated at 18.33 m
Target depth



DRILLING

NMLC	NMLC Coring	HQ	HQ Coring	TCR	% core run recovered
NQ	NQ Coring	PQ	PQ Coring	RQD	% core run > 100mm long (rock fraction only measured)

GROUNDWATER SYMBOLS

▼ = Water level (static) ▽ = Water level (during drilling)

Piezometer Installation Details

BH221

Project:	M12 Motorway Concept Design			**Page:**	1 of 2
Client:	Roads and Maritime Services	**Location:**	Kemps Creek, NSW	**Project No:**	IA145100

Contractor:	Terratest	**Easting:**	296319.7	**Elevation:**	45.24	**Started:**	21/05/2018
Plant:	Comacchio 405	**Northing:**	6249207.7	**Datum:**	AHD	**Finished:**	21/05/2018
Logged by:	GC **Checked by:**	**Grid:**	MGA94 Zone 56	**Inclination:**	-90°	**Orientation:**	

DRILLING | MATERIAL SUBSTANCE | INSTALLATION DETAILS

Method & Support | Water | RL (m) | Depth (m) | Graphic Log

Description of Strata

ROCK TYPE : Colour, Grain size, Structure
(texture, fabric, mineral composition, hardness
alteration, cementation, major defect type)

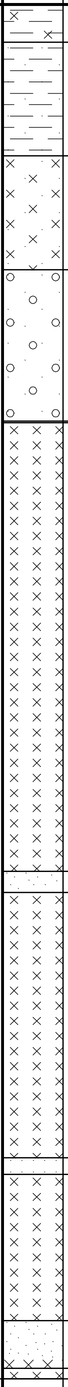
ID	Type	Stick Up & RL	Tip Depth & RL
BH221	Standpipe Piezometer		18.14 m 27.10 m

Method & Support: AD/V; WB; HQ3

Water: 30/05/18; Not Encountered

RL (m): 44; 42; 40; 38; 36; 34; 32; 30; 28; 26

Depth (m): 2; 4; 6; 8; 10; 12; 14; 16; 18



Silty CLAY: High plasticity, brown and orange-brown, trace rootlets.

Sandy CLAY/ Clayey SAND: Low plasticity, brown, sand is fine grained, trace organic matter.

Sandy SILT/ Silty SAND: Low plasticity, brown, sand is fine grained

Sandy GRAVEL: Sand is fine to coarse grained, red-brown and brown, gravel is fine to medium, with some clay.

SILTSTONE: Grey and dark grey, extremely weathered, very low strength.

SILTSTONE: Grey and dark grey.
6.05m: As above, but with some sandstone laminations up to 10mm thick.

9.91-10.57m: With sandstone bands up to 20mm thick.

Interlaminated SILTSTONE and SANDSTONE (60% Siltstone, 40% Sandstone): Siltstone is dark grey, sandstone is grey, fine grained, distinctly laminated at 0-5°.

SILTSTONE: Dark grey.
12.44-12.51m: With some grey sandstone bands up to 15mm thick.

14.40m: Becoming grey and dark grey.

14.84m: With sandstone bands up to 80mm thick.

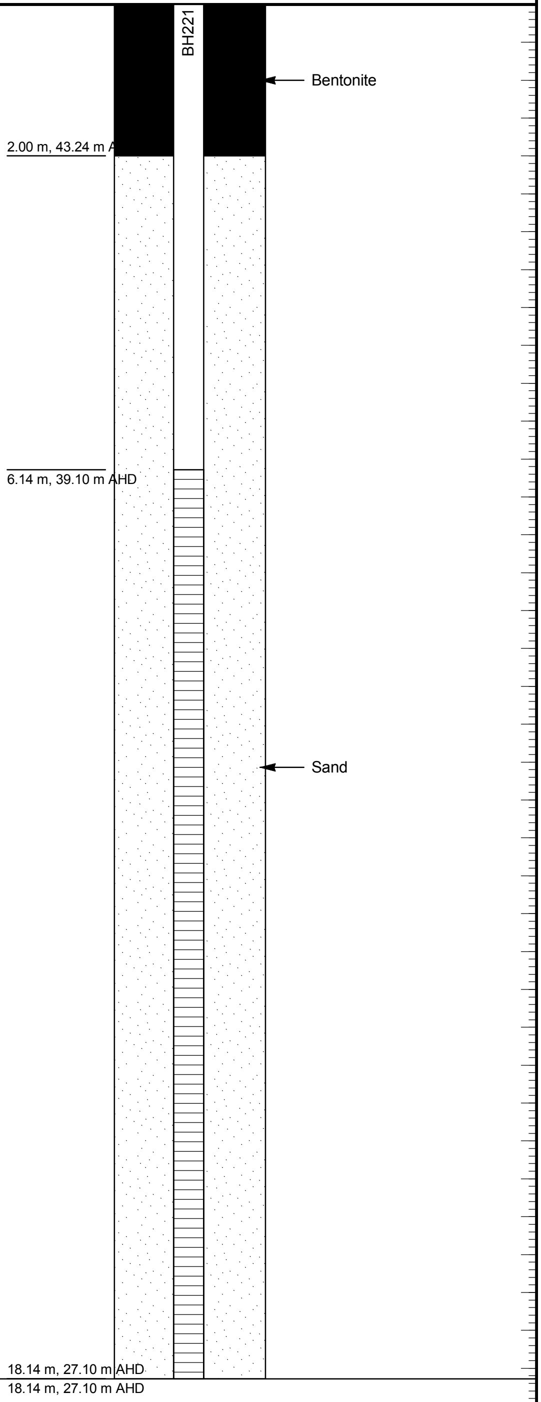
SANDSTONE: Grey, fine grained.

SILTSTONE: Dark grey
15.56-15.64m: With some sandstone bands up to 40mm thick.

Interlaminated SILTSTONE and SANDSTONE (50% Siltstone, 50% Sandstone): Siltstone is dark grey, sandstone is grey, fine grained, distinctly laminated at 0-5°.

SILTSTONE: Dark grey.

Hole Terminated at 18.14 m
Target depth



DRILLING

NMLC NMLC Coring
NQ NQ Coring
HQ HQ Coring
PQ PQ Coring
TCR % core run recovered
RQD % core run > 100mm long
(rock fraction only measured)

GROUNDWATER SYMBOLS

▼ = Water level (static)
▽ = Water level (during drilling)

JACOBS

Piezometer Installation Details

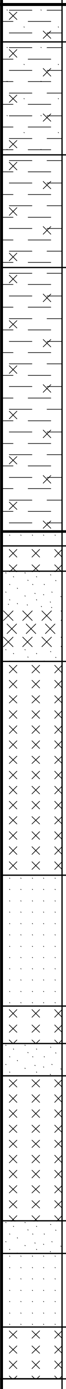
BH223

Project:	M12 Motorway Concept Design			**Page:**	1 of 2
Client:	Roads and Maritime Services	**Location:**	1255 Mamre Rd, Kemps Creek, NSW	**Project No:**	IA145100

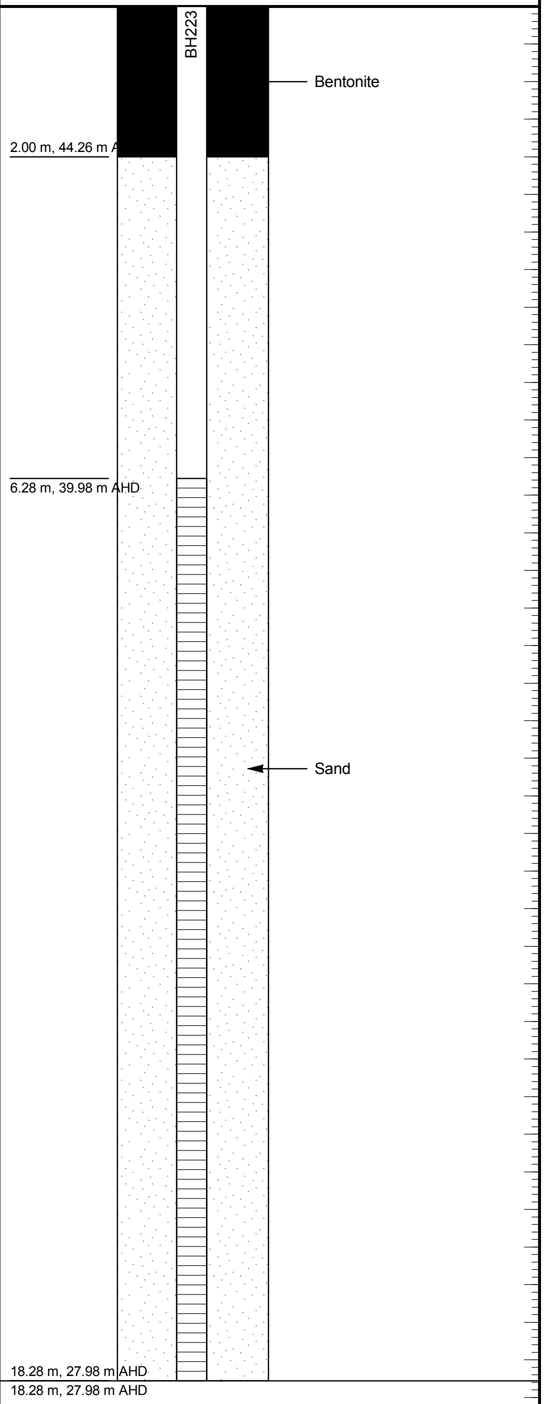
Contractor:	Terratest	**Easting:**	296465.8	**Elevation:**	46.26	**Started:**	15/05/2018
Plant:	Comacchio 405	**Northing:**	6249150.2	**Datum:**	AHD	**Finished:**	16/05/2018
Logged by:	GC **Checked by:**	**Grid:**	MGA94 Zone 56	**Inclination:**	-90°	**Orientation:**	

DRILLING | MATERIAL SUBSTANCE | INSTALLATION DETAILS

Method & Support	Water	RL (m)	Depth (m)	Graphic Log	Description of Strata ROCK TYPE : Colour, Grain size, Structure (texture, fabric, mineral composition, hardness alteration, cementation, major defect type)
AD/V		46			Silty Sandy CLAY: Medium to high plasticity, brown, sand is fine grained.
					Silty Sandy CLAY: Low to medium plasticity, grey and brown mottled orange-brown,.
		44	2		Silty CLAY: High plasticity, grey mottled orange and red-brown, with trace medium ironstone gravel.
WB	30/05/18				Silty CLAY: High plasticity, grey and orange-brown.
		42	4		
		40	6		
HQ3					SILTSTONE: Grey and dark grey, extremely weathered, very low strength.
					SANDSTONE: Grey with dark grey laminae, fine grained.
			8		SILTSTONE: Dark grey, distinctly laminated.
		38			Interlaminated SILTSTONE and SANDSTONE (50% Siltstone/ 50% Sandstone): Siltstone is dark grey, sandstone is grey, fine grained. 7.74m: Becoming 70% Siltstone, 30% Sandstone.
					SILTSTONE: Dark grey, indistinctly laminated, with trace of sandstone bands up to 40mm thick.
		36	10		10.65m: As above, but grey.
			12		SANDSTONE: Grey, fine grained.
		34			12.20m: As above, but with some dark grey laminae.
					SILTSTONE: Dark grey and grey, indistinctly laminated, with trace fine grained sandstone bands, grey up to 10mm thick.
		32	14		Interbedded SILTSTONE and SANDSTONE (70% Siltstone/ 30% Sandstone): Siltstone is dark grey, sandstone is grey, fine grained, subhorizontal bedded.
					SILTSTONE: Dark grey. 14.54-14.60m: Fine grained sandstone band.
		30	16		Interbedded SILTSTONE and SANDSTONE (50% Siltstone/ 50% Sandstone): Siltstone is dark grey, sandstone is grey, fine grained, indistinctly bedded.
					SANDSTONE: Grey, fine grained, with thin dark grey laminations. 17.41-17.44m: Dark grey siltstone band.
			18		SILTSTONE: Dark grey, distinctly laminated. 17.99m: As above, but with sandstone bands up to 30mm thick.
		28			Hole Terminated at 18.28 m Target depth
			20		



ID	Type	Stick Up & RL	Tip Depth & RL
BH223	Standpipe Piezometer		18.28 m 27.98 m



DRILLING

NMLC NMLC Coring
NQ NQ Coring
HQ HQ Coring
PQ PQ Coring
TCR % core run recovered
RQD % core run > 100mm long (rock fraction only measured)

GROUNDWATER SYMBOLS

▼ = Water level (static)
▽ = Water level (during drilling)

Piezometer Installation Details

BH227

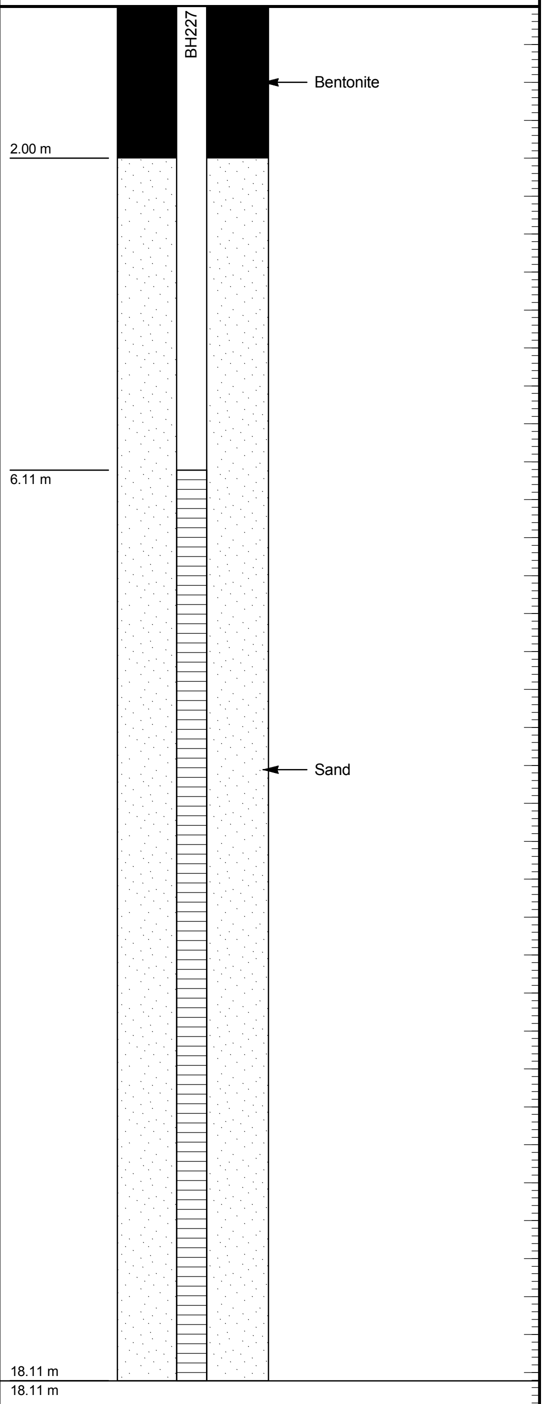
Project: M12 Motorway Concept Design
Page: 1 of 2
Client: Roads and Maritime Services
Location: Cnr Elizabeth Dr & Mamre Rd, Cecil Park, NSW
Project No: IA145100

Contractor: Terratest
Plant: Comacchio 405
Logged by: GC
Checked by:
Easting:
Northing:
Grid: MGA94 Zone 56
Elevation:
Datum: AHD
Inclination: -90°
Started: 07/06/2018
Finished: 07/06/2018
Orientation:

DRILLING				MATERIAL SUBSTANCE
Method & Support	Water	RL (m)	Depth (m)	Description of Strata ROCK TYPE : Colour, Grain size, Structure (texture, fabric, mineral composition, hardness alteration, cementation, major defect type)
AD/V				FILL: Silty CLAY, high plasticity, dark brown, trace rootlets.
				FILL: Silty CLAY, medium plasticity, orange-brown.
	15/06/18		2	Silty CLAY: Medium to high plasticity, brown mottled red-brown and grey, with some fine ironstone gravel, trace fine grained sand.
WB			4	Silty CLAY: High plasticity, grey and orange-brown, trace subangular to subrounded fine ironstone gravel.
			6	SILTSTONE: Grey and dark grey, extremely weathered, very low strength.
HQ3				SANDSTONE: Orange-brown, fine grained, with a trace of dark grey laminae.
	Not Encountered		8	SILTSTONE: Grey and orange-brown, indistinct. 8.61-8.80m: Dark grey with iron indurated nodules.
				SANDSTONE: Grey and orange-brown, fine grained.
			10	SILTSTONE: Dark grey and brown.
				Interbedded SILTSTONE and SANDSTONE (60% Siltstone, 40% Sandstone): Siltstone is dark grey, sandstone is grey, fine grained, with some interlaminated bands.
			12	SILTSTONE: Grey.
				Interbedded SANDSTONE and SILTSTONE (60% Sandstone, 40% Siltstone): Sandstone is grey and grey, fine grained, siltstone is dark grey. 13.15-13.68m: With a trace of pebbles.
			14	SILTSTONE: Pale grey.
			16	SILTSTONE: Dark grey. 17.55m: Carbonaceous band.
			18	SANDSTONE: Grey, with dark grey laminations. Hole Terminated at 18.11 m Target depth

INSTALLATION DETAILS

ID	Type	Stick Up & RL	Tip Depth & RL
BH227	Standpipe Piezometer		18.11 m



DRILLING

NMLC NMLC Coring	HQ HQ Coring	TCR % core run recovered
NQ NQ Coring	PQ PQ Coring	RQD % core run > 100mm long (rock fraction only measured)

GROUNDWATER SYMBOLS

▼ = Water level (static)
▽ = Water level (during drilling)

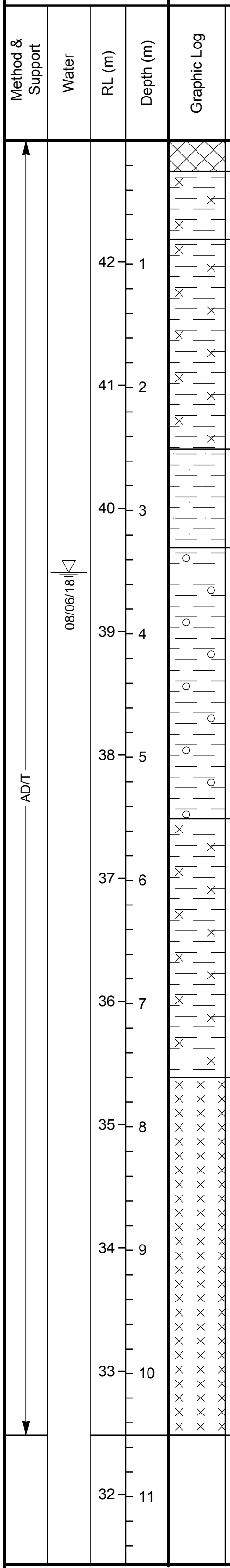
Piezometer Installation Details

BH301

Project: M12 Motorway Concept Design
Page: 1 of 1
Client: Roads and Maritime Services
Location: Badgery's Creek, NSW
Project No: IA145100

Contractor: Terratest
Easting: 292746.4
Elevation: 42.98
Started: 07/06/2018
Plant: Comacchio 205
Northing: 6251170.7
Datum: AHD
Finished: 07/06/2018
Logged by: MG
Checked by:
Grid: MGA94 Zone 56
Inclination: -90°
Orientation:

DRILLING



MATERIAL SUBSTANCE

Description of Strata

ROCK TYPE : Colour, Grain size, Structure
(texture, fabric, mineral composition, hardness
alteration, cementation, major defect type)

FILL: Clayey SILT, dark grey with some rootlets and a trace of sand.

Silty CLAY: Medium plasticity, brown and red-brown, with a trace of sand.

Silty CLAY: High plasticity, brown, grey and red-brown.

1.40m: Becoming brown and yellow-brown.

Sandy CLAY: High plasticity, grey and yellow-brown, sand is fine to medium grained.

Gravelly CLAY: High plasticity, red-brown, grey and yellow-brown, gravel is fine to medium, subangular to angular, with a trace of sand.

Silty CLAY: High plasticity, grey and brown and orange-brown, with some extremely weathered bands of siltstone and ironstone gravel.

6.30m: Becoming brown and dark brown.

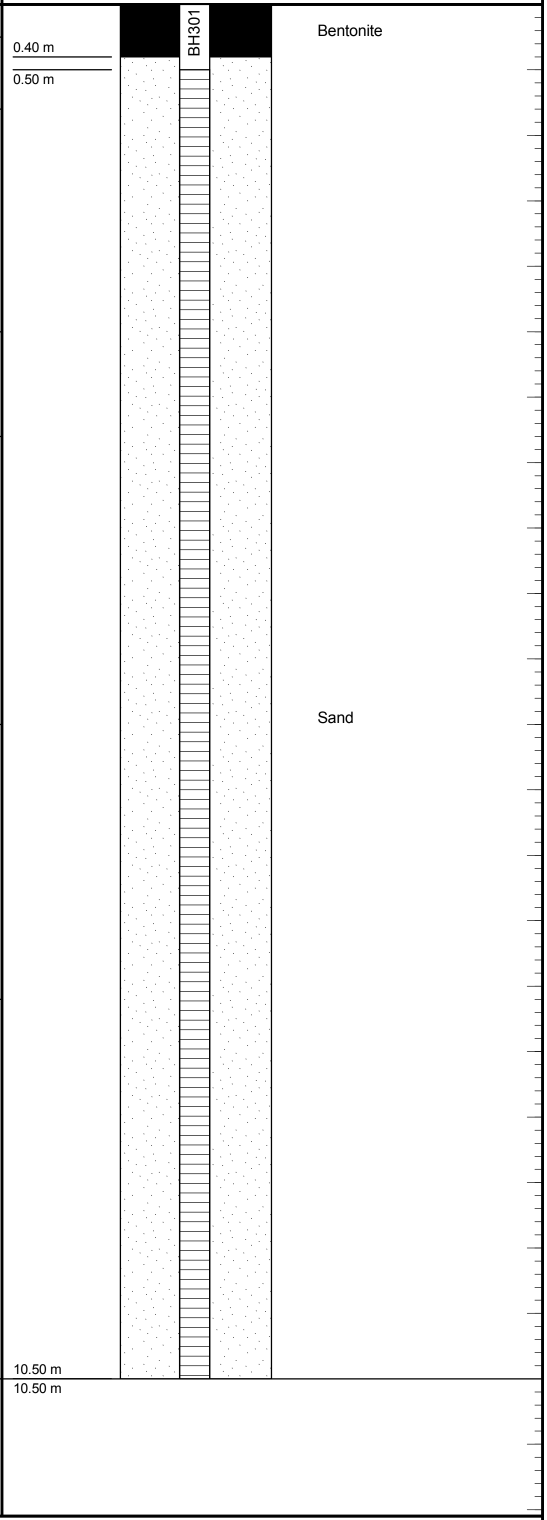
SILTSTONE: Grey-brown and grey, extremely weathered, very low strength.

10.20m: Becoming very low to low strength.

Hole Terminated at 10.50 m

INSTALLATION DETAILS

ID	Type	Stick Up & RL	Tip Depth & RL
BH301	Standpipe		10.50 m 32.48 m



DRILLING

NMLC NMLC Coring
NQ NQ Coring
HQ HQ Coring
PQ PQ Coring
TCR % core run recovered
RQD % core run > 100mm long
(rock fraction only measured)

GROUNDWATER SYMBOLS

▼ = Water level (static)
▽ = Water level (during drilling)

Piezometer Installation Details

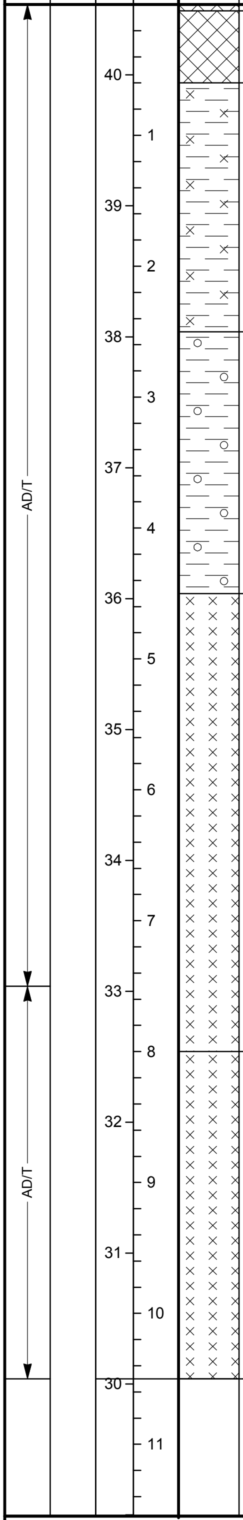
BH302

Project: M12 Motorway Concept Design
Page: 1 of 1
Client: Roads and Maritime Services
Location: Badgery's Creek, NSW
Project No: IA145100

Contractor:	Terratest	**Easting:**	292934.6	**Elevation:**	40.54	**Started:**	07/06/2018
Plant:	Comacchio 205	**Northing:**	6251153.7	**Datum:**	AHD	**Finished:**	08/06/2018
Logged by:	MG **Checked by:**	**Grid:**	MGA94 Zone 56	**Inclination:**	-90°	**Orientation:**	

DRILLING | MATERIAL SUBSTANCE | INSTALLATION DETAILS

ID	Type	Stick Up & RL	Tip Depth & RL
BH302	Standpipe		10.50 m 30.04 m



Description of Strata

ROCK TYPE : Colour, Grain size, Structure (texture, fabric, mineral composition, hardness alteration, cementation, major defect type)

FILL: Silty CLAY, medium plasticity, dark brown, some rootlets.

FILL: Clayey SILT, pale brown.

Silty CLAY: High plasticity, grey and orange-brown.

1.25m: With some iron indurated bands.

1.80m: With some fine grained sand.

Gravelly CLAY: High plasticity, red-brown, grey and yellow-brown, gravel is fine to medium, subangular to angular ironstone, with a trace of sand.

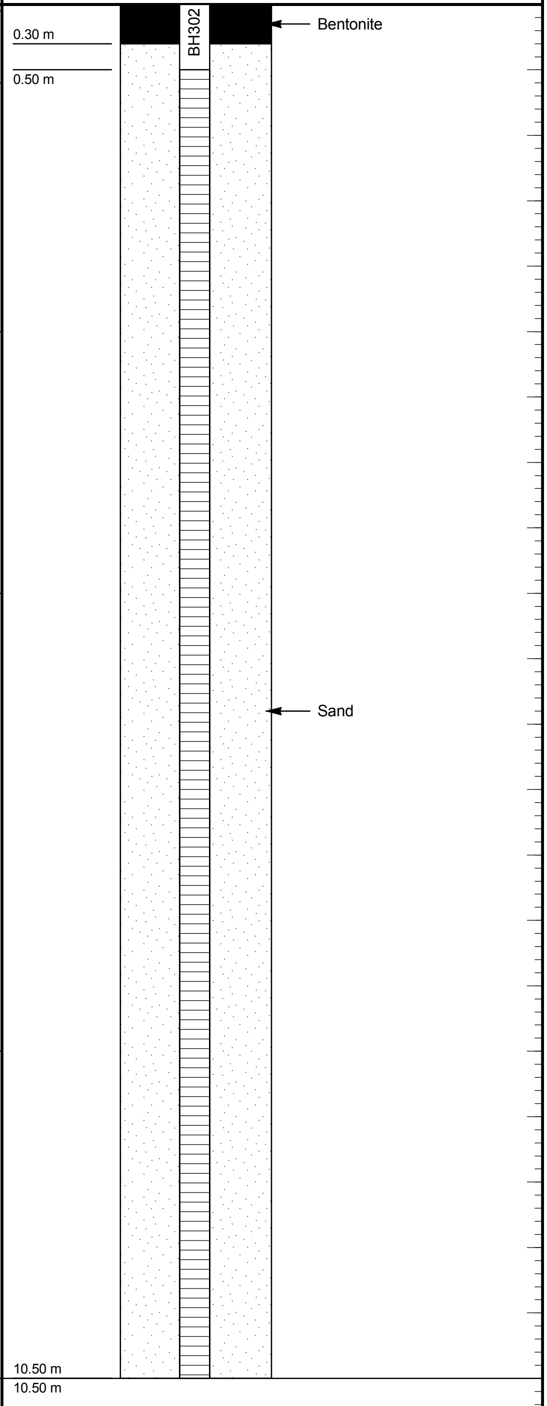
SILTSTONE: Grey and dark grey, extremely weathered, very low strength.

5.50m: Becoming dark grey.

7.00m: Becoming very low to low strength.

SILTSTONE: Dark grey, highly weathered, very low to low strength.

Hole Terminated at 10.50 m
Target depth



DRILLING

NMLC NMLC Coring
NQ NQ Coring
HQ HQ Coring
PQ PQ Coring
TCR % core run recovered
RQD % core run > 100mm long (rock fraction only measured)

GROUNDWATER SYMBOLS

▼ = Water level (static)
▽ = Water level (during drilling)

Piezometer Installation Details

BH162

Project: M12 Concept Design

Client: Roads and Maritime Services **Location:** Walgrove Rd, Cecil Hills, NSW

Page: 1 of 2

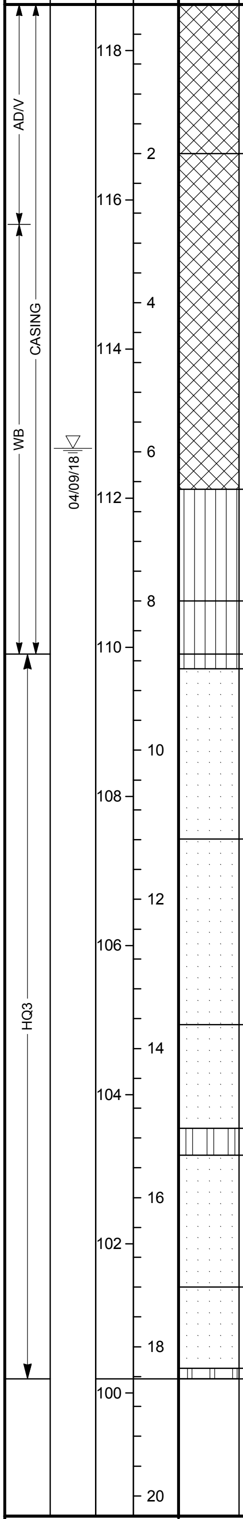
Project No: IA145100

Contractor:	Terratest	**Easting:**	300514.2	**Elevation:**	118.62	**Started:**	20/08/2018
Plant:	Comacchio 405	**Northing:**	6249490.7	**Datum:**	AHD	**Finished:**	21/08/2018
Logged by:	GC **Checked by:** NC	**Grid:**	MGA94 Zone 56	**Inclination:**	-90°	**Orientation:**	

DRILLING | MATERIAL SUBSTANCE | INSTALLATION DETAILS

Method & Support	Water	RL (m)	Depth (m)	Graphic Log	Description of Strata ROCK TYPE : Colour, Grain size, Structure (texture, fabric, mineral composition, hardness alteration, cementation, major defect type)

ID	Type	Stick Up & RL	Tip Depth & RL
BH162	Standpipe		18.43 m 100.19 m



SANDY GRAVELLY CLAY: low plasticity, brown, fine to coarse grained sand, fine subangular to angular gravel, trace rootlets.; dry

SANDY GRAVELLY CLAY: medium plasticity, mottled brown, red-brown and grey, fine to coarse grained sand, fine to coarse subangular to angular gravel, trace iron staining and subrounded to rounded cobbles.; dry

SILTY CLAY: high plasticity, mottled red-brown and grey, trace rootlets.; moist, very stiff

SILTY SANDY CLAY: high plasticity, red-brown and pale grey, trace fine, subrounded to subangular ironstone gravel; moist, hard

SILTY CLAY: high plasticity, red-brown mottled grey, hard, moist.
8.85m: Becoming grey.

SANDSTONE: fine grained, dark brown, trace dark grey, sub-horizontal, laminations.; moderately weathered, low and high strength

SANDSTONE: fine to medium grained, grey, trace dark grey, sub-horizontal laminations, with brown staining around defects.; moderately weathered to slightly weathered, medium to high strength

12.09-12.15m: With carbonaceous laminations.

12.71m: Becomes fine grained.

SANDSTONE: fine to medium grained, grey, trace dark grey, sub-horizontal laminations.; slightly weathered, medium strength

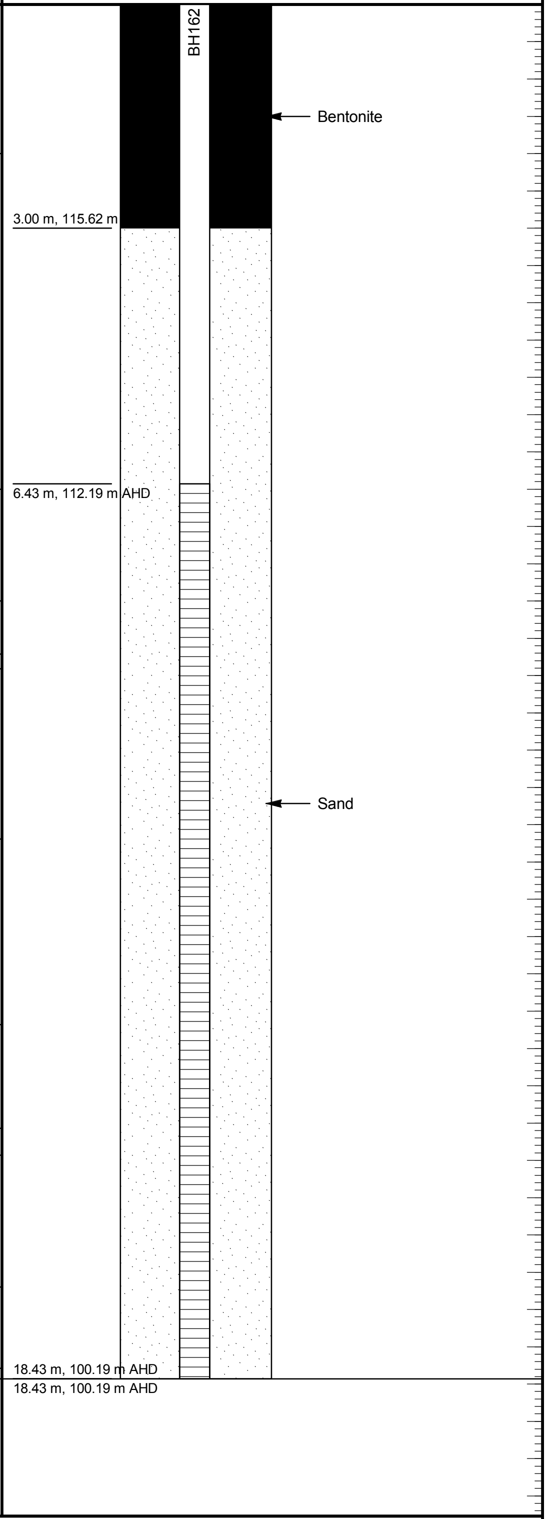
SILTSTONE: dark grey, with some sandstone laminations.; moderately weathered - slightly weathered, medium and high strength

SANDSTONE: fine grained, grey, with some dark grey, sub-horizontal laminations.; slightly weathered to fresh, medium to high strength

SANDSTONE: fine grained, grey, trace dark grey sub-horizontal laminations.; fresh, medium to high strength

INTERBEDDED SANDSTONE AND CARBONACEOUS SILTSTONE: sandstone is fine grained, grey; siltstone is dark grey, subhorizontally laminated.; fresh, medium strength

Hole Terminated at 18.43 m
Target depth



DRILLING

NMLC	NMLC Coring	HQ	HQ Coring	TCR	% core run recovered
NQ	NQ Coring	PQ	PQ Coring	RQD	% core run > 100mm long (rock fraction only measured)

GROUNDWATER SYMBOLS

▼ = Water level (static) ▽ = Water level (during drilling)

JACOBS Piezometer Installation Details

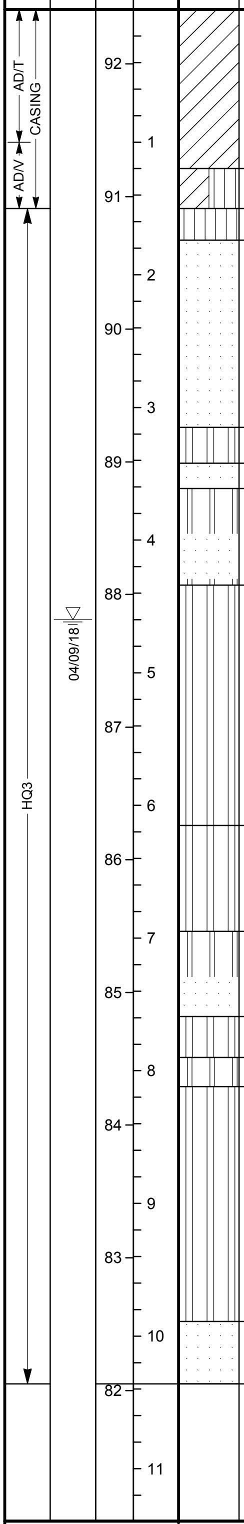
BH170

Project: M12 Concept Design
Client: Roads and Maritime Services
Location: Western Sydney Parklands, NSW
Page: 1 of 2
Project No: IA145100

Contractor:	Terratest	**Easting:**	300394.5	**Elevation:**	92.41	**Started:**	27/08/2018
Plant:	Comacchio 205	**Northing:**	6248905.0	**Datum:**	AHD	**Finished:**	27/08/2018
Logged by:	GC **Checked by:** NC	**Grid:**	MGA94 Zone 56	**Inclination:**	-90°	**Orientation:**	

DRILLING | MATERIAL SUBSTANCE | INSTALLATION DETAILS

Method & Support | Water | RL (m) | Depth (m) | Graphic Log



Description of Strata

ROCK TYPE : Colour, Grain size, Structure (texture, fabric, mineral composition, hardness alteration, cementation, major defect type)

SILTY SANDY CLAY: medium plasticity, dark brown, fine grained sand, trace fine, subangular to subrounded gravel; dry, hard

0.50m: Becoming brown

SANDY SILTY CLAY: medium to high plasticity, mottled grey, red-brown and orange-brown, some fine, subangular to subrounded gravel, fine grained sand.; dry, hard

SILTY CLAY: high plasticity, red-brown and grey, trace fine grained sand, trace fine, subangular ironstone gravel, moist, hard.

SANDSTONE: fine grained, brown, trace carbonaceous laminations, interbedded with clay seams.; extremely weathered to highly weathered, extremely low to low strength

2.86m: Appearing as sandstone gravels in clay matrix

SILTSTONE: brown-grey, trace sandstone laminations.; moderately weathered, low strength

SANDSTONE: fine to medium grained, brown; moderately weathered, low strength

INTERBEDDED SANDSTONE AND SILTSTONE (70% SANDSTONE/30% SILTSTONE): sandstone is fine grained, brown, subhorizontally laminated.; siltstone is dark grey; moderately weathered, low strength
4.05m: Increasing in siltstone

SILTSTONE: brown-grey, trace carbonaceous and sandstone laminations.; extremely weathered to moderately weathered, very low to low strength

SILTSTONE: dark grey to grey, distinct, with some highly weathered laminations.; highly weathered to slightly weathered, low to medium strength
6.56m: Becoming grey with trace carbonaceous veins

INTERBEDDED SILTSTONE AND SANDSTONE (60% SILTSTONE/40% SANDSTONE): siltstone is dark grey; sandstone is fine grained, grey; slightly weathered, low to medium strength
7.08-7.14m: Sandstone band, 60mm

SILTSTONE: dark grey, trace subrounded to rounded pebbles.; moderately weathered, low and medium strength

INTERBEDDED SILTSTONE AND SANDSTONE (50% SILTSTONE/50% SANDSTONE): siltstone is dark grey; sandstone is fine grained, grey; moderately weathered, low to medium strength

SILTSTONE: dark grey, with brown bands, distinct laminations, trace fine to medium subrounded to rounded pebbles.; extremely weathered to slightly weathered, very low to high strength

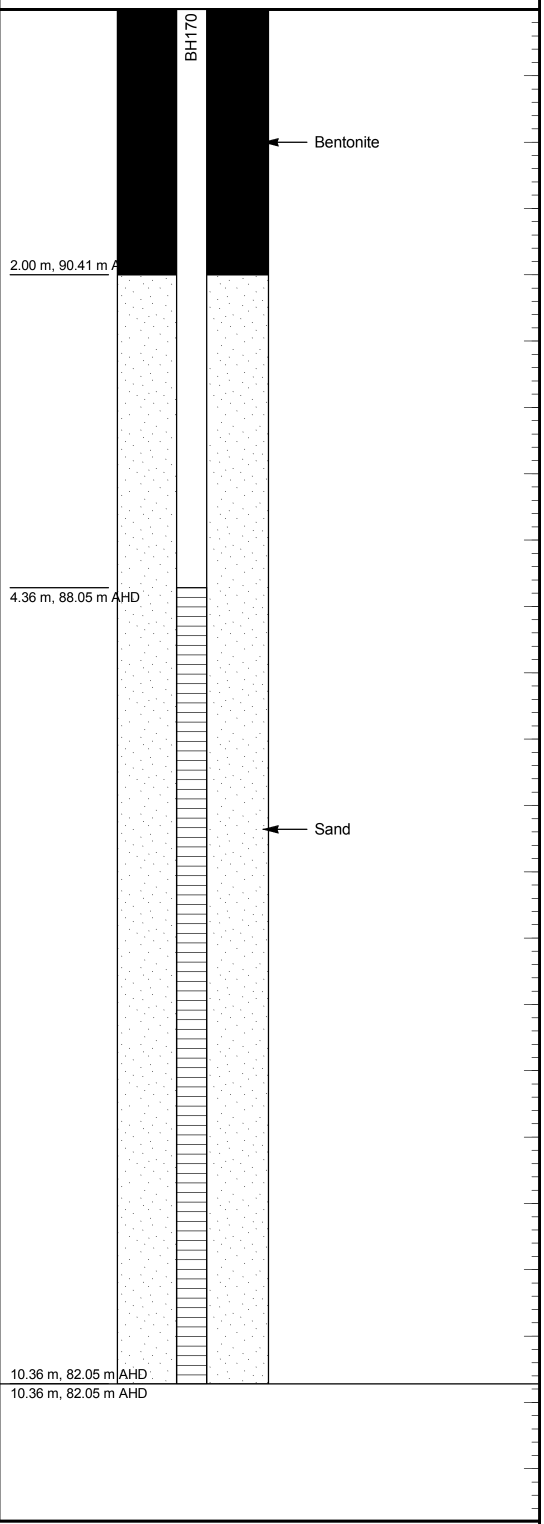
9.40m: With trace sub-horizontal sandstone laminations.

SANDSTONE: fine grained, grey, with some siltstone laminations.; slightly weathered, medium to high strength

10.29m: Becoming dark grey siltstone

Hole Terminated at 10.36 m
Target depth

ID	Type	Stick Up & RL	Tip Depth & RL
BH170	Standpipe		10.36 m 82.05 m



DRILLING

NMLC	NMLC Coring	HQ	HQ Coring	TCR	% core run recovered
NQ	NQ Coring	PQ	PQ Coring	RQD	% core run > 100mm long (rock fraction only measured)

GROUNDWATER SYMBOLS

▼ = Water level (static) ▽ = Water level (during drilling)

JACOBS

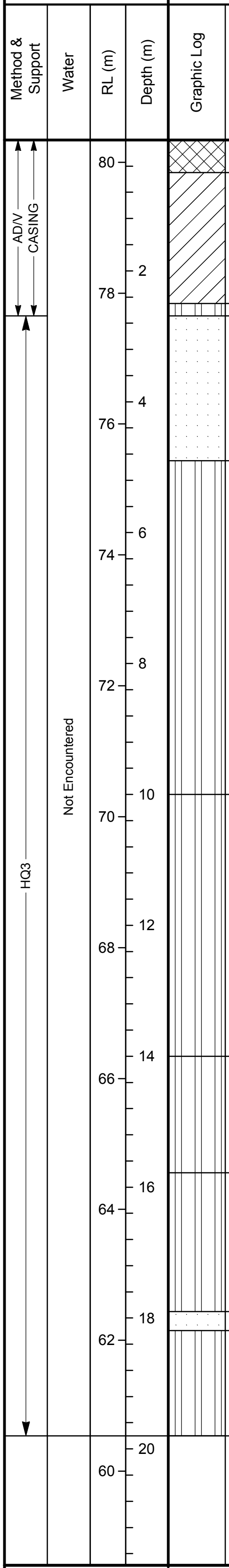
Piezometer Installation Details

BH175

Project: M12 Concept Design
Page: 1 of 2
Client: Roads and Maritime Services
Location: M7 Motorway, Cecil Hills, NSW
Project No: IA145100

Contractor:	Terratest	**Easting:**	299999.3	**Elevation:**	80.34	**Started:**	07/08/2018
Plant:	Comacchio 405	**Northing:**	6248562.1	**Datum:**	AHD	**Finished:**	08/08/2018
Logged by:	GC **Checked by:** NC	**Grid:**	MGA94 Zone 56	**Inclination:**	-90°	**Orientation:**	

DRILLING | MATERIAL SUBSTANCE | INSTALLATION DETAILS



Description of Strata

ROCK TYPE : Colour, Grain size, Structure
(texture, fabric, mineral composition, hardness
alteration, cementation, major defect type)

SILTY CLAY: medium to high plasticity, dark brown, with a trace of fine grained sand.

SILTY CLAY: medium plasticity, mottled grey and orange-brown, with a trace of rootlets and some organic matter.; moist, hard

2.00m: Becoming extremely weathered siltstone, pale orange-brown and red-grey, recovered as subangular to angular gravel.

SILTSTONE: dark grey, extremely weathered, very low strength, recovered as fine subangular to angular gravel.

SANDSTONE: fine grained, brown, with dark grey laminations, trace iron staining.; extremely weathered to moderately weathered, extremely low to medium strength

SILTSTONE: dark grey and brown, and sub-horizontal sandstone bands up to 10mm thick., trace of iron staining; extremely weathered to moderately weathered, extremely low to medium strength
5.40-5.44m: Fine grained sandstone band.

8.40-8.75m: With subrounded to rounded ironstone pebbles.

SILTSTONE: dark grey, indistinctly laminated.; extremely weathered to fresh, extremely low to medium strength

13.41m: Becoming grey.

SILTSTONE: dark grey, trace fine to medium sub-rounded to rounded pebbles.; fresh, medium and high strength

15.07m: Becoming grey.

SILTSTONE: dark grey, with some fine grained sandstone bands, trace fine to medium sub-rounded to rounded pebbles, distinct to indistinct sub-horizontal laminations.; fresh, medium to high strength

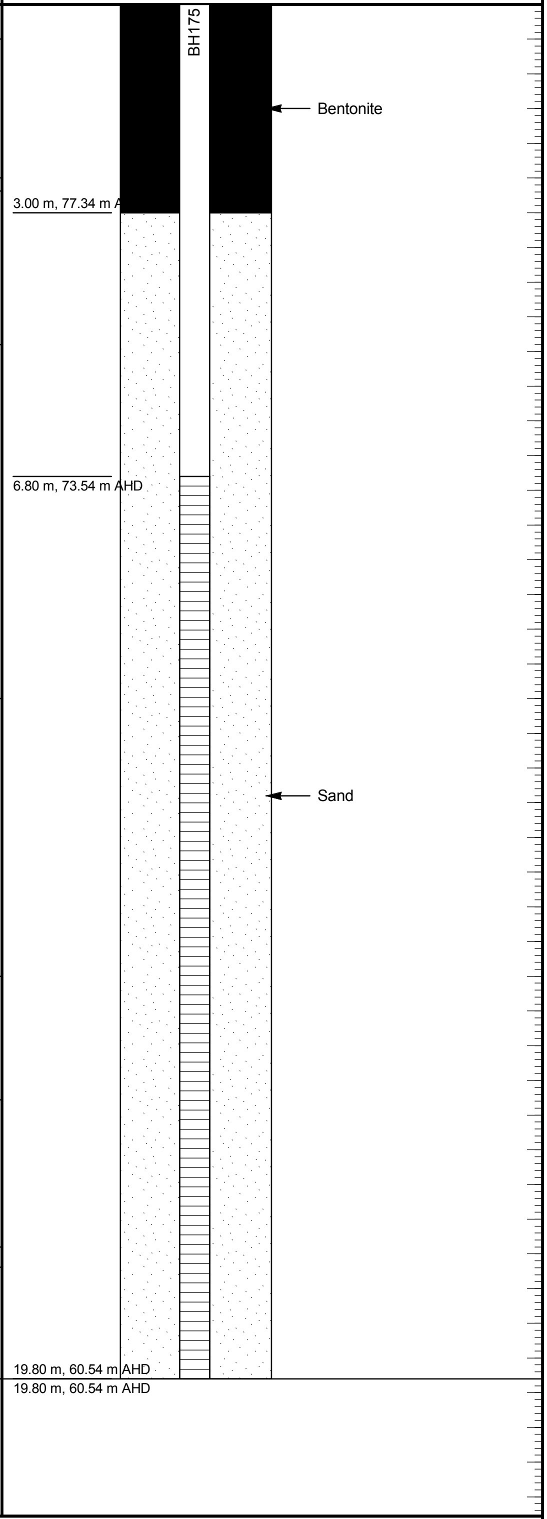
17.82m: Becoming interbedded sandstone and siltstone.

SANDSTONE: fine grained, grey, with some dark grey bands.; fresh, high strength

SILTSTONE: dark grey, distinct to indistinct sub-horizontal laminations.; fresh, medium and high strength
18.80-19.27m: With subrounded to rounded pebbles.

Hole Terminated at 19.80 m
Target depth

ID	Type	Stick Up & RL	Tip Depth & RL
BH175	Standpipe Piezometer		19.80 m 60.54 m



DRILLING

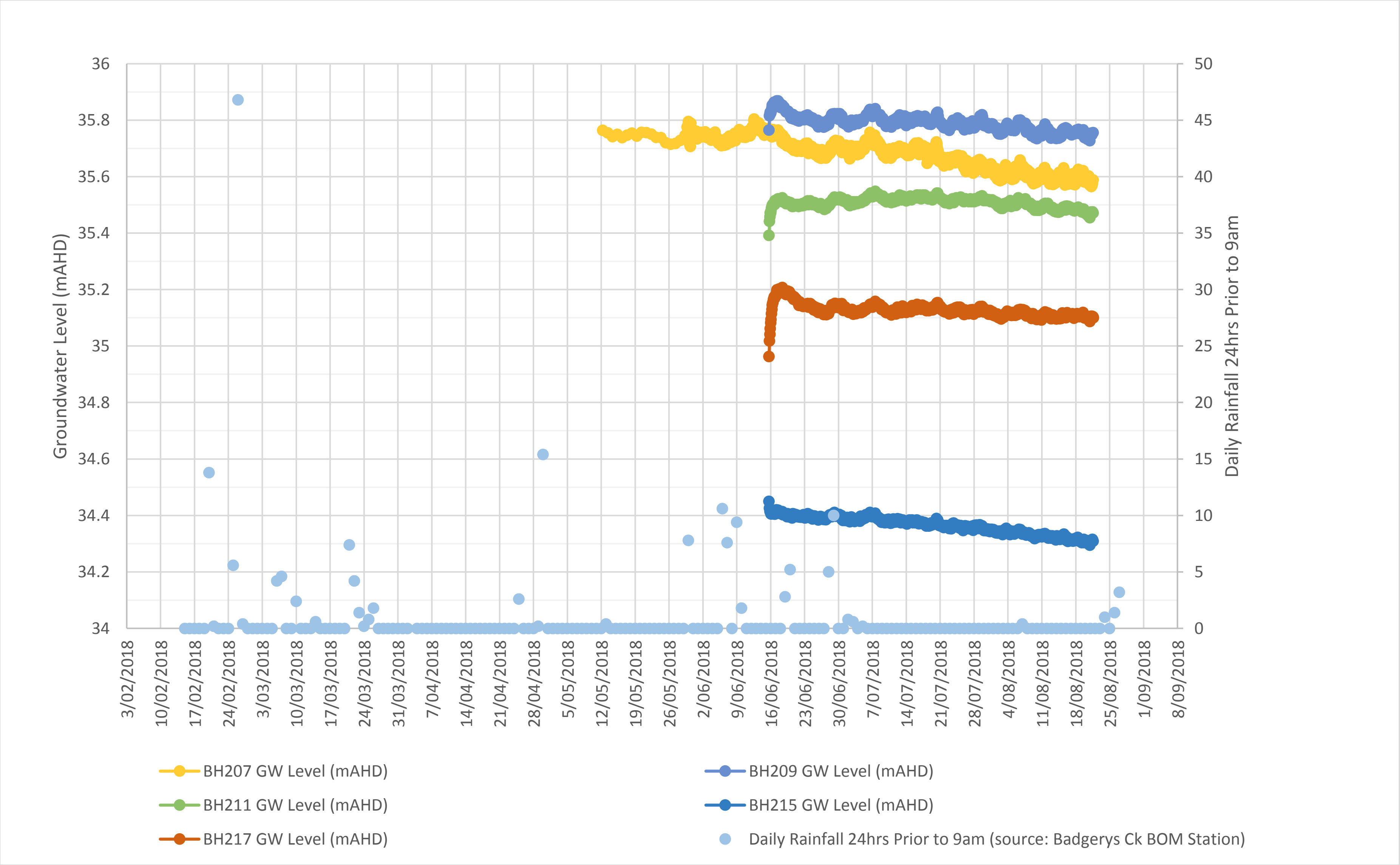
NMLC	NMLC Coring	HQ	HQ Coring	TCR	% core run recovered
NQ	NQ Coring	PQ	PQ Coring	RQD	% core run > 100mm long (rock fraction only measured)

GROUNDWATER SYMBOLS

▼ = Water level (static)
▽ = Water level (during drilling)

Annexure C

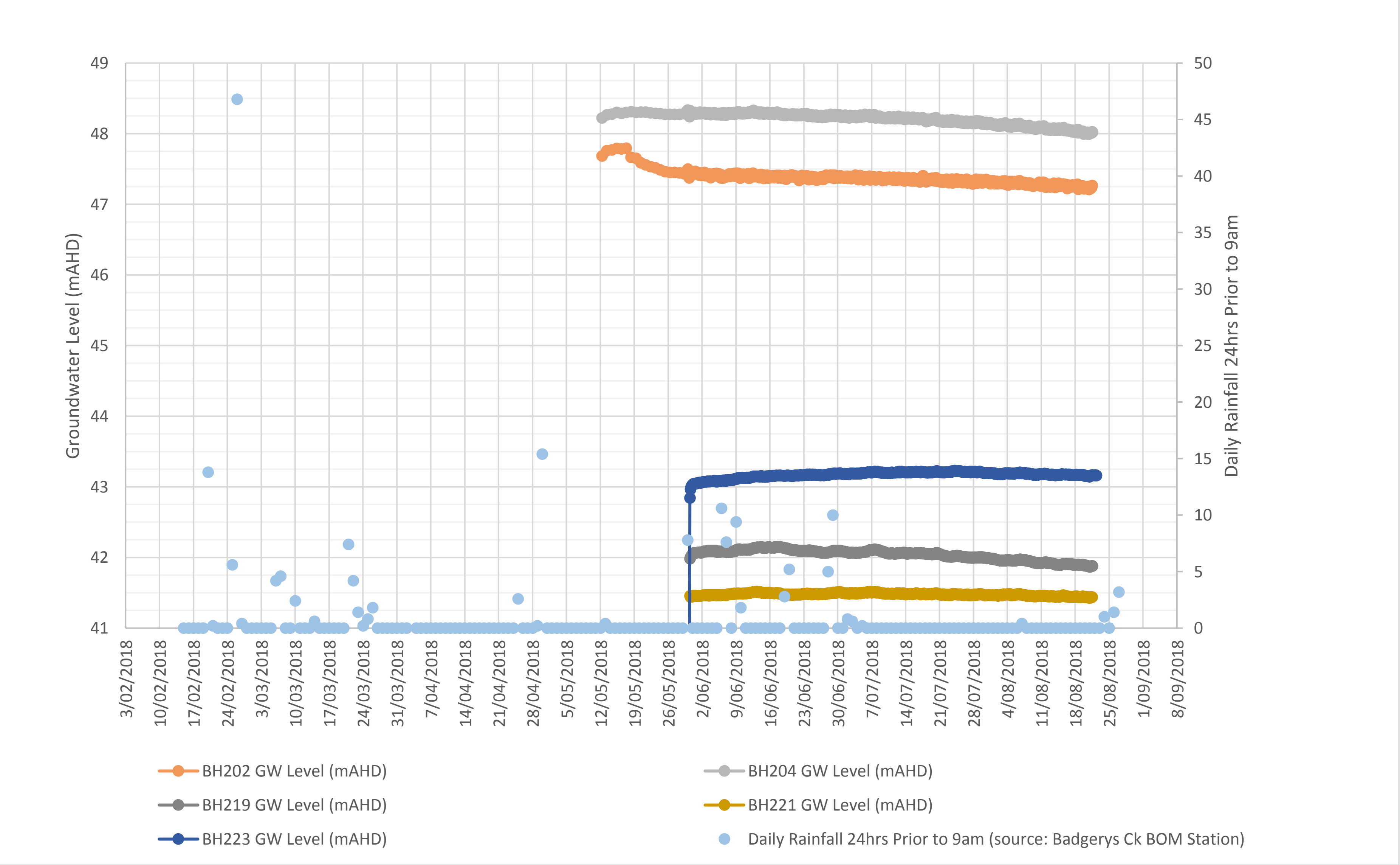
Project monitoring bore hydrographs



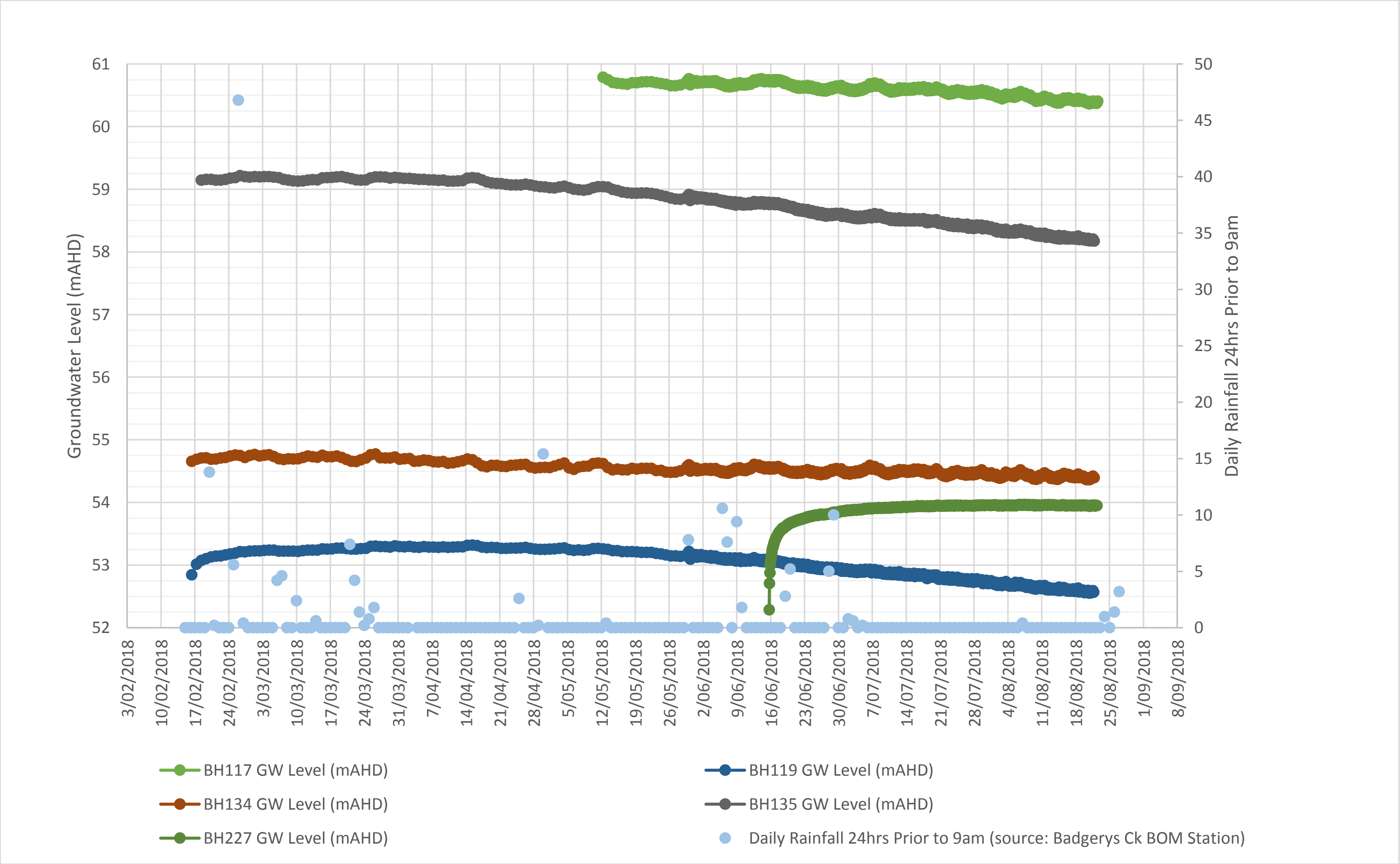
JACOBS

M12 Motorway Groundwater Monitoring Bore Hydrographs: BH207, BH209, BH211, BH215, BH217 - Figure 4

C:\Users\rosebj\Desktop\M12\[GW level data logger analysis.xlsx]set 1



M12 Motorway Groundwater Monitoring Bore Hydrographs: BH202, BH204, BH219, BH221, BH223 - Figure 5



M12 Motorway Groundwater Monitoring Bore Hydrographs: BH117, BH119, BH227, BH134, BH135 - Figure 6

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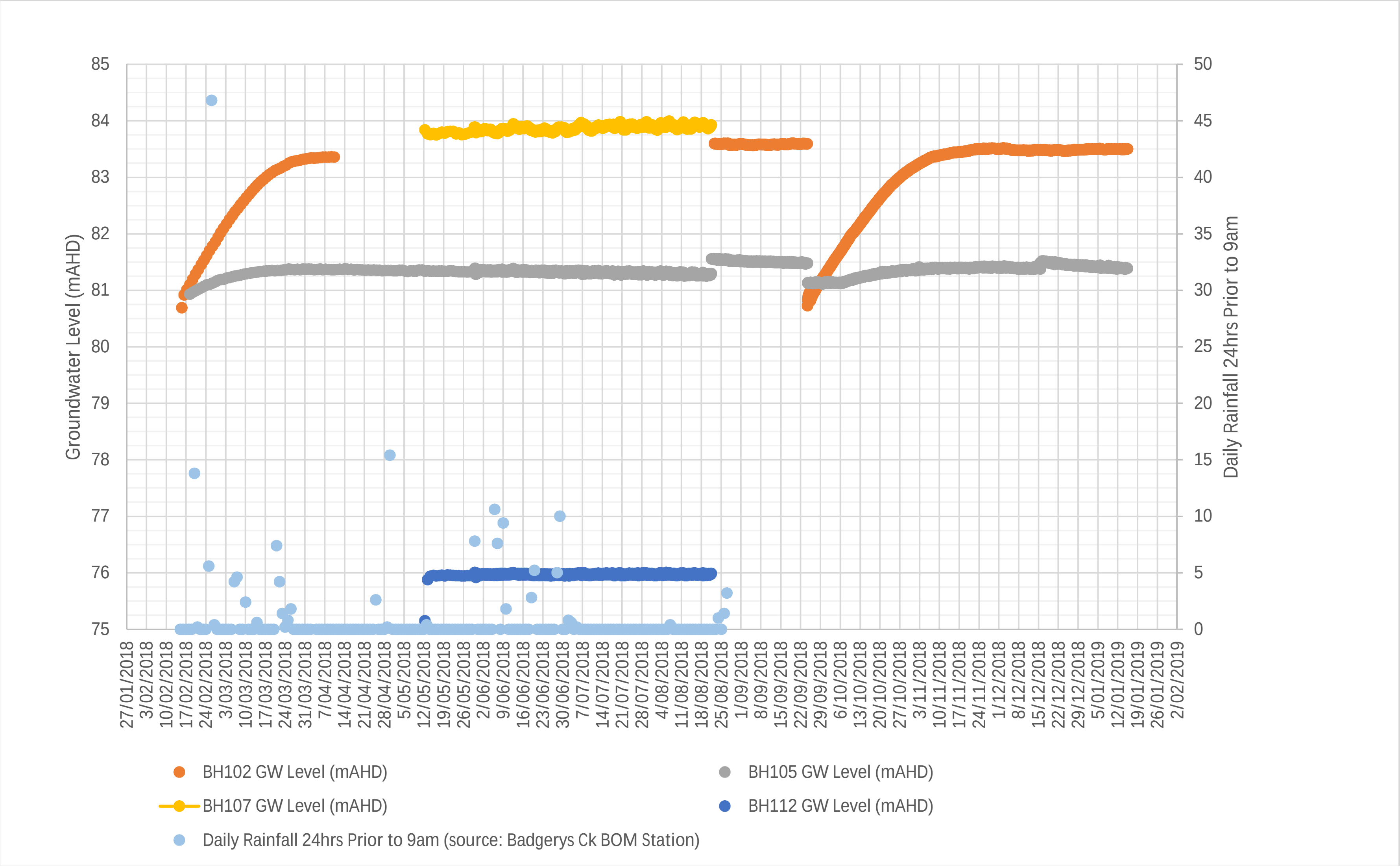
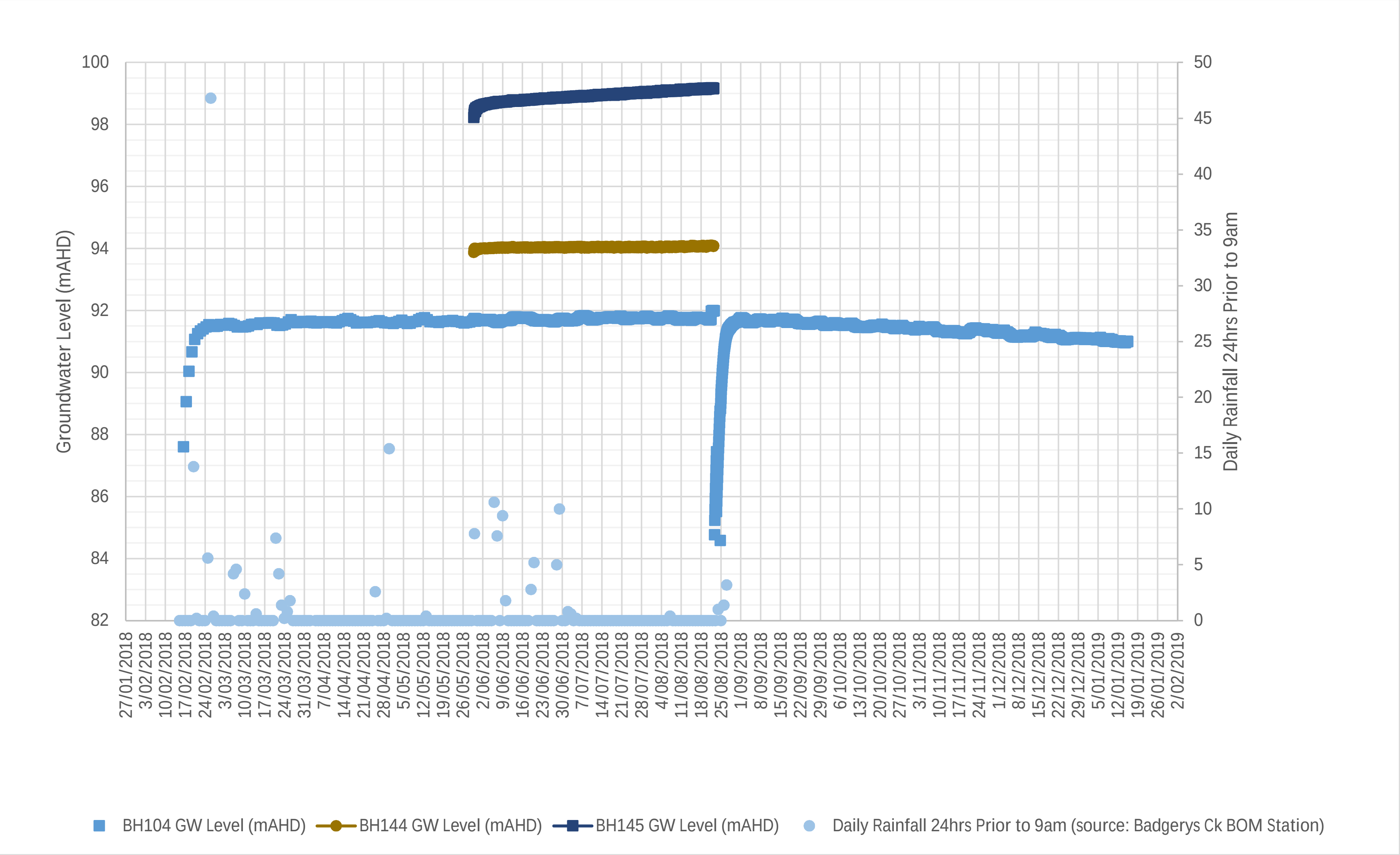


JACOBS

M12 Motorway Groundwater Monitoring Bore Hydrographs: BH102, BH105, BH107, BH112 - Figure 7

\\Jacobs.com\ANZ\IE\Projects\04_Eastern\IA145100\09 Environmental\Surface and Ground Water\Groundwater\[GW level data logger analysis_80%report.xlsx]set 4



M12 Motorway Groundwater Monitoring Bore Hydrographs: BH104, BH144, BH145 - Figure 8

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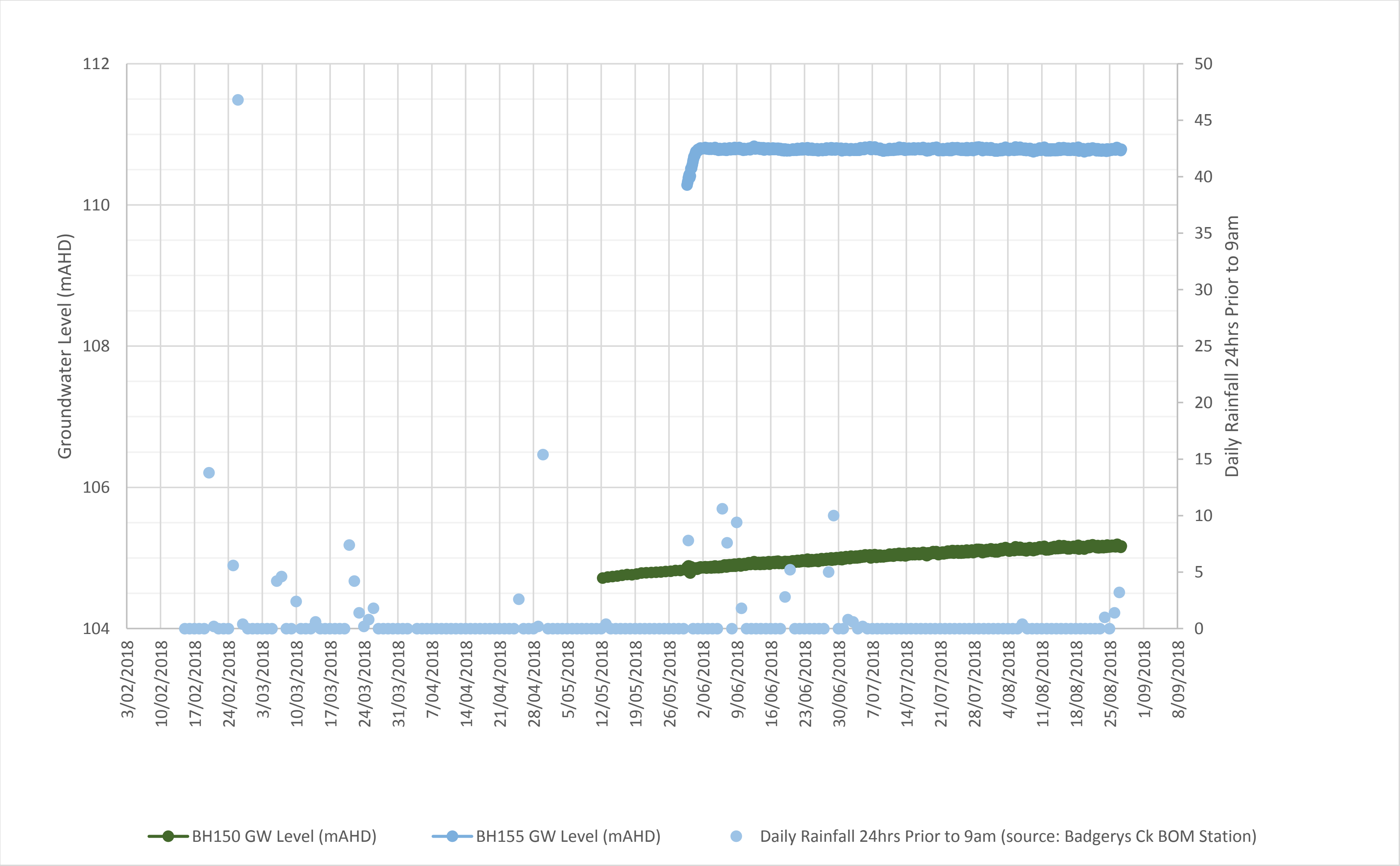

M12 Motorway Groundwater Monitoring Bore Hydrographs: BH150, BH155 - Figure 9

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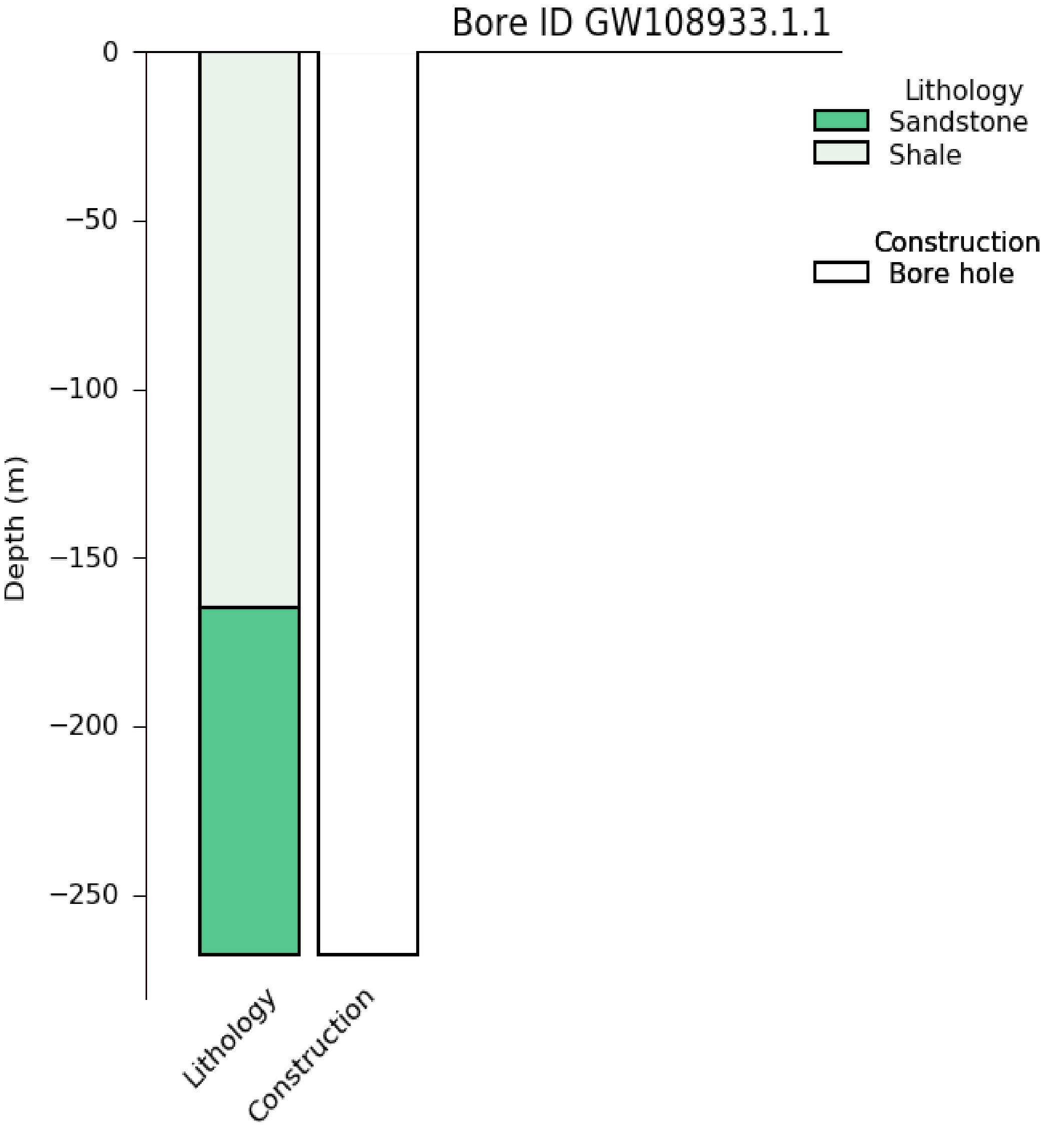
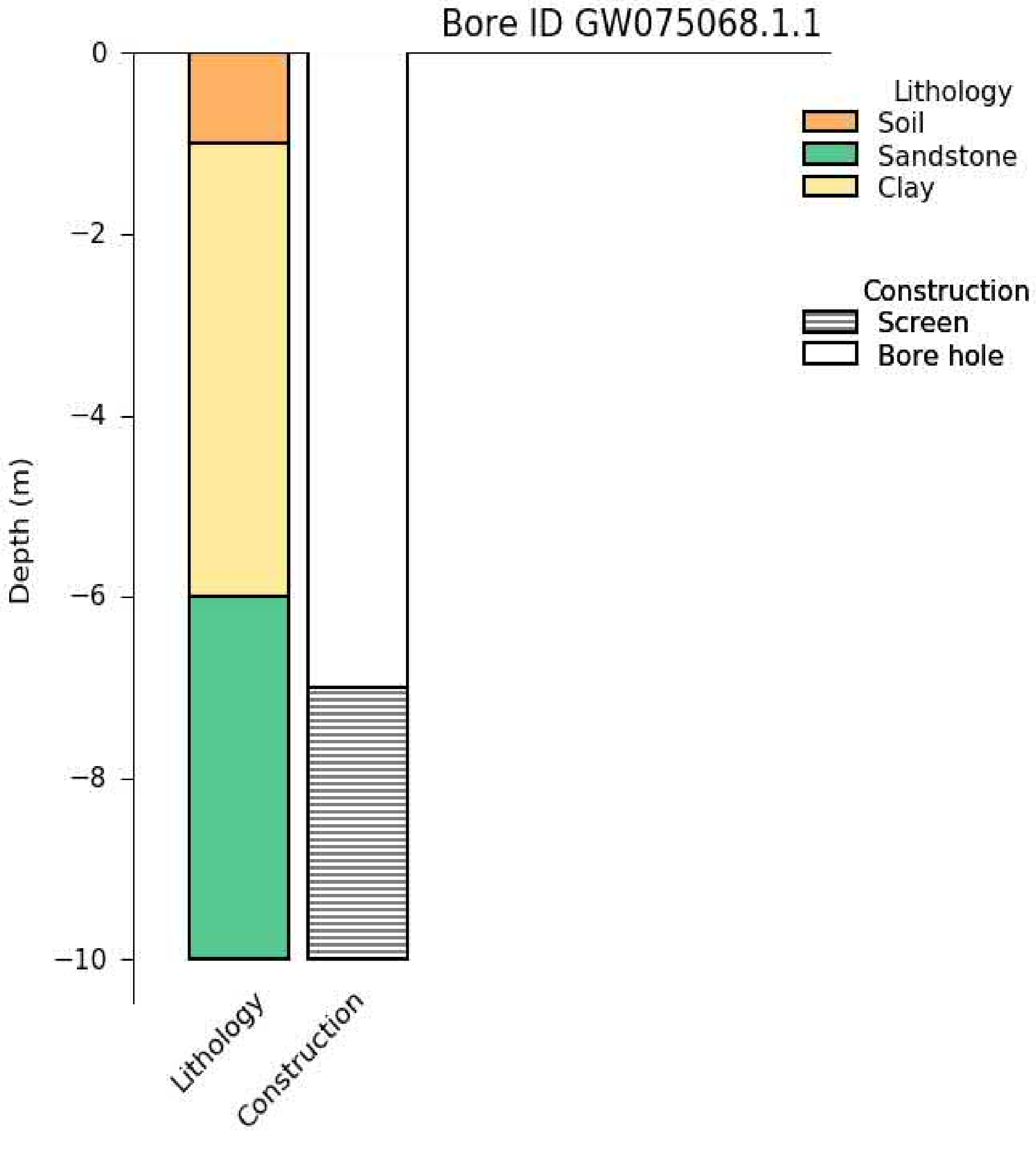
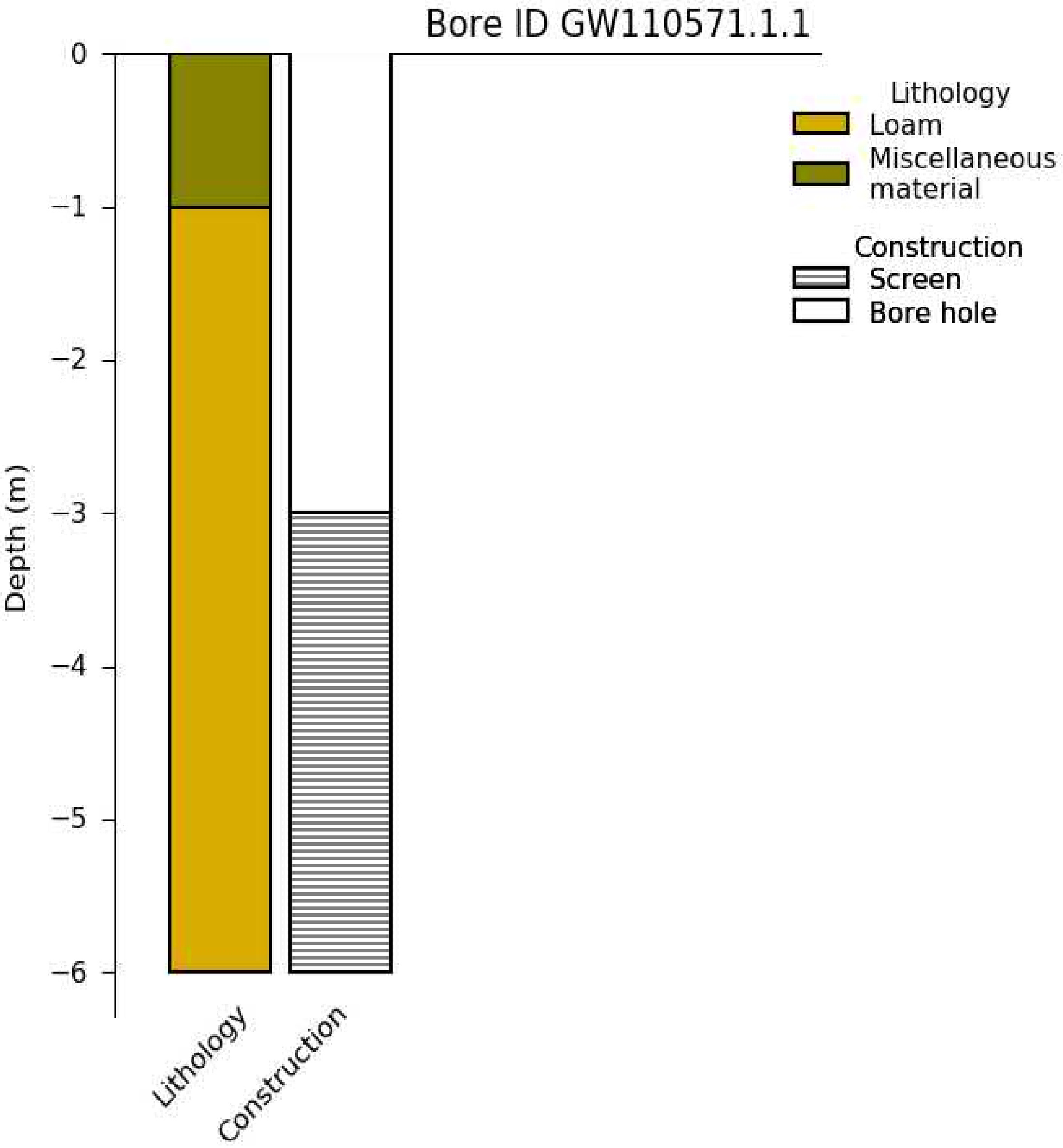
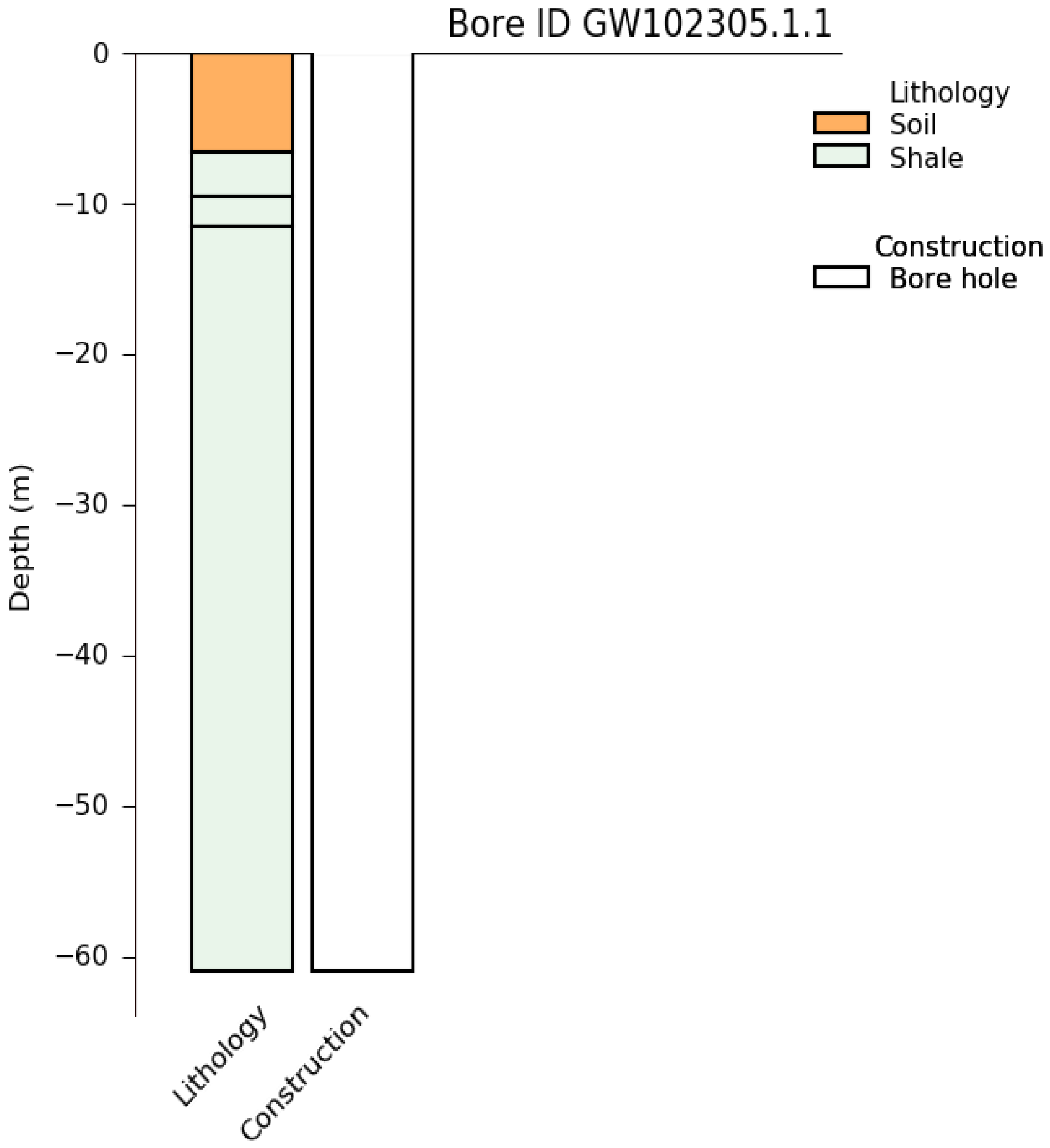
Annexure D

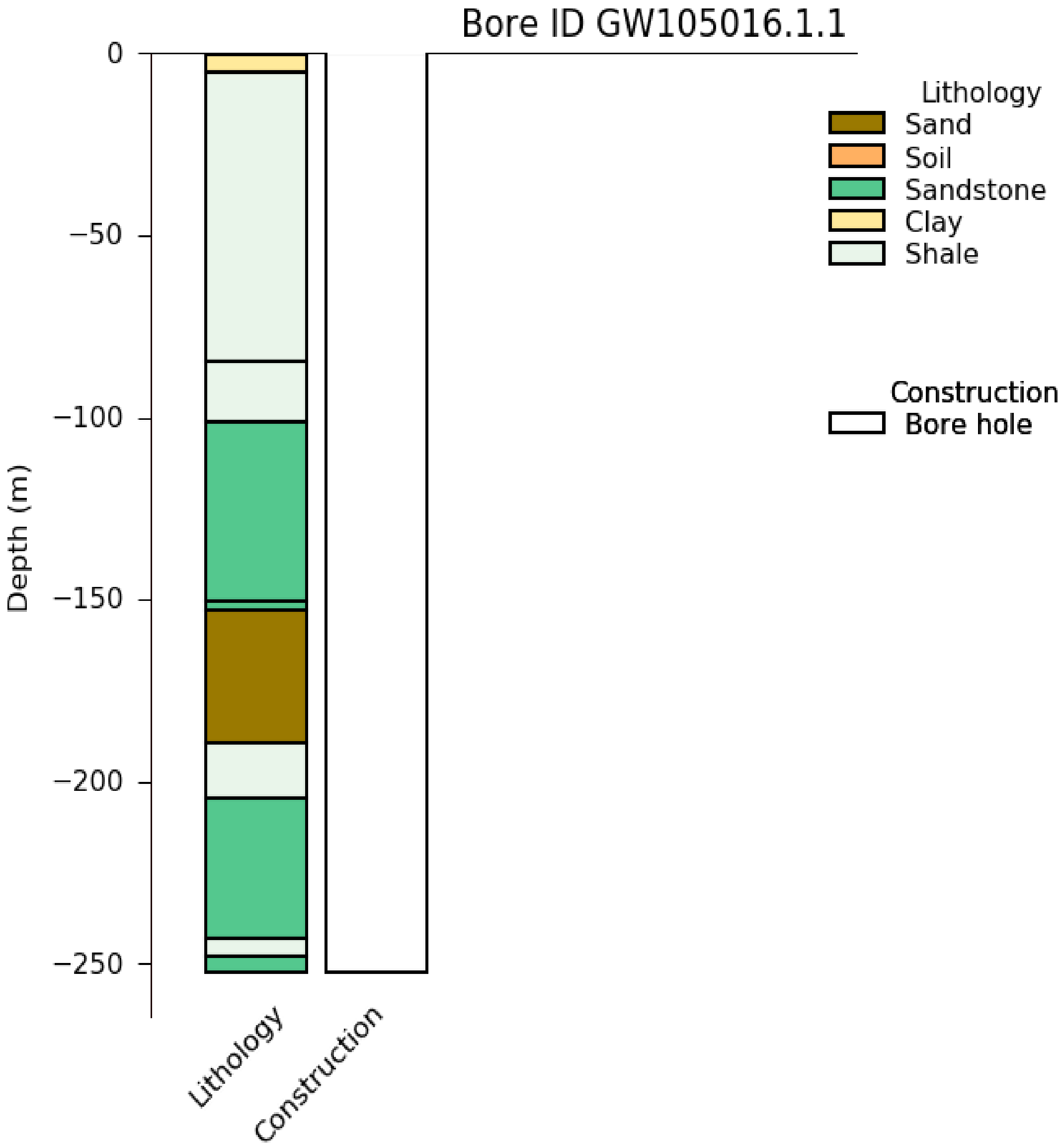
Registered groundwater bore lithology logs


Bore ID GW108933.1.1
0
−50
−100
−150
−200
−250
Depth (m)
Lithology
Construction
Lithology
Sandstone
Shale
Construction
Bore hole

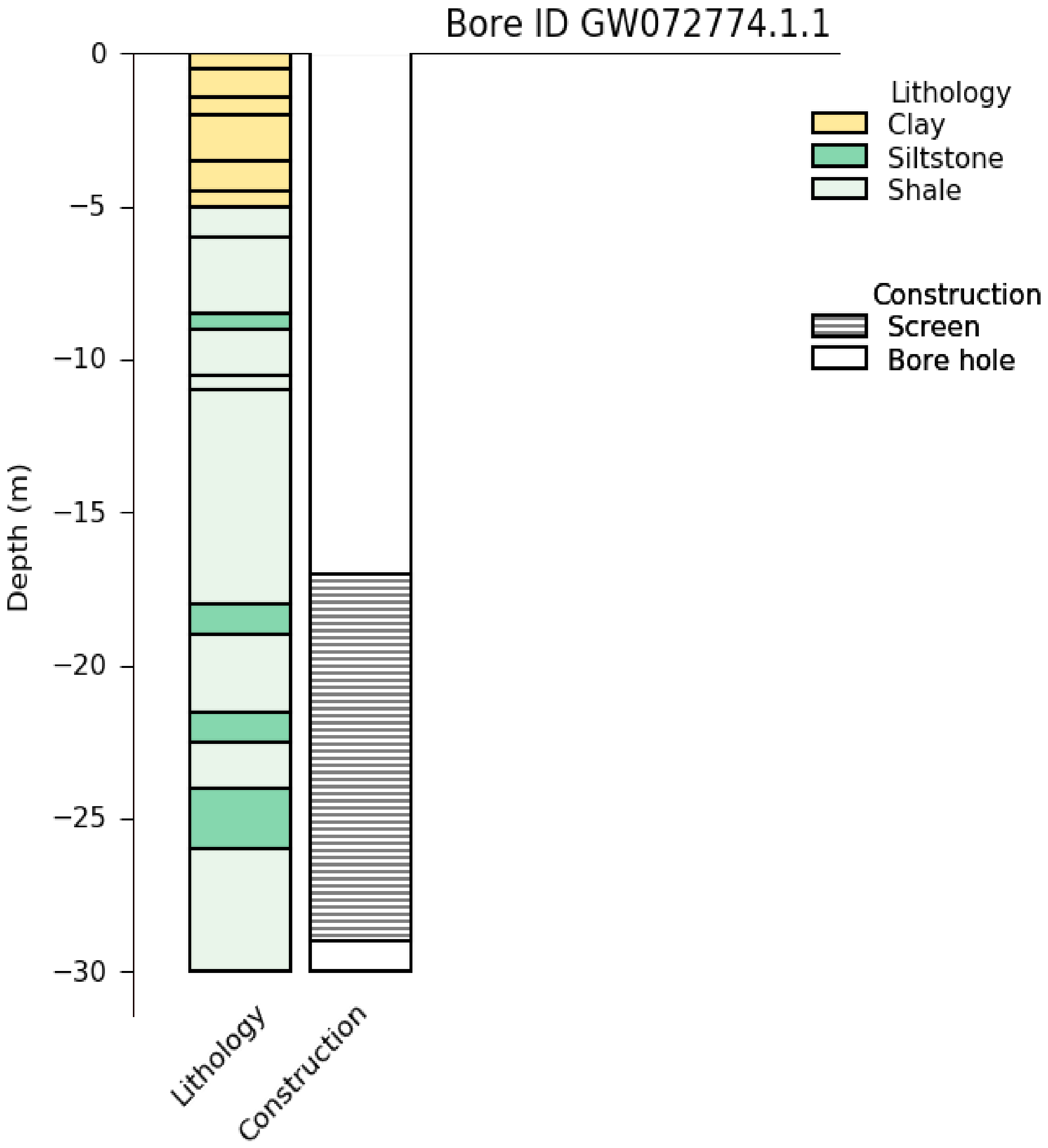

Bore ID GW075068.1.1
Depth (m)
0
−2
−4
−6
−8
−10
Lithology
Construction
Lithology
Soil
Sandstone
Clay
Construction
Screen
Bore hole

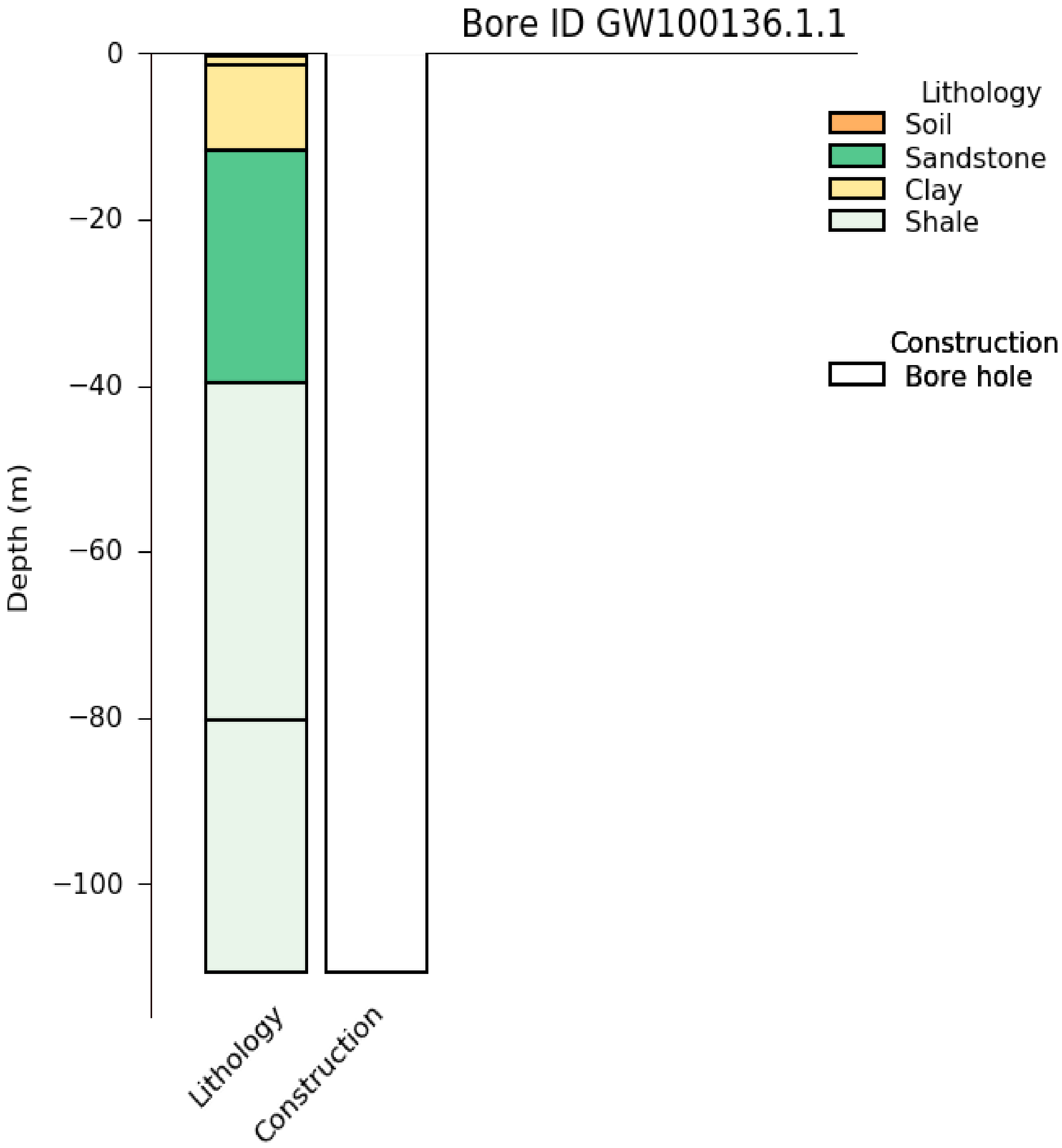

Bore ID GW110571.1.1
0
−1
−2
−3
−4
−5
−6
Depth (m)
Lithology
Construction
Lithology
Loam
Miscellaneous material
Construction
Screen
Bore hole

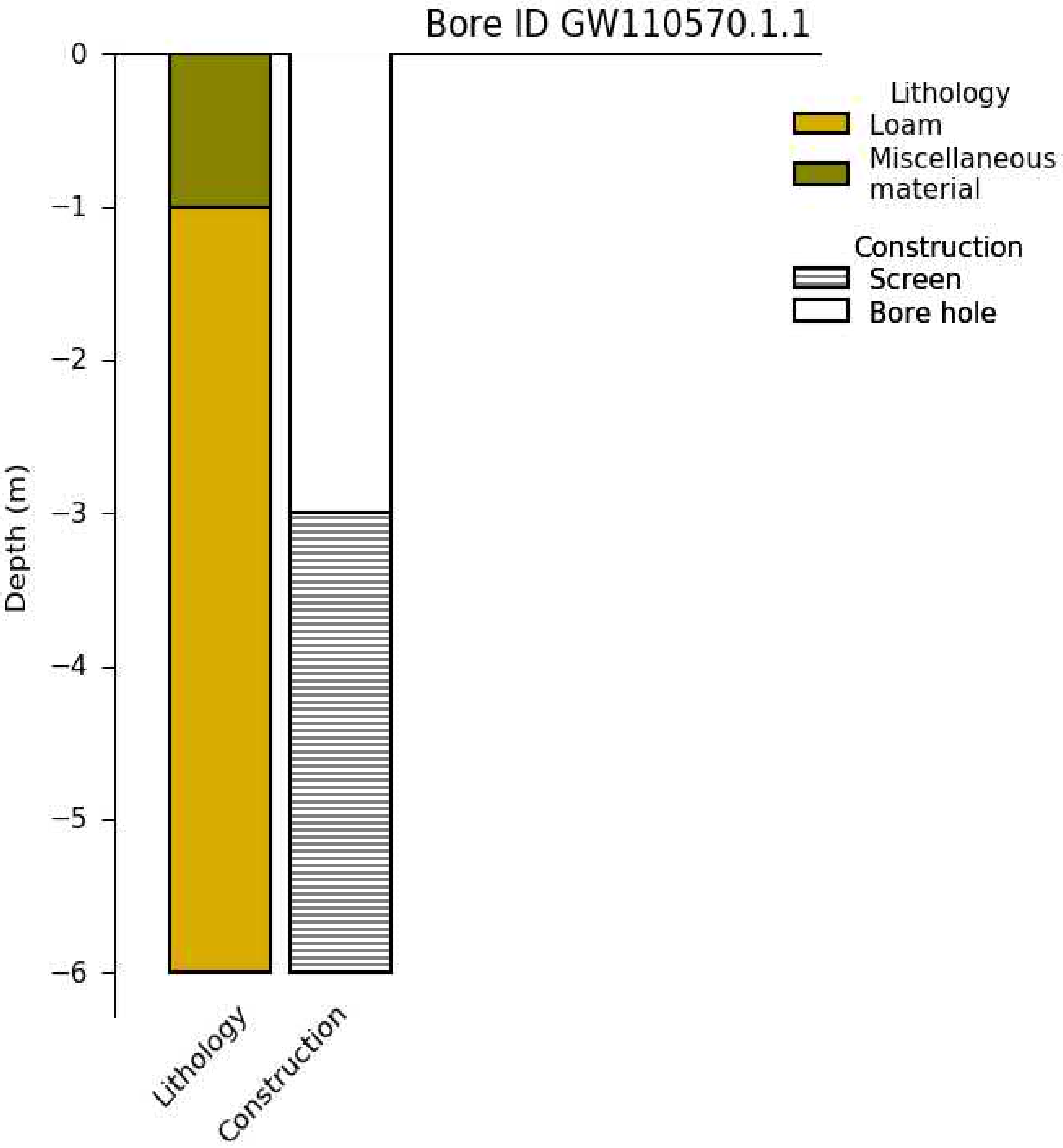

Bore ID GW102305.1.1
0
−10
−20
−30
−40
−50
−60
Depth (m)
Lithology
Construction
Lithology
Soil
Shale
Construction
Bore hole

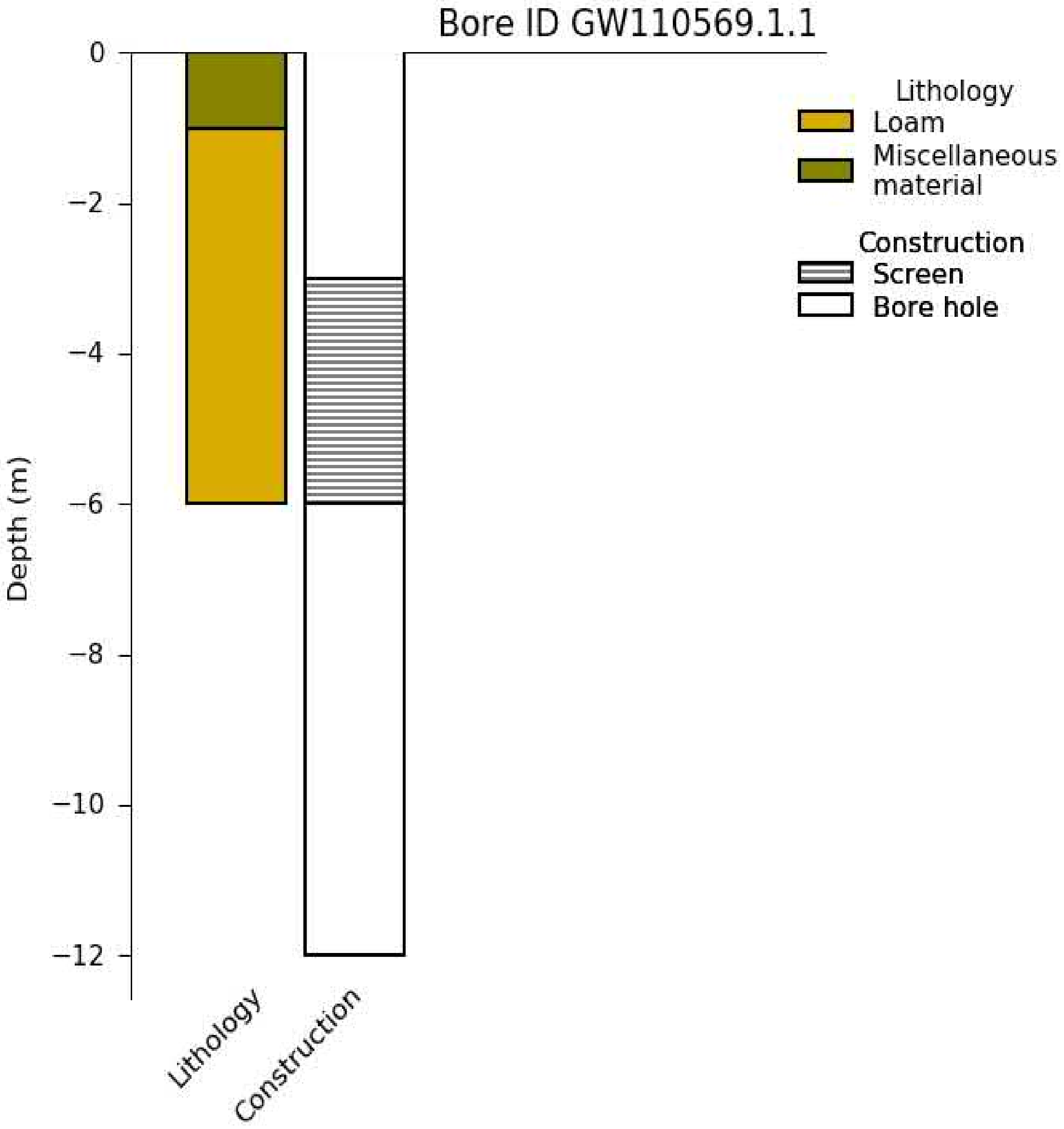


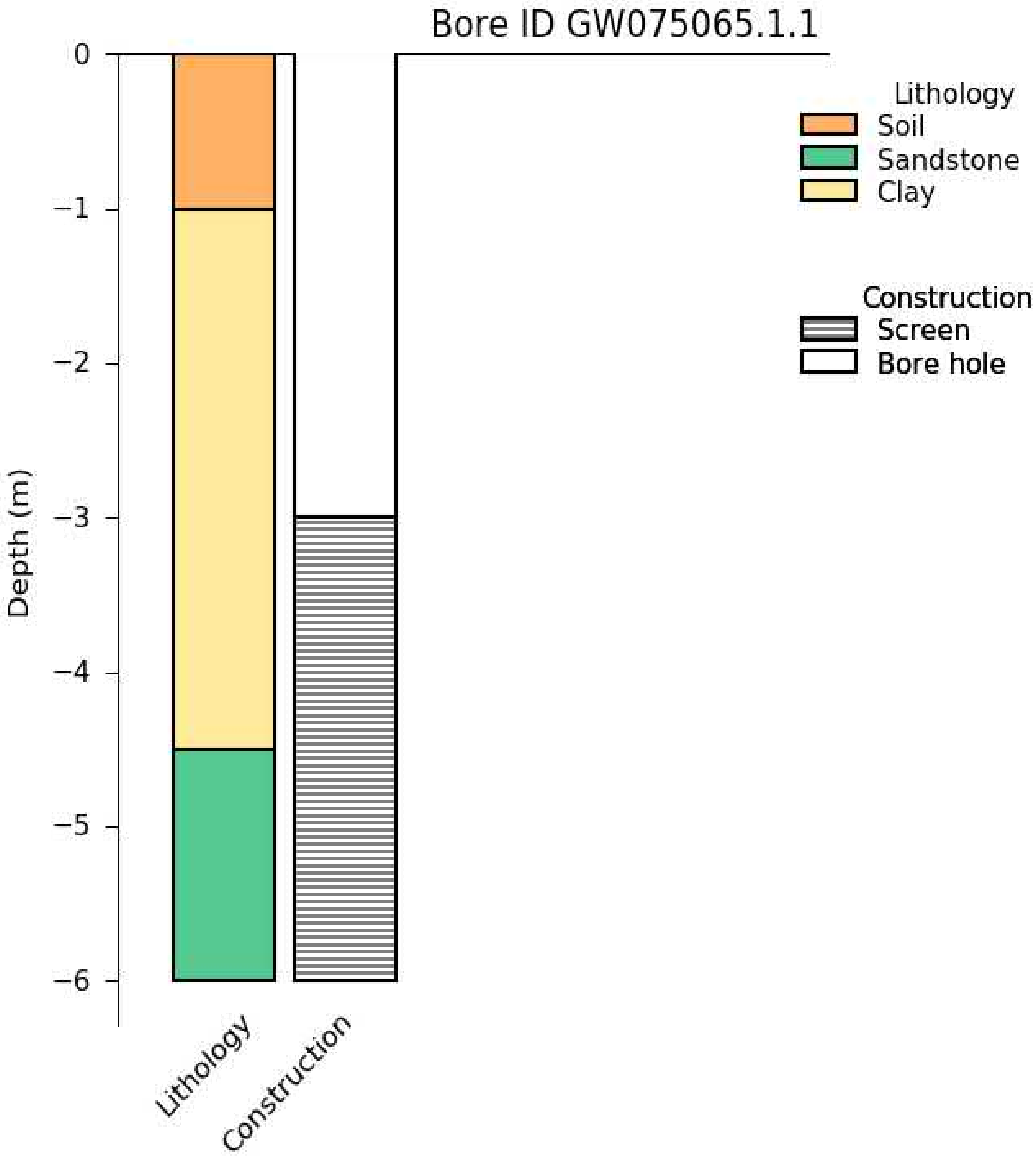
Bore ID GW105016.1.1
0
−50
−100
−150
−200
−250
Depth (m)
Lithology
Construction
Lithology
Sand
Soil
Sandstone
Clay
Shale
Construction
Bore hole

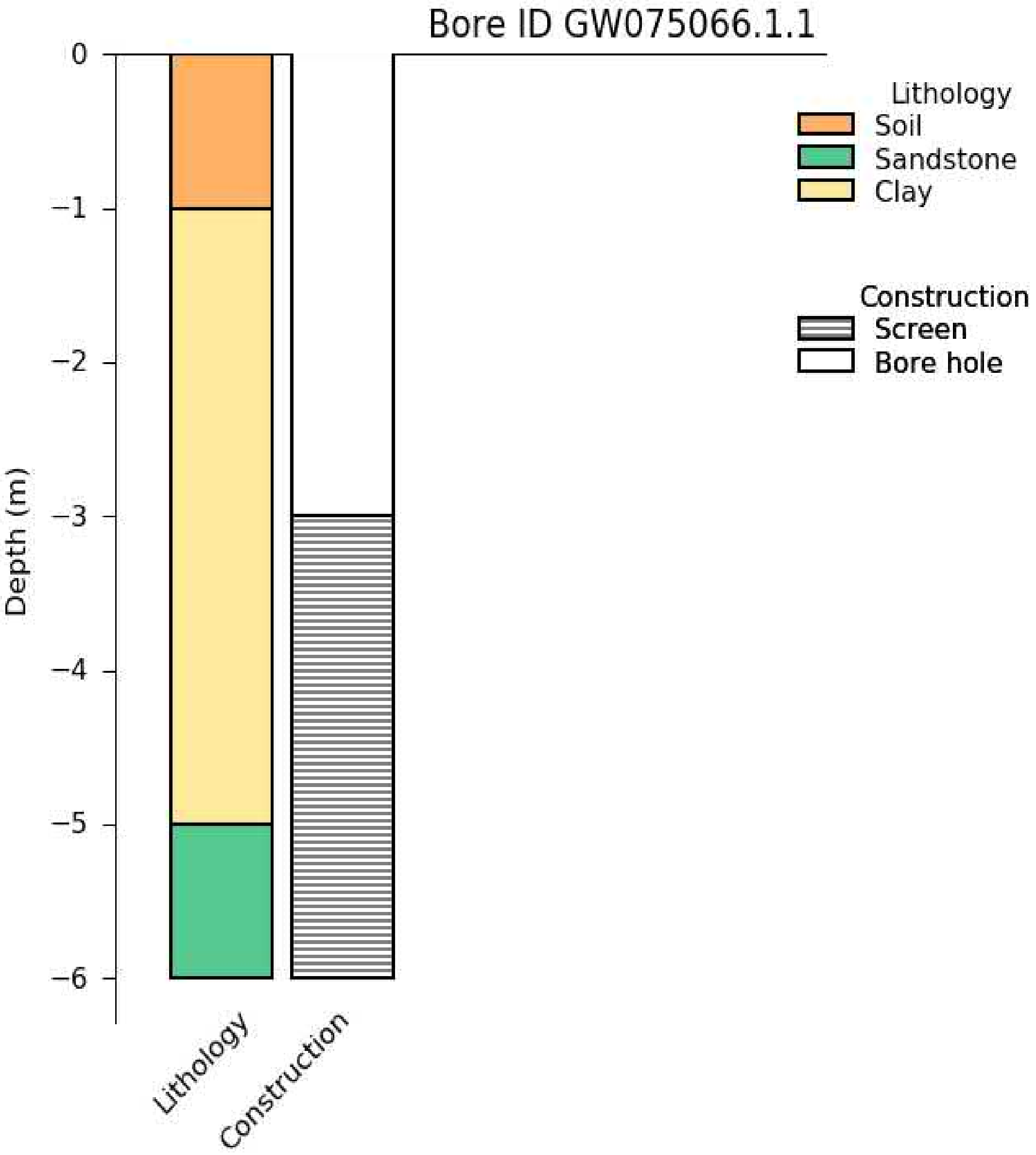

Bore ID GW072774.1.1
Depth (m)
0
−5
−10
−15
−20
−25
−30
Lithology
Construction
Lithology
Clay
Siltstone
Shale
Construction
Screen
Bore hole

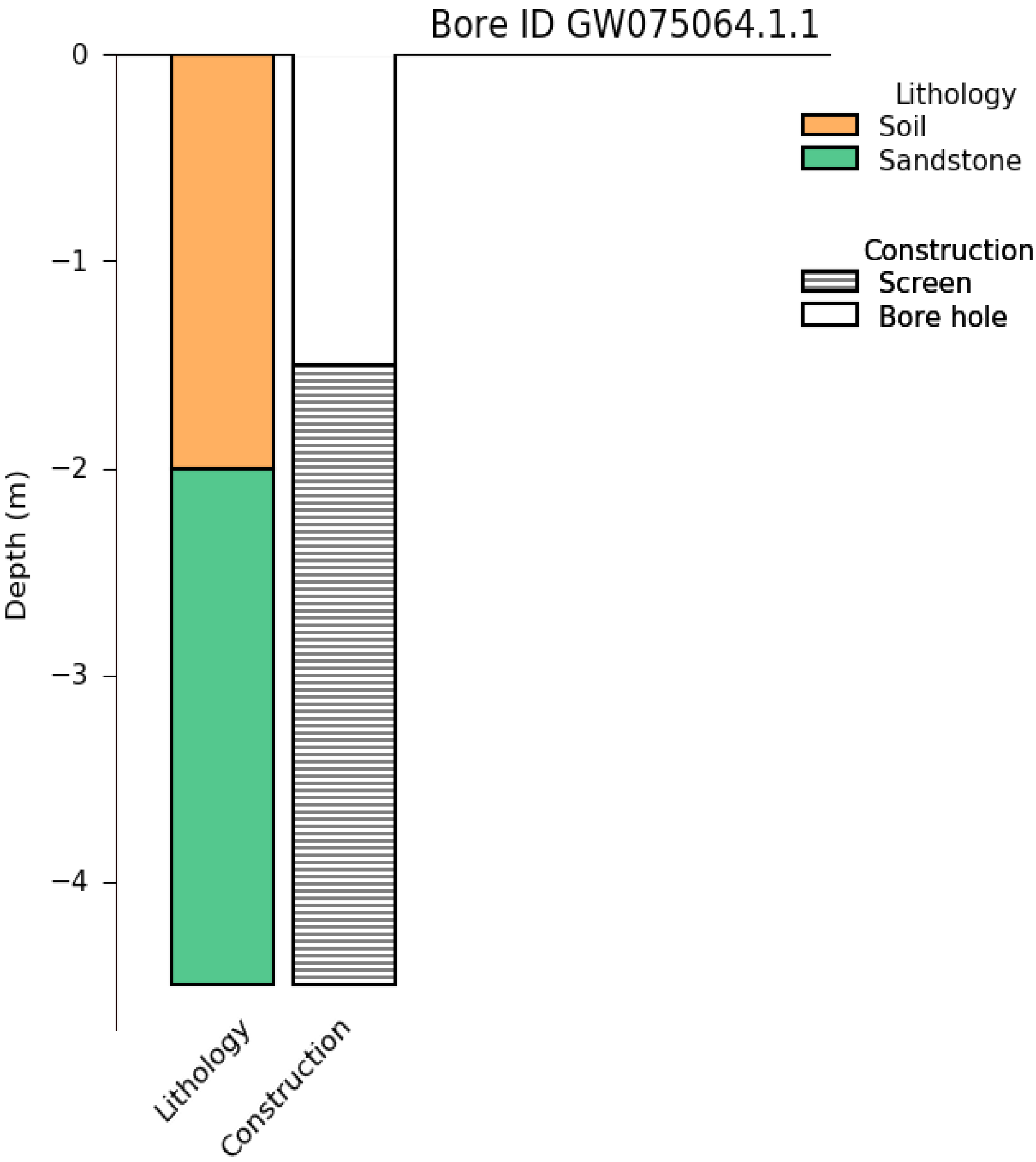

Bore ID GW100136.1.1
Depth (m)
0
−20
−40
−60
−80
−100
Lithology
Construction
Lithology
Soil
Sandstone
Clay
Shale
Construction
Bore hole

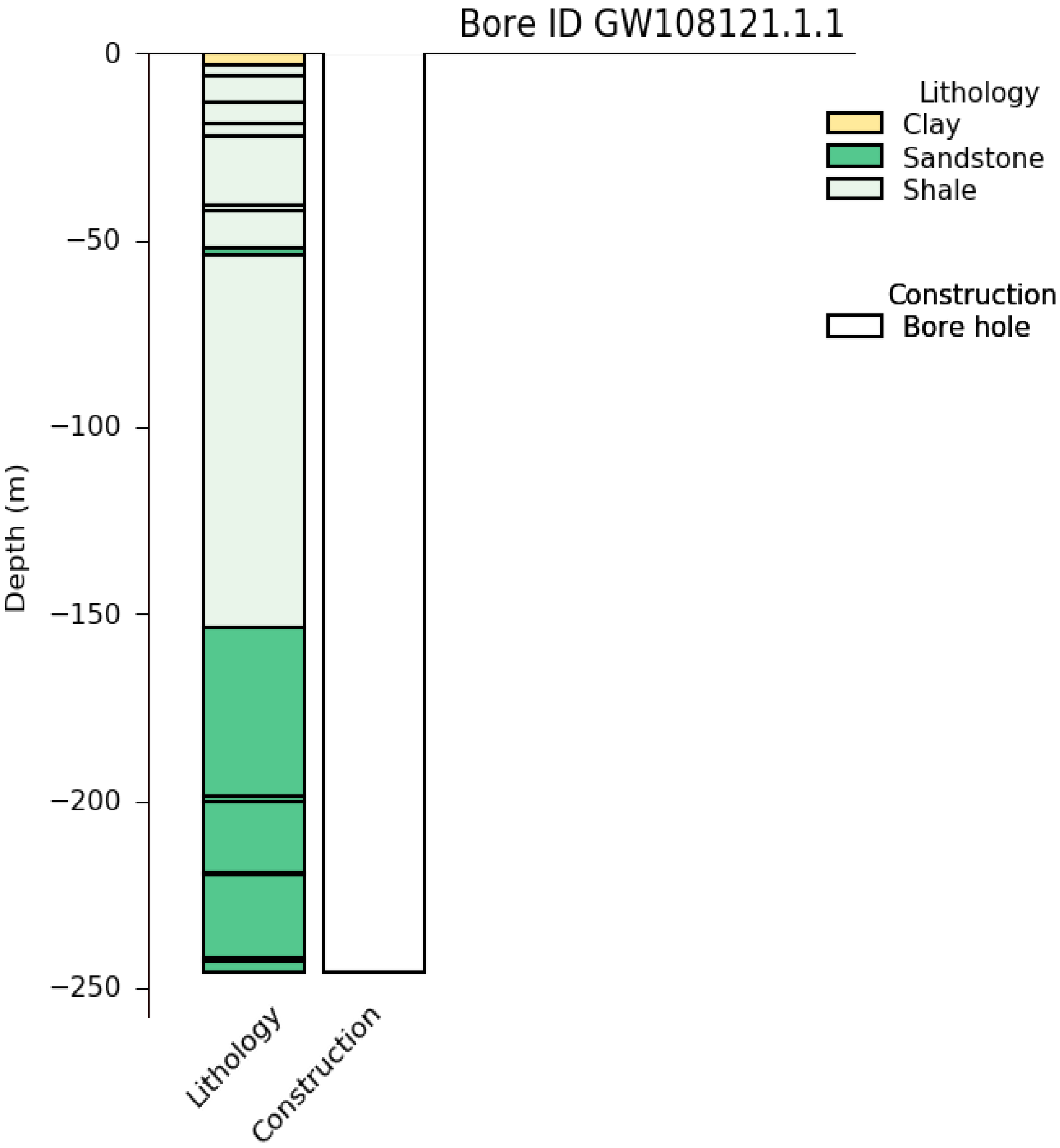

Bore ID GW110570.1.1
0
−1
−2
−3
−4
−5
−6
Depth (m)
Lithology
Construction
Lithology
Loam
Miscellaneous material
Construction
Screen
Bore hole

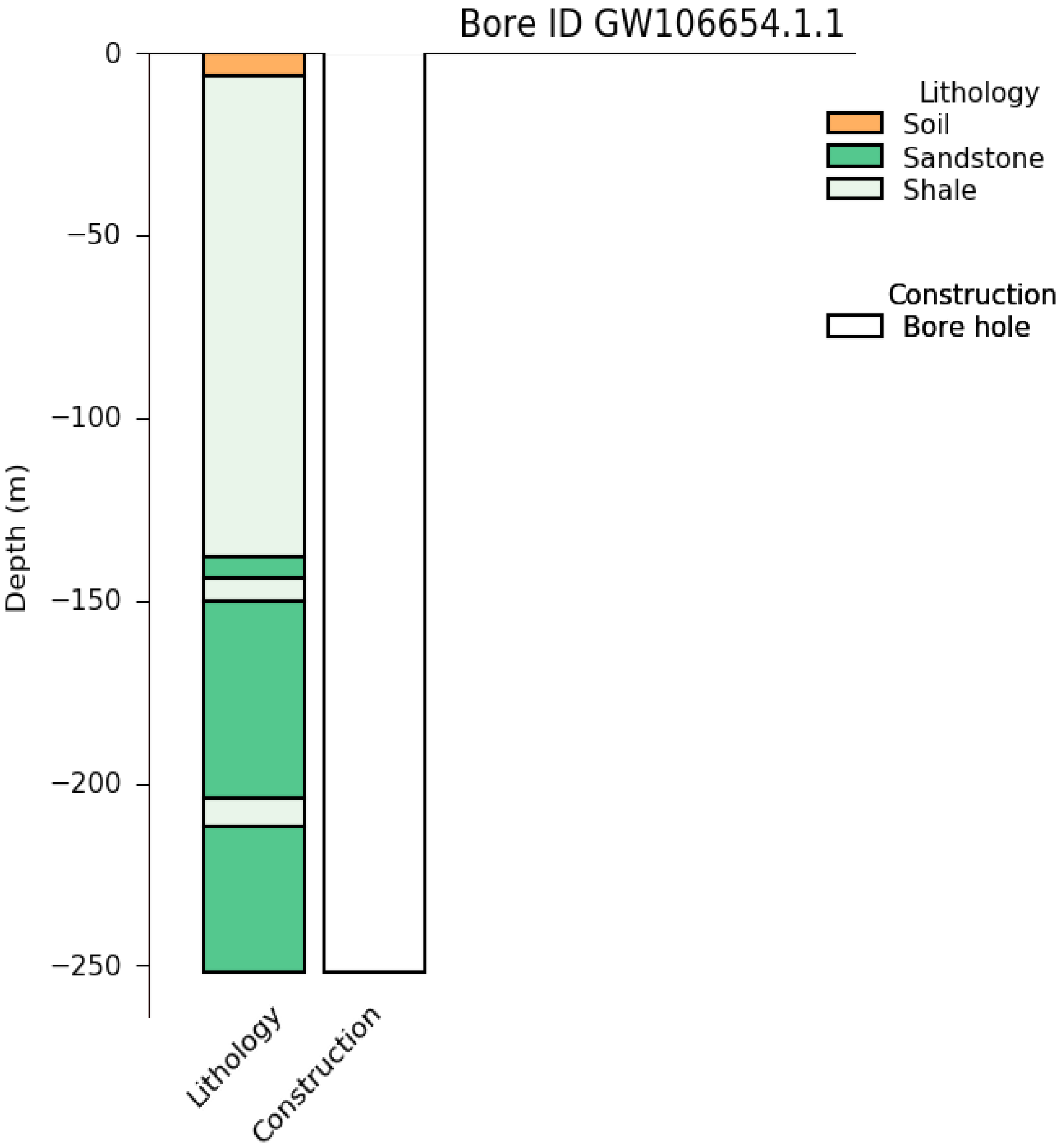

Bore ID GW110569.1.1
0
−2
−4
−6
−8
−10
−12
Depth (m)
Lithology
Construction
Lithology
Loam
Miscellaneous material
Construction
Screen
Bore hole

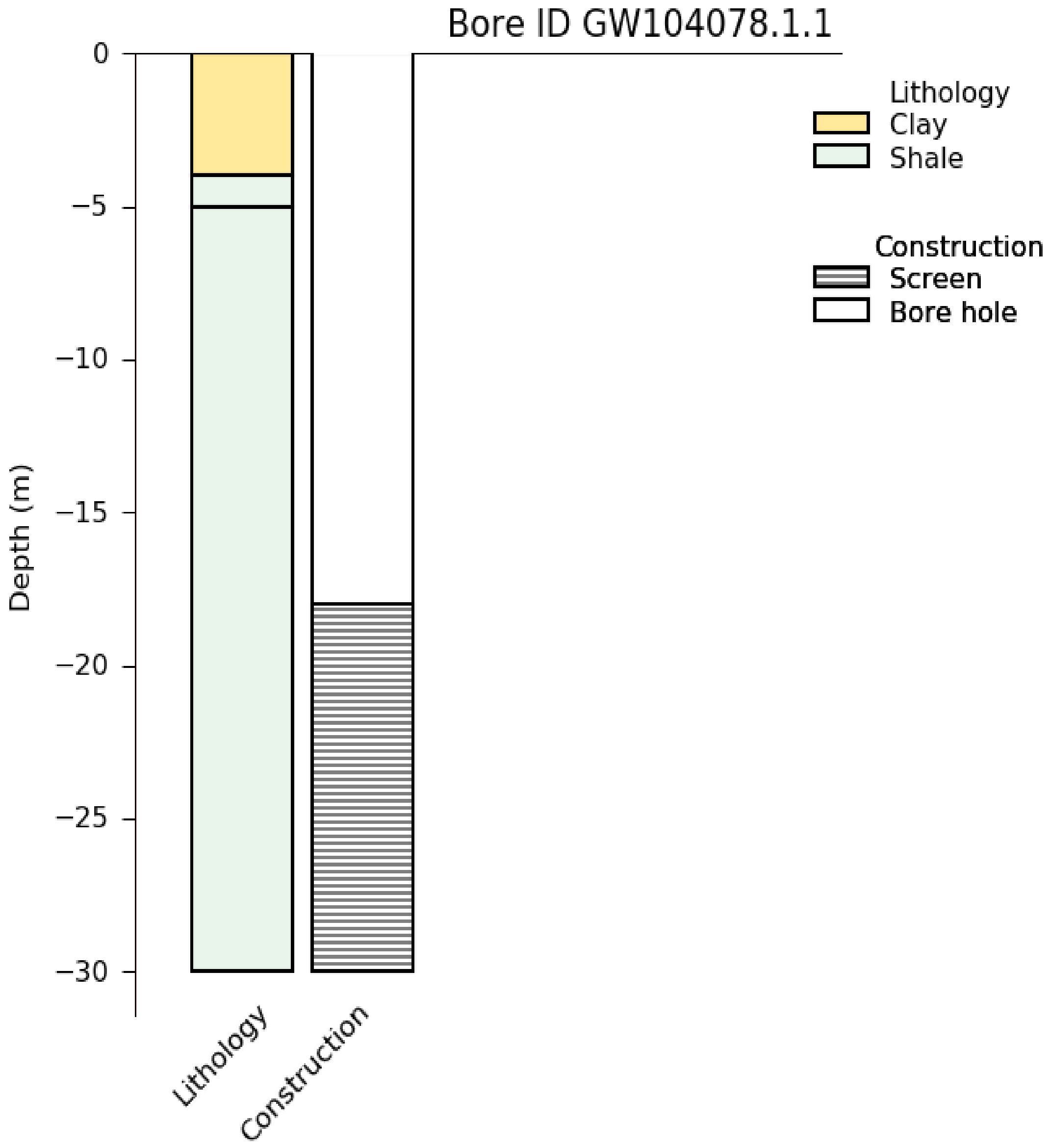

Bore ID GW075065.1.1
0
−1
−2
−3
−4
−5
−6
Depth (m)
Lithology
Construction
Lithology
Soil
Sandstone
Clay
Construction
Screen
Bore hole

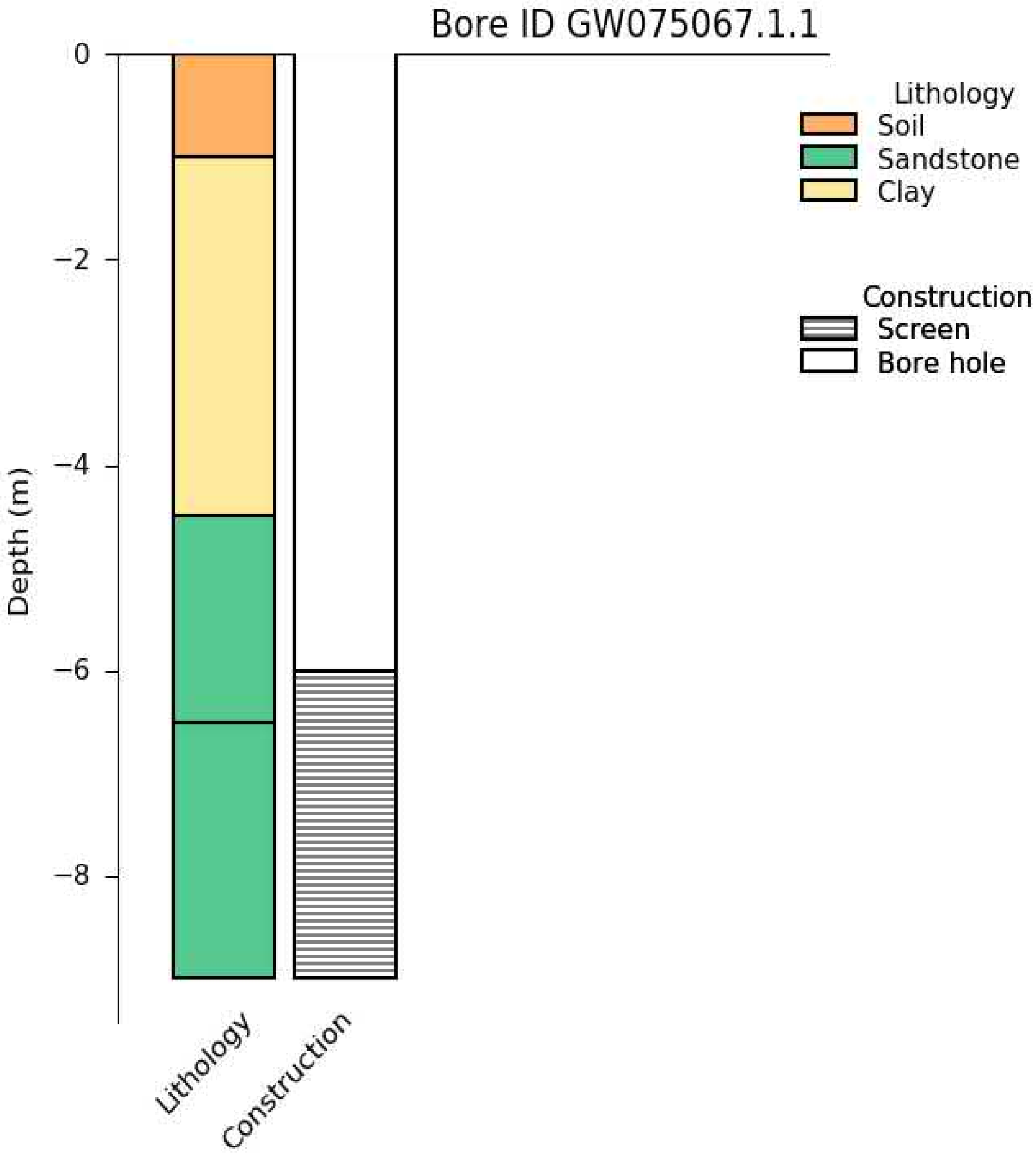

Bore ID GW075066.1.1
0
−1
−2
−3
−4
−5
−6
Depth (m)
Lithology
Construction
Lithology
Soil
Sandstone
Clay
Construction
Screen
Bore hole

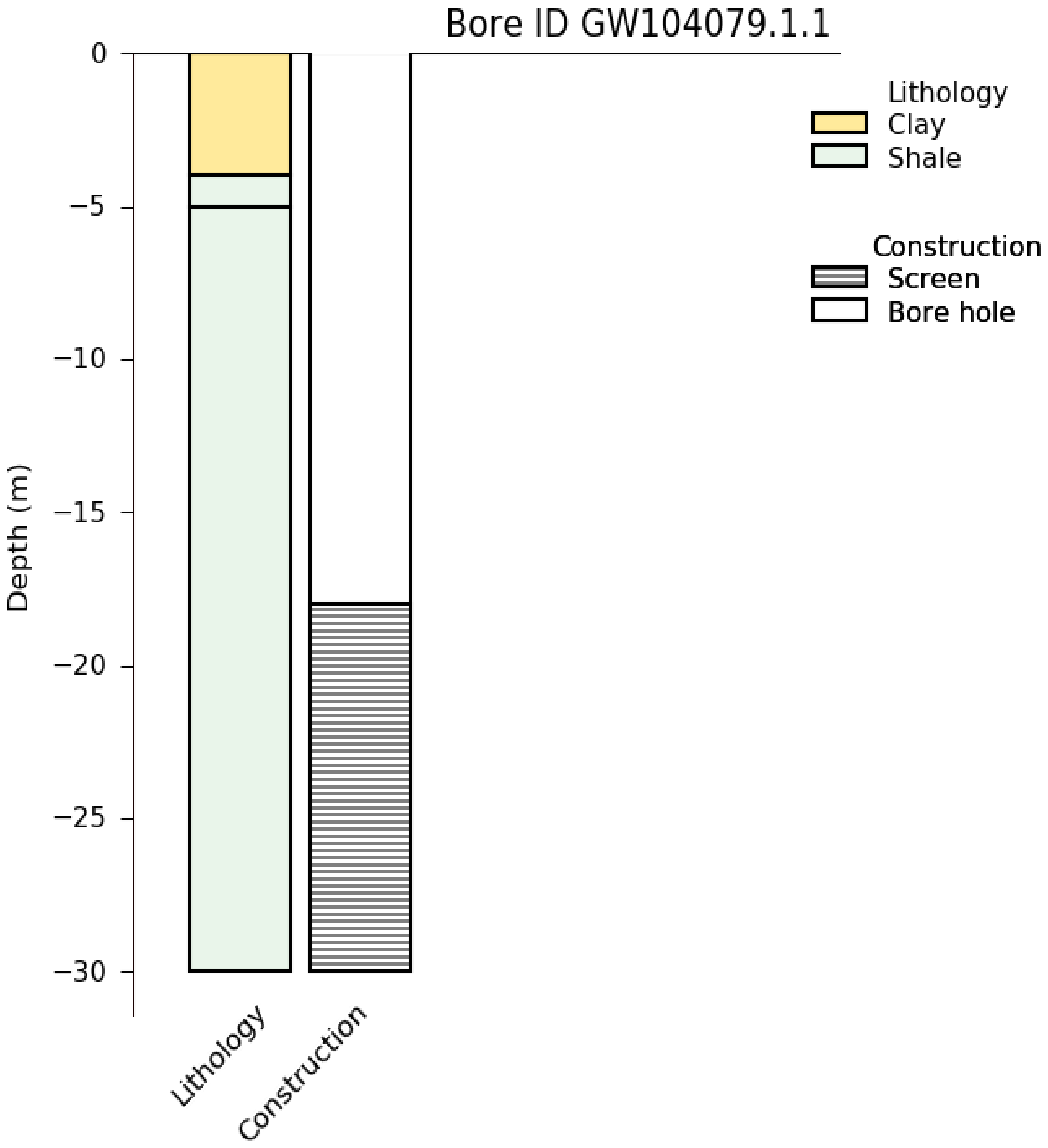

Bore ID GW075064.1.1
0
−1
−2
−3
−4
Depth (m)
Lithology
Construction
Lithology
Soil
Sandstone
Construction
Screen
Bore hole

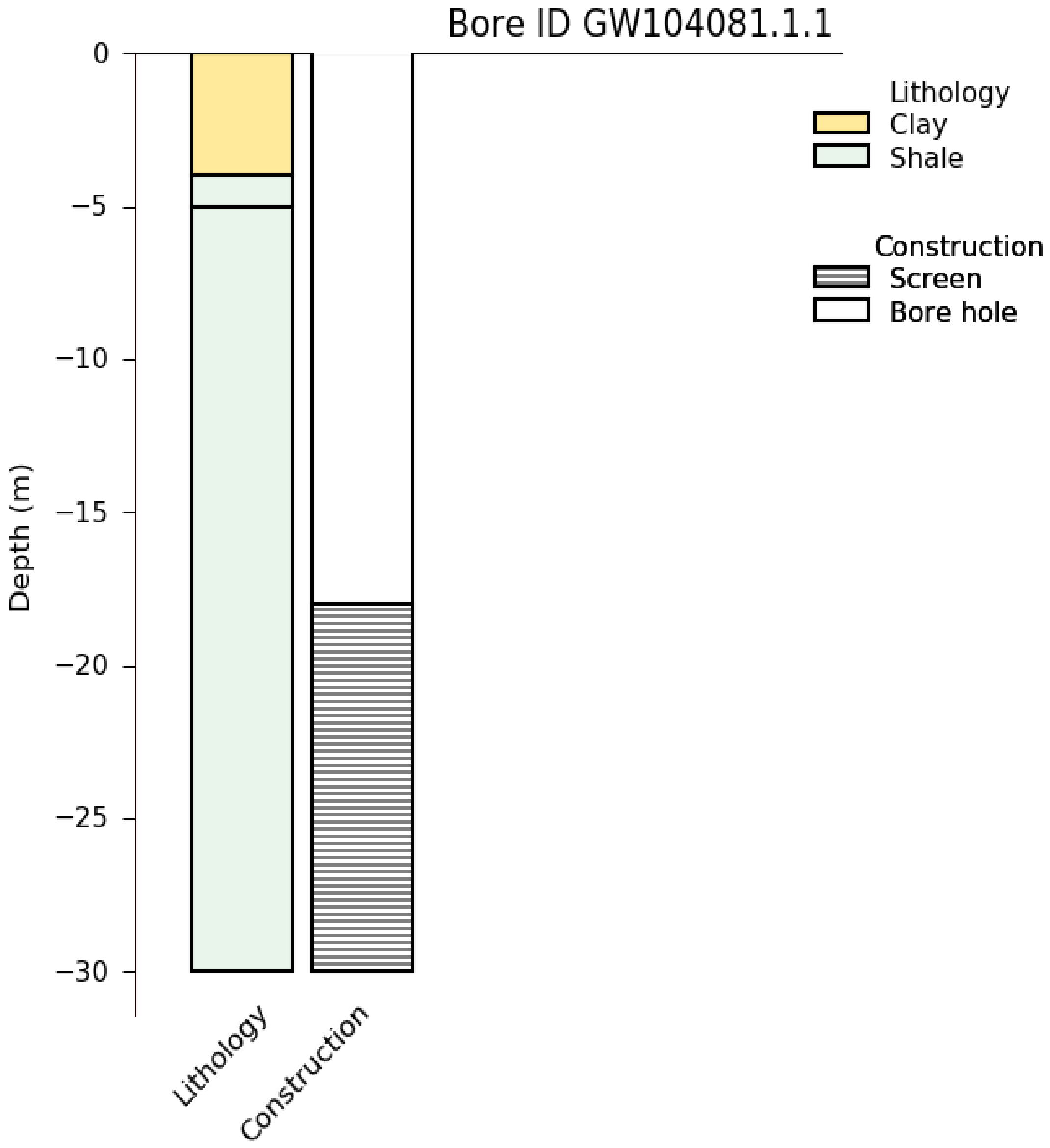

Bore ID GW108121.1.1
0
−50
−100
−150
−200
−250
Depth (m)
Lithology
Construction
Lithology
Clay
Sandstone
Shale
Construction
Bore hole

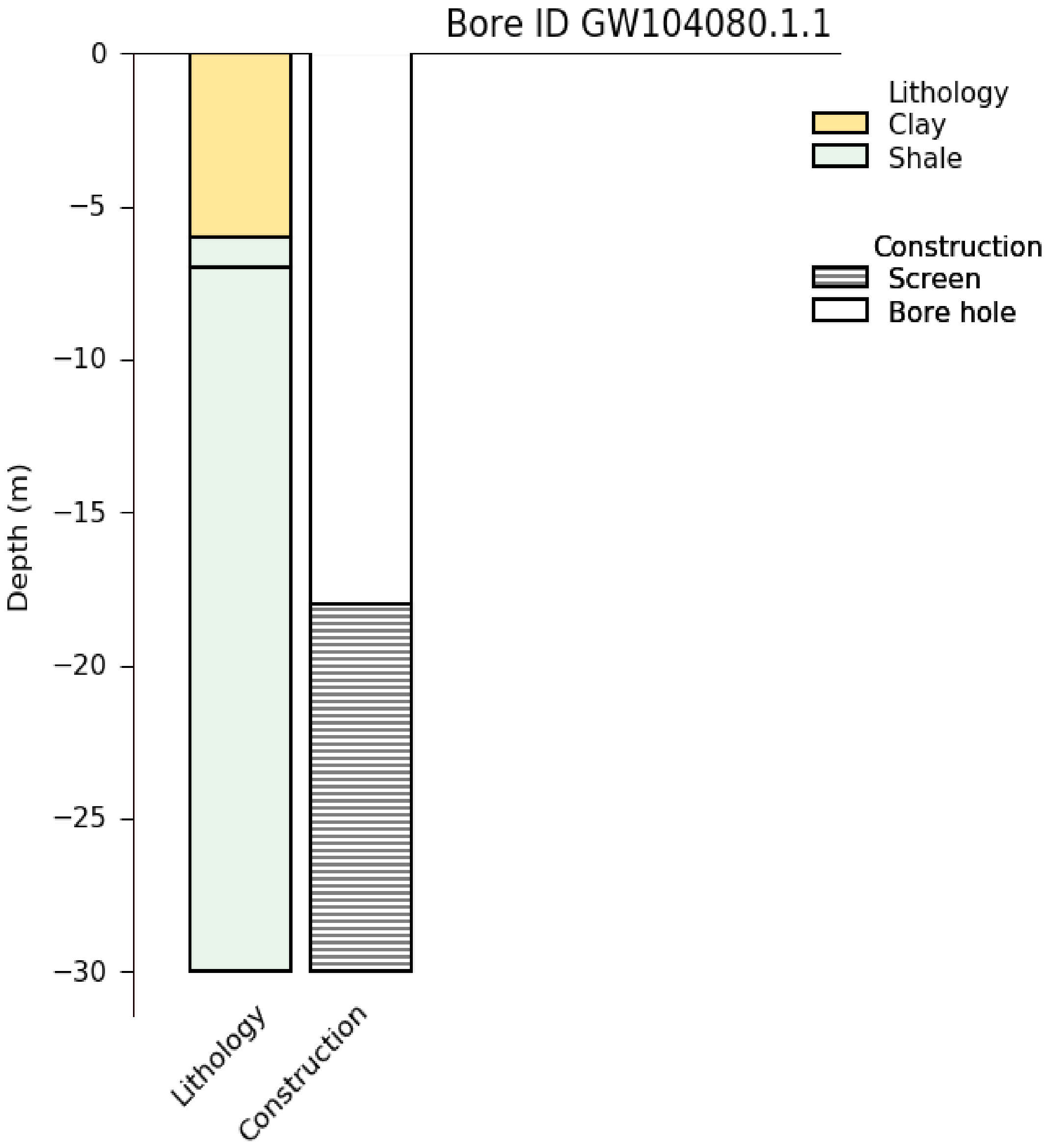

Bore ID GW106654.1.1
0
−50
−100
−150
−200
−250
Depth (m)
Lithology
Construction
Lithology
Soil
Sandstone
Shale
Construction
Bore hole

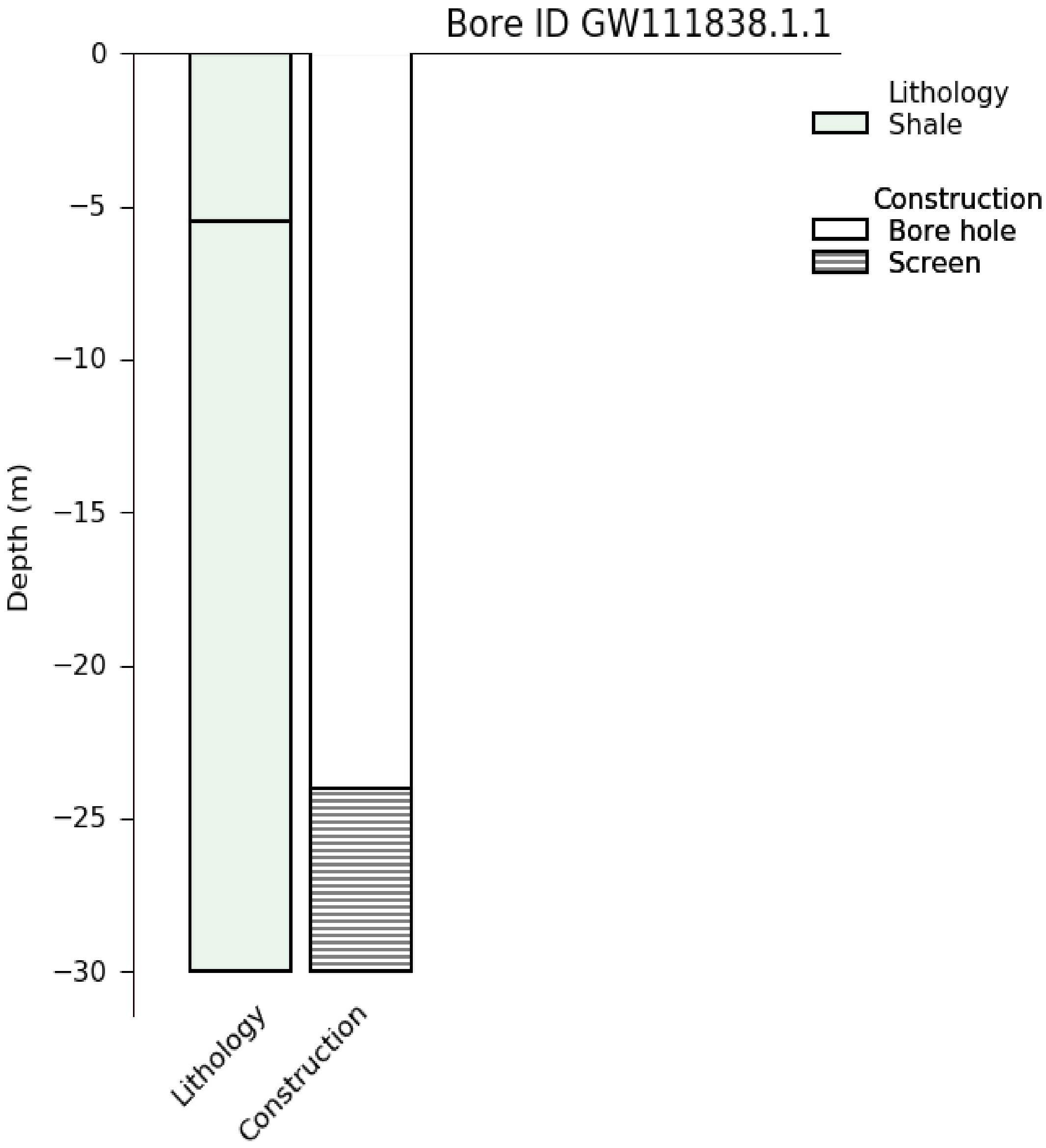

Bore ID GW104078.1.1
0
−5
−10
−15
−20
−25
−30
Depth (m)
Lithology
Construction
Lithology
Clay
Shale
Construction
Screen
Bore hole

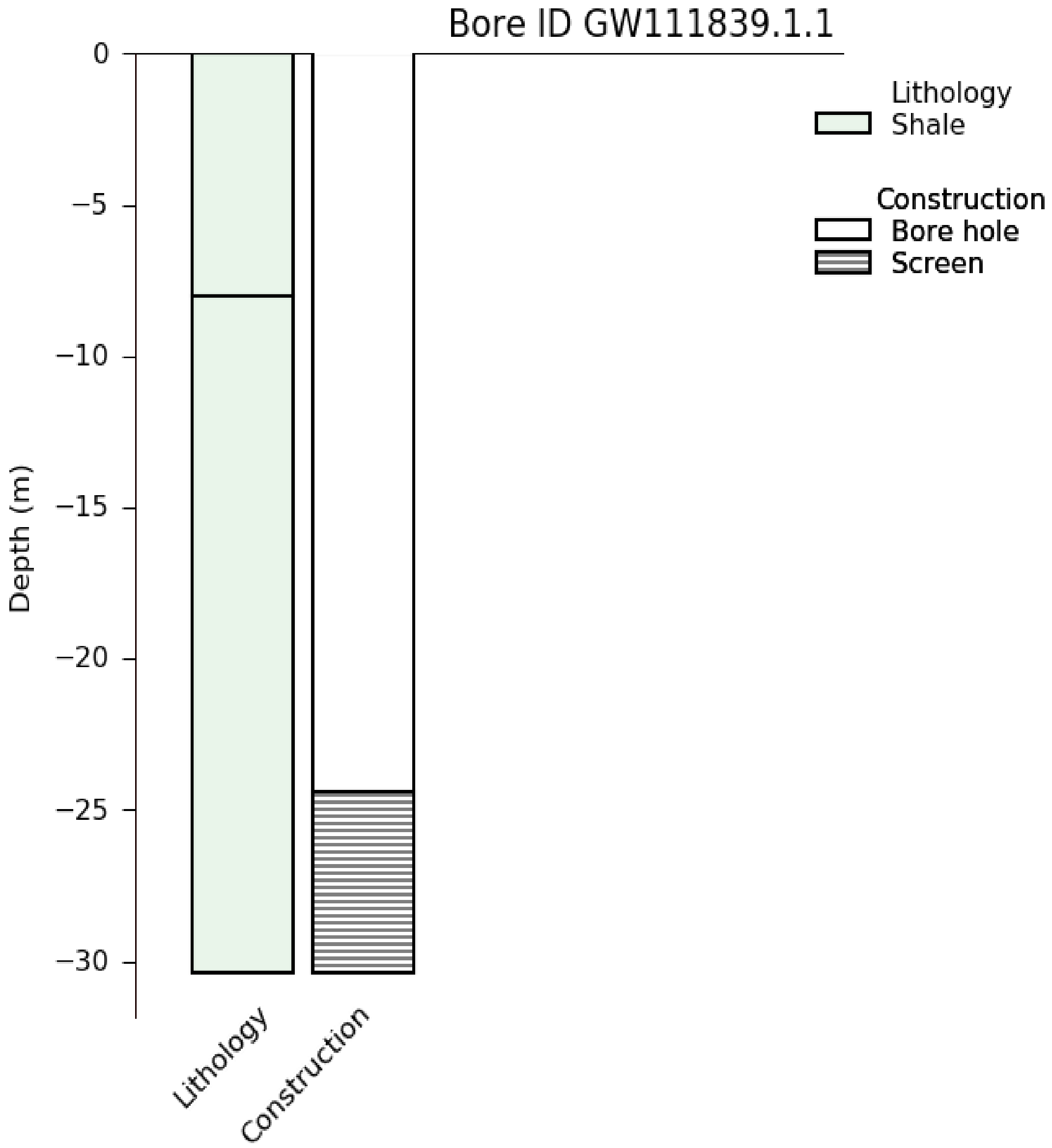

Bore ID GW075067.1.1
0
−2
−4
−6
−8
Depth (m)
Lithology
Construction
Lithology
Soil
Sandstone
Clay
Construction
Screen
Bore hole

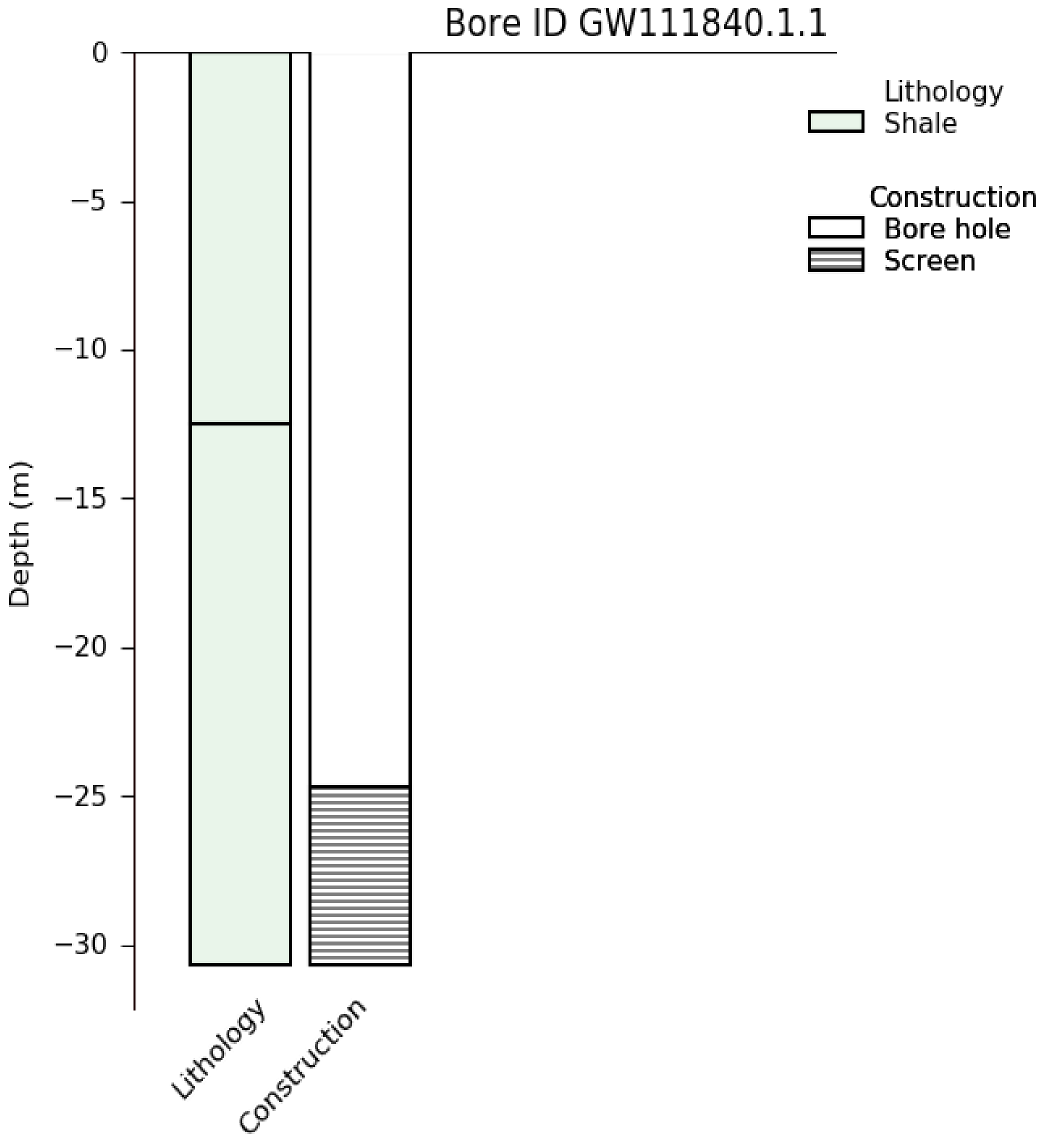

Bore ID GW104079.1.1
0
−5
−10
−15
−20
−25
−30
Depth (m)
Lithology
Construction
Lithology
Clay
Shale
Construction
Screen
Bore hole


Bore ID GW104081.1.1
0
−5
−10
−15
−20
−25
−30
Depth (m)
Lithology
Construction
Lithology
Clay
Shale
Construction
Screen
Bore hole


Bore ID GW104080.1.1
0
−5
−10
−15
−20
−25
−30
Depth (m)
Lithology
Construction
Lithology
Clay
Shale
Construction
Screen
Bore hole


Bore ID GW111838.1.1
Depth (m)
0
−5
−10
−15
−20
−25
−30
Lithology
Construction
Lithology
Shale
Construction
Bore hole
Screen


Bore ID GW111839.1.1
0
−5
−10
−15
−20
−25
−30
Depth (m)
Lithology
Construction
Lithology
Shale
Construction
Bore hole
Screen

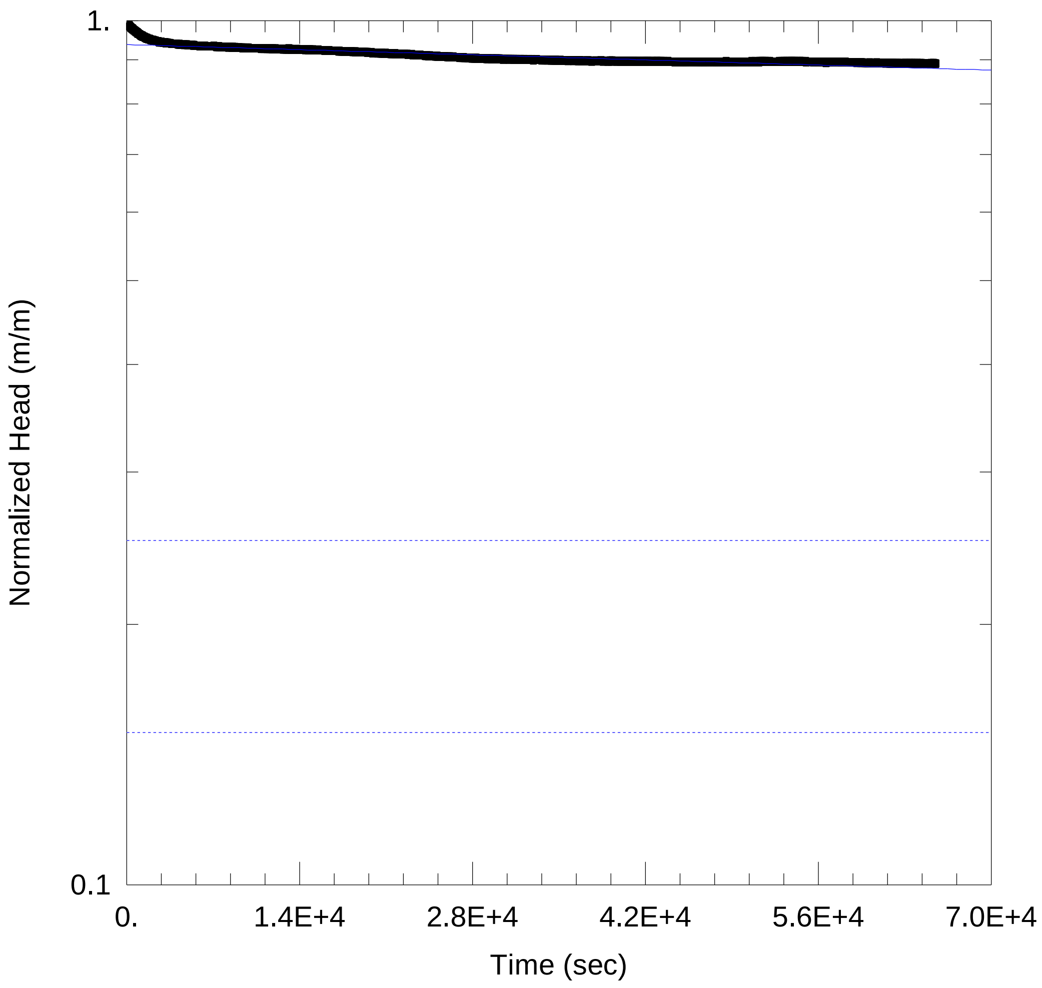


Note: lithology logs for the following bores were not available:

- GW112168.1.1
- GW112169.1.1
- GW112166.1.1
- GW112116.1.1
- GW112171.1.1
- GW112170.1.1
- GW112173.1.1
- GW112174.1.1
- GW112165.1.1
- GW112172.1.1
- GW112567.1.1
- GW114297.1.1
- GW114298.1.1
- GW114294.1.1
- GW114295.1.1
- GW106198.1.1

Annexure E

Slug test analysis sheets



WELL TEST ANALYSIS

Data Set: J:\...\BH145.aqt
Date: 08/31/18 Time: 13:20:10

PROJECT INFORMATION

Company: Jacobs
Client: RMS
Project: IA145100
Location: M12
Test Well: BH145
Test Date: 23-24/08/2018

AQUIFER DATA

Saturated Thickness: 2.97 m Anisotropy Ratio (Kz/Kr): 1.

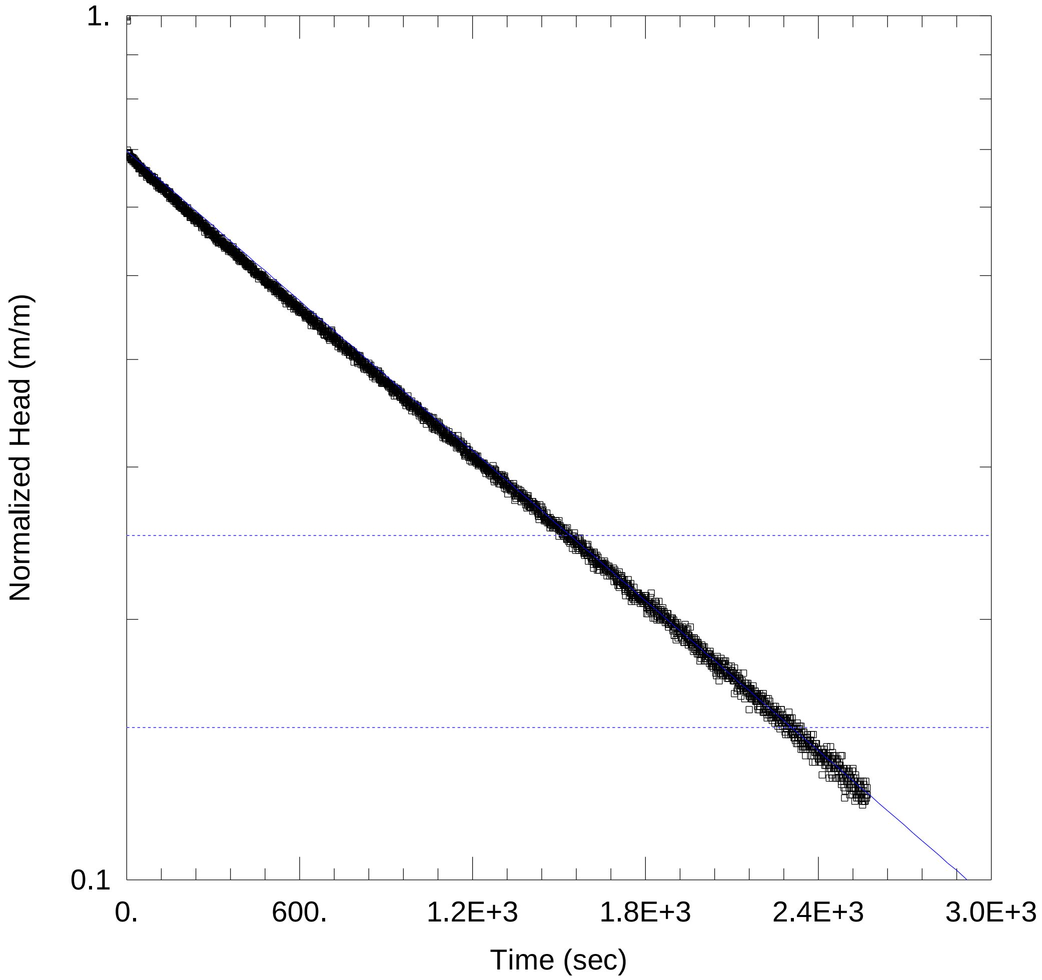
WELL DATA (BH145)

Initial Displacement: 2.582 m Static Water Column Height: 2.97 m
Total Well Penetration Depth: 2.97 m Screen Length: 2.97 m
Casing Radius: 0.025 m Well Radius: 0.025 m

SOLUTION

Aquifer Model: Confined Solution Method: Hvorslev

K = 4.682E-5 m/day y0 = 2.421 m



WELL TEST ANALYSIS

Data Set: J:\...\BH202.aqt
Date: 08/31/18 Time: 13:21:06

PROJECT INFORMATION

Company: Jacobs
Client: RMS
Project: IA145100
Location: M12
Test Well: BH202
Test Date: 24/08/2018

AQUIFER DATA

Saturated Thickness: 15.72 m
Anisotropy Ratio (Kz/Kr): 1.

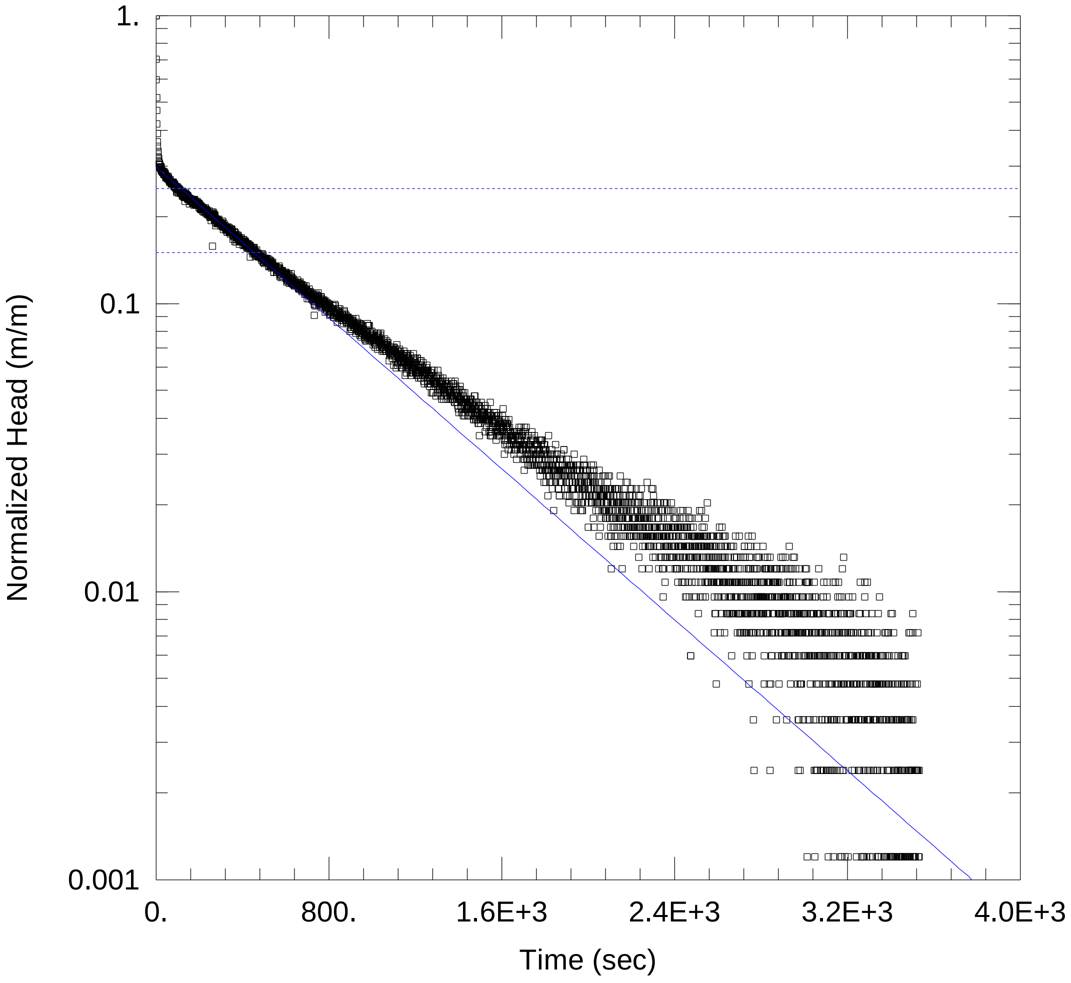
WELL DATA (BH202)

Initial Displacement: 0.877 m
Static Water Column Height: 15.72 m
Total Well Penetration Depth: 17.93 m
Screen Length: 12. m
Casing Radius: 0.025 m
Well Radius: 0.025 m

SOLUTION

Aquifer Model: Unconfined
Solution Method: Hvorslev

K = 0.01029 m/day
y0 = 0.6115 m



WELL TEST ANALYSIS

Data Set: J:\...\BH217.aqt

Date: 08/31/18 Time: 13:21:54

PROJECT INFORMATION

Company: Jacobs
Client: RMS
Project: IA145100
Location: M12
Test Well: BH217
Test Date: 23/08/2018

AQUIFER DATA

Saturated Thickness: 12.48 m Anisotropy Ratio (Kz/Kr): 1.

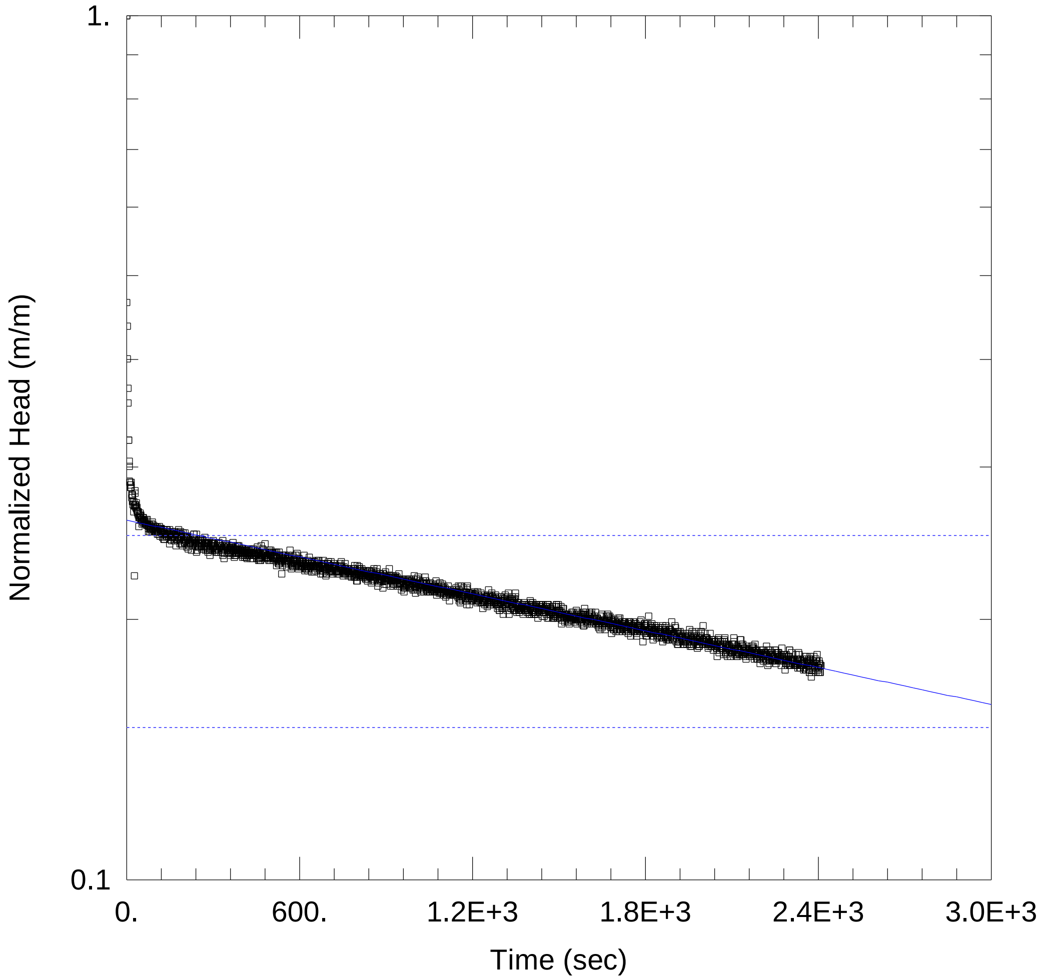
WELL DATA (BH217)

Initial Displacement: 0.836 m
Static Water Column Height: 12.48 m
Total Well Penetration Depth: 17.85 m
Screen Length: 12. m
Casing Radius: 0.025 m
Well Radius: 0.025 m

SOLUTION

Aquifer Model: Unconfined Solution Method: Hvorslev

K = 0.0233 m/day y0 = 0.2492 m



WELL TEST ANALYSIS

Data Set: J:\...\BH104.aqt
Date: 08/31/18 Time: 13:18:37

PROJECT INFORMATION

Company: Jacobs
Client: RMS
Project: IA145100
Location: M12
Test Well: BH104
Test Date: 24/08/2018

AQUIFER DATA

Saturated Thickness: 5.06 m
Anisotropy Ratio (Kz/Kr): 1.

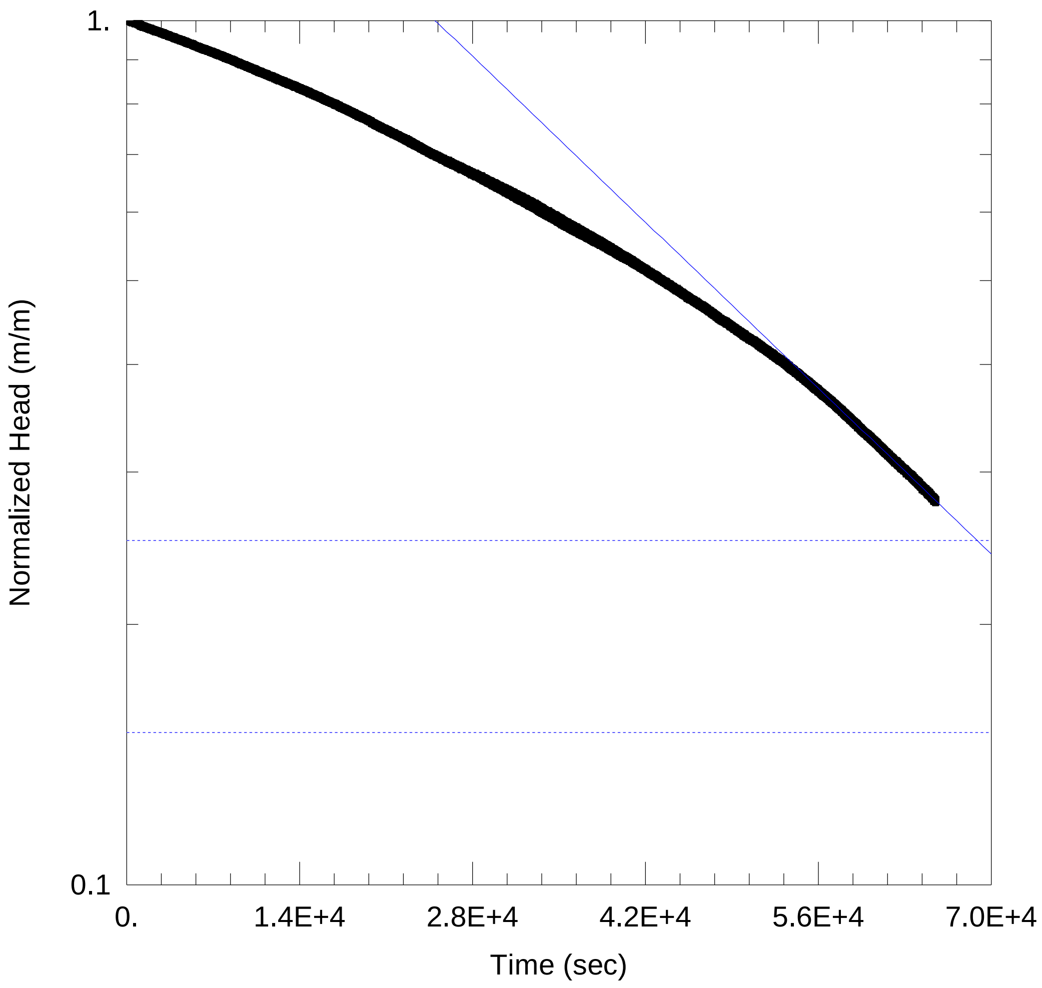
WELL DATA (BH104)

Initial Displacement: 0.961 m
Static Water Column Height: 5.06 m
Total Well Penetration Depth: 5.06 m
Screen Length: 5.06 m
Casing Radius: 0.025 m
Well Radius: 0.025 m

SOLUTION

Aquifer Model: Confined
Solution Method: Hvorslev

K = 0.004631 m/day
y0 = 0.2505 m



WELL TEST ANALYSIS

Data Set: J:\...\BH112.aqt
Date: 08/31/18 Time: 13:19:05

PROJECT INFORMATION

Company: Jacobs
Client: RMS
Project: IA145100
Location: M12
Test Well: BH112
Test Date: 23-24/08/2018

AQUIFER DATA

Saturated Thickness: 3.92 m
Anisotropy Ratio (Kz/Kr): 1.

WELL DATA (BH112)

Initial Displacement: 2.657 m
Static Water Column Height: 3.92 m
Total Well Penetration Depth: 3.92 m
Screen Length: 3.92 m
Casing Radius: 0.025 m
Well Radius: 0.025 m

SOLUTION

Aquifer Model: Confined
Solution Method: Hvorslev

K = 0.001152 m/day
y0 = 5.847 m

Annexure F

Water quality summary tables

			Metals									pH	Inorganics																							
			Arsenic (Filtered)	Cadmium (Filtered)	Chromium (III+VI) (Filtered)	Copper (Filtered)	Lead (Filtered)	Magnesium (Filtered)	Mercury (Filtered)	Nickel (Filtered)	Zinc (Filtered)	pH (lab)	Carbonate Alkalinity as CaCO3	Alkalinity (Hydroxide) as CaCO3	Alkalinity (total) as CaCO3	Ammonia as N	Anions Total	Bicarbonate	Calcium (Filtered)	Cations Total	Chloride	Electrical conductivity (lab)	Ionic Balance	Kjeldahl Nitrogen Total	Nitrate & Nitrite (as N)	Nitrate (as N)	Nitrite (as N)	Nitrogen (Total)	Phosphate total (P)	Phosphorus	Potassium (Filtered)	Reactive Phosphorus as P	Sodium (Filtered)	Sulfate as SO4 - Turbidimetric (Filtered)	Total Dissolved Solids	TSS
			µg/L	µg/L	µg/L	µg/L	µg/L	mg/L	µg/L	µg/L	µg/L	pH Units	mg/L	mg/L	mg/L	mg/L	meq/L	mg/L	mg/L	meq/L	mg/L	uS/cm	%	mg/L	mg/L	mg/L	µg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
EQL												0.01	1	1	1	0.01	0.01	1		0.01	1	1	0.01	0.1	0.01	0.01	10	0.1	0.05	0.01		0.01			10	5
ADWG 2015 Aesthetic						1000					3000										250												180		600	
ADWG 2015 Health			10	2		2000	10		1	20																11.29	910									
ANZECC 2000 FW 95%			24	0.2	1	1.4	3.4		0.6	11	8					0.9										0.1581										
ANZECC 2000 FW 99%				0.06	0.01	1	1		0.06	8	2.4					0.32										0.00384		0.35		0.01						
ANZECC (2000) trigger values for lowland rivers												6.5-8																0.5		0.05		0.02				
Field ID	Location	Sample Date																																		
BH104	BH104	23/08/2018	1	<0.1	<1	10	<1	570	<0.1	9	9	7.61	<1	<1	941	-	205	941	252	203	5920	20,200	0.51	-	-	-	-	-	-	-	29	-	3280	921	14,600	373
BH112	BH112	24/08/2018	3	<0.1	<1	3	<1	268	<0.1	11	15	7.62	<1	<1	1200	-	131	1200	138	125	3320	12,400	2.31	-	-	-	-	-	-	-	37	-	2180	624	7680	1730
BH145	BH145	24/08/2018	12	<0.1	<1	<1	<1	8	<0.1	33	<5	7.8	<1	<1	725	-	36.1	725	13	36.6	730	3750	0.58	-	-	-	-	-	-	-	6	-	807	51	2650	39,300
BH202	BH202	22/08/2018	2	<0.1	<1	12	2	843	<0.1	6	49	7.16	<1	<1	870	-	260	870	568	267	8590	26,400	1.41	-	-	-	-	-	-	-	42	-	3870	<1	19,500	9
BH207	BH207	24/08/2018	4	<0.1	<1	18	<1	-	<0.1	7	36	7.35	-	-	-	4.6	-	-	-	-	5580	-	-	4.9	<0.01	<0.01	<10	4.9	-	<0.02	-	<0.01	-	<1	-	-
BH209	BH209	23/08/2018	<1	<0.1	<1	5	<1	-	<0.1	4	18	7.59	-	-	-	1.26	-	-	-	-	6740	-	-	1.5	<0.01	<0.01	<10	1.5	-	<0.02	-	<0.01	-	366	-	-
BH217	BH217	24/08/2018	4	<0.1	<1	6	<1	517	<0.1	10	16	7.14	<1	<1	531	-	216	531	260	228	7070	22,500	2.78	-	-	-	-	-	-	-	20	-	3960	283	15,900	413
BH223	BH223	22/08/2018	2	<0.1	<1	1	<1	279	<0.1	4	14	7.55	<1	<1	371	-	142	371	225	142	4770	14,800	0.07	-	-	-	-	-	-	-	13	-	2470	9	9240	72
BH301	BH301	23/08/2018	1	<0.1	<1	10	1	-	<0.1	14	25	7.21	-	-	-	0.34	-	-	-	-	10,800	-	-	<0.5	<0.01	<0.01	<10	<0.5	-	<0.05	-	<0.01	-	973	-	-
BH302	BH302	23/08/2018	19	<0.1	<1	32	2	-	<0.1	8	57	-	-	-	-	1.12	-	-	-	-	-	-	-	1.2	<0.01	<0.01	<10	1.2	-	<0.02	-	<0.01	-	-	-	-
QAQC1	BH207	24/08/2018	4	<0.1	<1	<1	<1	-	<0.1	4	17	-	-	-	-	4.47	-	-	-	-	-	-	-	4.5	<0.01	<0.01	<10	4.5	-	<0.02	-	0.01	-	-	-	-
QAQC2	BH207	24/08/2018	3	<0.2	<1	<1	<1	-	<0.1	3	16	-	-	-	-	3.9	-	-	-	-	-	-	-	4.4	<0.05	<0.02	<20	4.4	0.06	-	-	-	-	-	-	-
Statistical Summary																																				
Maximum Concentration			19	<0.2	<1	32	2	843	<0.1	33	57	7.8	<1	<1	1200	4.6	260	1200	568	267	10800	26400	2.78	4.9	<0.05	<0.02	<20	4.9	0.06	<0.05	42	0.01	3960	973	19500	39300
Average Concentration			4.6	0.054	0.5	8.2	0.79	414	0.05	9.4	23	7.4	0.5	0.5	773	2.6	165	773	243	167	5947	16675	1.3	2.8	0.0083	0.0058	5.8	2.8		0.013	25	0.006	2761	359	11595	6983
Standard Deviation			5.4	0.014	0	9.3	0.58	291	0	8.1	16	0.24	0	0	297	1.9	79	297	185	83	2917	8121	1.1	2	0.0082	0.002	2	2		0.0067	14	0.0022	1198	394	6180	15844

Note: For toxicants, ANZECC 2000 Freshwater 95% values were incorporated into the groundwater quality criteria. 99% values are shown in this table for context.

			Turbidity	TRH - NEPM 2013 Fractions							TPH - NEPM 1999 Fractions					BTEXN								PAHs																
			Turbidity	TRH >C6 - C10	TRH >C10 - C16	TRH >C16 - C34	TRH >C34 - C40	TRH >C10 - C40 (Sum of total)	TRH >C6 - C10 less BTEX (F1)	TRH >C10 - C16 less Naphthalene (F2)	TPH C6 - C9	TPH C10 - C14	TPH C15 - C28	TPH C29-C36	TPH C10 - C36 (Sum of total)	Benzene	Ethylbenzene	Naphthalene	Toluene	Total BTEX	Xylene (m & p)	Xylene (o)	Xylene Total	Benzo[b+j]fluoranthene	Acenaphthene	Acenaphthylene	Anthracene	Benz(a)anthracene	Benzo(a) pyrene	Benzo(a)pyrene TEQ calc (zero)	Benzo(g,h,i)perylene	Benzo(k)fluoranthene	Chrysene	Dibenz(a,h)anthracene	Fluoranthene	Fluorene	Indeno(1,2,3-c,d)pyrene	Phenanthrene	Pyrene	PAHs (Sum of total)
			NTU	µg/L	µg/L	µg/L	µg/L	µg/L	mg/L	mg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	mg/L	µg/L	µg/L	µg/L	mg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L
EQL			0.1	20	100	100	100	100	0.02	0.1	20	50	100	50	50	1	2	1	2	0.001	2	2	2	0.001	1	1	1	1	0.5	0.5	1	1	1	1	1	1	1	1	1	0.5
ADWG 2015 Aesthetic			5														3		25				20																	
ADWG 2015 Health																1	300		800				600						0.01											0.01
ANZECC 2000 FW 95%																950		16				350																		
ANZECC 2000 FW 99%																600		2.5				200																		
ANZECC (2000) trigger values for lowland rivers																																								
Field ID	Location	Sample Date																																						
BH104	BH104	23/08/2018	306	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
BH112	BH112	24/08/2018	1650	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
BH145	BH145	24/08/2018	22,800	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
BH202	BH202	22/08/2018	12.5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
BH207	BH207	24/08/2018	-	<20	<100	<100	<100	<100	<0.02	<0.1	<20	<50	<100	<50	<50	<1	<2	<1	<2	<0.001	<2	<2	<2	<0.001	<1	<1	<1	<1	<0.5	<0.5	<1	<1	<1	<1	<1	<1	<1	<1	<1	<0.5
BH209	BH209	23/08/2018	-	<20	<100	<100	<100	<100	<0.02	<0.1	<20	<50	<100	<50	<50	<1	<2	<1	<2	<0.001	<2	<2	<2	<0.001	<1	<1	<1	<1	<0.5	<0.5	<1	<1	<1	<1	<1	<1	<1	<1	<1	<0.5
BH217	BH217	24/08/2018	224	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
BH223	BH223	22/08/2018	80.1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
BH301	BH301	23/08/2018	-	<20	<100	<100	<100	<100	<0.02	<0.1	<20	<50	<100	<50	<50	<1	<2	<1	<2	<0.001	<2	<2	<2	<0.001	<1	<1	<1	<1	<0.5	<0.5	<1	<1	<1	<1	<1	<1	<1	<1	<1	<0.5
BH302	BH302	23/08/2018	-	<20	<100	<100	<100	<100	<0.02	<0.1	<20	<50	<100	<50	<50	<1	<2	<1	<2	<0.001	<2	<2	<2	<0.001	<1	<1	<1	<1	<0.5	<0.5	<1	<1	<1	<1	<1	<1	<1	<1	<1	<0.5
QAQC1	BH207	24/08/2018	-	<20	<100	<100	<100	<100	<0.02	<0.1	<20	<50	<100	<50	<50	<1	<2	<1	<2	<0.001	<2	<2	<2	<0.001	<1	<1	<1	<1	<0.5	<0.5	<1	<1	<1	<1	<1	<1	<1	<1	<1	<0.5
QAQC2	BH207	24/08/2018	-	<20	<50	<100	<100	<100	<0.02	<0.05	<20	<50	<100	<100	<100	<1	<1	<1	2	-	<2	<1	<3	<0.001	<1	<1	<1	<1	<1	-	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Statistical Summary																																								
Maximum Concentration			22800	<20	<100	<100	<100	<100	<0.02	<0.1	<20	<50	<100	<100	<100	<1	<2	<1	2	<0.001	<2	<2	<3	<0.001	<1	<1	<1	<1	<1	<0.5	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Average Concentration			4179	10	46	50	50	50	0.01	0.046	10	25	50	29	29	0.5	0.92	0.5	1.2	0.0005	1	0.92	1.1	0.0005	0.5	0.5	0.5	0.5	0.29	0.25	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.29
Standard Deviation			9143	0	10	0	0	0	0	0.01	0	0	0	10	10	0	0.2	0	0.41	0	0	0.2	0.2	0	0	0	0	0	0.1	0	0	0	0	0	0	0	0	0	0	0.1

Note: For toxicants, ANZECC 2000 Freshwater 95% values were incorporated into the groundwater quality criteria. 99% values are shown in this table for context.

Annexure G

Groundwater quality testing laboratory certificate

ALS Environmental

CERTIFICATE OF ANALYSIS

Work Order	: **ES1825044**	Page	: 1 of 14
Client	: **JACOBS GROUP (AUSTRALIA) PTY LTD**	Laboratory	: Environmental Division Sydney
Contact	: SATH DAVE	Contact	: Brenda Hong
Address	: 100 CHRISTIE STREET P O BOX 164 ST LEONARDS NSW, AUSTRALIA 2065	Address	:
Telephone	: ----	Telephone	:
Project	: IA145100 M12 Groundwater	Date Samples Received	: 24-Aug-2018 14:45
Order number	: IA145100	Date Analysis Commenced	: 24-Aug-2018
C-O-C number	: ----	Issue Date	: 30-Aug-2018 18:32
Sampler	: SATH DAVE		
Site	: ----		
Quote number	: SY/426/18		
No. of samples received	: 14		
No. of samples analysed	: 13		

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

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

This Certificate of Analysis contains the following information:

- General Comments
- Analytical Results
- Surrogate Control Limits

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

Signatories

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

Signatories	*Position*	*Accreditation Category*
Ankit Joshi	Inorganic Chemist	Sydney Inorganics, Smithfield, NSW
Celine Conceicao	Senior Spectroscopist	Sydney Inorganics, Smithfield, NSW
Edwandy Fadjar	Organic Coordinator	Sydney Organics, Smithfield, NSW
Ivan Taylor	Analyst	Sydney Inorganics, Smithfield, NSW

General Comments

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

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

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

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

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

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

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

- EK061G/EK067G/EK062G: : LOR raised for TKN & TN on various samples due to sample matrix.
- EP080: Sample TRIP SPIKE contains volatile compounds spiked into the sample containers prior to dispatch from the laboratory. BTEX compounds spiked at 20 ug/L.
- Benzo(a)pyrene Toxicity Equivalent Quotient (TEQ) is the sum total of the concentration of the eight carcinogenic PAHs multiplied by their Toxicity Equivalence Factor (TEF) relative to Benzo(a)pyrene. TEF values are provided in brackets as follows: Benz(a)anthracene (0.1), Chrysene (0.01), Benzo(b+j) & Benzo(k)fluoranthene (0.1), Benzo(a)pyrene (1.0), Indeno(1.2.3.cd)pyrene (0.1), Dibenz(a.h)anthracene (1.0), Benzo(g.h.i)perylene (0.01). Less than LOR results for 'TEQ Zero' are treated as zero.
- Sodium Adsorption Ratio (where reported): Where results for Na, Ca or Mg are <LOR, a concentration at half the reported LOR is incorporated into the SAR calculation. This represents a conservative approach for Na relative to the assumption that <LOR = zero concentration and a conservative approach for Ca & Mg relative to the assumption that <LOR is equivalent to the LOR concentration.

Analytical Results

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

			Client sample ID	**BH104**	**BH112**	**BH209**	**BH207**	**BH217**
			Client sampling date / time	23-Aug-2018 00:00	24-Aug-2018 00:00	23-Aug-2018 00:00	24-Aug-2018 00:00	24-Aug-2018 00:00
Compound	*CAS Number*	*LOR*	*Unit*	**ES1825044-001**	**ES1825044-002**	**ES1825044-003**	**ES1825044-004**	**ES1825044-005**
				Result	Result	Result	Result	Result
EA005P: pH by PC Titrator								
pH Value	----	0.01	pH Unit	**7.61**	**7.62**	**7.59**	**7.35**	**7.14**
EA010P: Conductivity by PC Titrator								
Electrical Conductivity @ 25°C	----	1	µS/cm	**20200**	**12400**	----	----	**22500**
EA015: Total Dissolved Solids dried at 180 ± 5 °C								
Total Dissolved Solids @180°C	----	10	mg/L	**14600**	**7680**	----	----	**15900**
EA025: Total Suspended Solids dried at 104 ± 2°C								
Suspended Solids (SS)	----	5	mg/L	**373**	**1730**	----	----	**413**
EA045: Turbidity								
Turbidity	----	0.1	NTU	**306**	**1650**	----	----	**224**
ED037P: Alkalinity by PC Titrator								
Hydroxide Alkalinity as CaCO3	DMO-210-001	1	mg/L	<1	<1	----	----	<1
Carbonate Alkalinity as CaCO3	3812-32-6	1	mg/L	<1	<1	----	----	<1
Bicarbonate Alkalinity as CaCO3	71-52-3	1	mg/L	**941**	**1200**	----	----	**531**
Total Alkalinity as CaCO3	----	1	mg/L	**941**	**1200**	----	----	**531**
ED041G: Sulfate (Turbidimetric) as SO4 2- by DA								
Sulfate as SO4 - Turbidimetric	14808-79-8	1	mg/L	**921**	**624**	**366**	<1	**283**
ED045G: Chloride by Discrete Analyser								
Chloride	16887-00-6	1	mg/L	**5920**	**3320**	**6740**	**5580**	**7070**
ED093F: Dissolved Major Cations								
Calcium	7440-70-2	1	mg/L	**252**	**138**	----	----	**260**
Magnesium	7439-95-4	1	mg/L	**570**	**268**	----	----	**517**
Sodium	7440-23-5	1	mg/L	**3280**	**2180**	----	----	**3960**
Potassium	7440-09-7	1	mg/L	**29**	**37**	----	----	**20**
EG020F: Dissolved Metals by ICP-MS								
Arsenic	7440-38-2	0.001	mg/L	**0.001**	**0.003**	<0.001	**0.004**	**0.004**
Cadmium	7440-43-9	0.0001	mg/L	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Chromium	7440-47-3	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001
Copper	7440-50-8	0.001	mg/L	**0.010**	**0.003**	**0.005**	**0.018**	**0.006**
Nickel	7440-02-0	0.001	mg/L	**0.009**	**0.011**	**0.004**	**0.007**	**0.010**
Lead	7439-92-1	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001
Zinc	7440-66-6	0.005	mg/L	**0.009**	**0.015**	**0.018**	**0.036**	**0.016**
EG035F: Dissolved Mercury by FIMS								
Mercury	7439-97-6	0.0001	mg/L	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001

Analytical Results

Sub-Matrix: **WATER** (Matrix: **WATER**)			*Client sample ID*	**BH104**	**BH112**	**BH209**	**BH207**	**BH217**
			Client sampling date / time	23-Aug-2018 00:00	24-Aug-2018 00:00	23-Aug-2018 00:00	24-Aug-2018 00:00	24-Aug-2018 00:00
Compound	*CAS Number*	*LOR*	*Unit*	**ES1825044-001**	**ES1825044-002**	**ES1825044-003**	**ES1825044-004**	**ES1825044-005**
				Result	Result	Result	Result	Result
EK055G: Ammonia as N by Discrete Analyser								
Ammonia as N	7664-41-7	0.01	mg/L	----	----	**1.26**	**4.60**	----
EK057G: Nitrite as N by Discrete Analyser								
Nitrite as N	14797-65-0	0.01	mg/L	----	----	<0.01	<0.01	----
EK058G: Nitrate as N by Discrete Analyser								
Nitrate as N	14797-55-8	0.01	mg/L	----	----	<0.01	<0.01	----
EK059G: Nitrite plus Nitrate as N (NOx) by Discrete Analyser								
Nitrite + Nitrate as N	----	0.01	mg/L	----	----	<0.01	<0.01	----
EK061G: Total Kjeldahl Nitrogen By Discrete Analyser								
Total Kjeldahl Nitrogen as N	----	0.1	mg/L	----	----	**1.5**	**4.9**	----
EK062G: Total Nitrogen as N (TKN + NOx) by Discrete Analyser								
^ **Total Nitrogen as N**	----	0.1	mg/L	----	----	**1.5**	**4.9**	----
EK067G: Total Phosphorus as P by Discrete Analyser								
Total Phosphorus as P	----	0.01	mg/L	----	----	<0.02	<0.02	----
EK071G: Reactive Phosphorus as P by discrete analyser								
Reactive Phosphorus as P	14265-44-2	0.01	mg/L	----	----	<0.01	<0.01	----
EN055: Ionic Balance								
Total Anions	----	0.01	meq/L	**205**	**131**	----	----	**216**
Total Cations	----	0.01	meq/L	**203**	**125**	----	----	**228**
Ionic Balance	----	0.01	%	**0.51**	**2.31**	----	----	**2.78**
EP075(SIM)B: Polynuclear Aromatic Hydrocarbons								
Naphthalene	91-20-3	1.0	µg/L	----	----	<1.0	<1.0	----
Acenaphthylene	208-96-8	1.0	µg/L	----	----	<1.0	<1.0	----
Acenaphthene	83-32-9	1.0	µg/L	----	----	<1.0	<1.0	----
Fluorene	86-73-7	1.0	µg/L	----	----	<1.0	<1.0	----
Phenanthrene	85-01-8	1.0	µg/L	----	----	<1.0	<1.0	----
Anthracene	120-12-7	1.0	µg/L	----	----	<1.0	<1.0	----
Fluoranthene	206-44-0	1.0	µg/L	----	----	<1.0	<1.0	----
Pyrene	129-00-0	1.0	µg/L	----	----	<1.0	<1.0	----
Benz(a)anthracene	56-55-3	1.0	µg/L	----	----	<1.0	<1.0	----
Chrysene	218-01-9	1.0	µg/L	----	----	<1.0	<1.0	----
Benzo(b+j)fluoranthene	205-99-2 205-82-3	1.0	µg/L	----	----	<1.0	<1.0	----
Benzo(k)fluoranthene	207-08-9	1.0	µg/L	----	----	<1.0	<1.0	----
Benzo(a)pyrene	50-32-8	0.5	µg/L	----	----	<0.5	<0.5	----
Indeno(1.2.3.cd)pyrene	193-39-5	1.0	µg/L	----	----	<1.0	<1.0	----

Analytical Results

Sub-Matrix: **WATER** (Matrix: **WATER**)			Client sample ID	**BH104**	**BH112**	**BH209**	**BH207**	**BH217**
			Client sampling date / time	23-Aug-2018 00:00	24-Aug-2018 00:00	23-Aug-2018 00:00	24-Aug-2018 00:00	24-Aug-2018 00:00
Compound	CAS Number	LOR	Unit	**ES1825044-001**	**ES1825044-002**	**ES1825044-003**	**ES1825044-004**	**ES1825044-005**
				Result	Result	Result	Result	Result
EP075(SIM)B: Polynuclear Aromatic Hydrocarbons - Continued								
Dibenz(a.h)anthracene	53-70-3	1.0	µg/L	----	----	<1.0	<1.0	----
Benzo(g.h.i)perylene	191-24-2	1.0	µg/L	----	----	<1.0	<1.0	----
^ **Sum of polycyclic aromatic hydrocarbons**	----	0.5	µg/L	----	----	<0.5	<0.5	----
^ **Benzo(a)pyrene TEQ (zero)**	----	0.5	µg/L	----	----	<0.5	<0.5	----
EP080/071: Total Petroleum Hydrocarbons								
C6 - C9 Fraction	----	20	µg/L	----	----	<20	<20	----
C10 - C14 Fraction	----	50	µg/L	----	----	<50	<50	----
C15 - C28 Fraction	----	100	µg/L	----	----	<100	<100	----
C29 - C36 Fraction	----	50	µg/L	----	----	<50	<50	----
^ **C10 - C36 Fraction (sum)**	----	50	µg/L	----	----	<50	<50	----
EP080/071: Total Recoverable Hydrocarbons - NEPM 2013 Fractions								
C6 - C10 Fraction	C6_C10	20	µg/L	----	----	<20	<20	----
^ **C6 - C10 Fraction minus BTEX (F1)**	C6_C10-BTEX	20	µg/L	----	----	<20	<20	----
>C10 - C16 Fraction	----	100	µg/L	----	----	<100	<100	----
>C16 - C34 Fraction	----	100	µg/L	----	----	<100	<100	----
>C34 - C40 Fraction	----	100	µg/L	----	----	<100	<100	----
^ **>C10 - C40 Fraction (sum)**	----	100	µg/L	----	----	<100	<100	----
^ **>C10 - C16 Fraction minus Naphthalene (F2)**	----	100	µg/L	----	----	<100	<100	----
EP080: BTEXN								
Benzene	71-43-2	1	µg/L	----	----	<1	<1	----
Toluene	108-88-3	2	µg/L	----	----	<2	<2	----
Ethylbenzene	100-41-4	2	µg/L	----	----	<2	<2	----
meta- & para-Xylene	108-38-3 106-42-3	2	µg/L	----	----	<2	<2	----
ortho-Xylene	95-47-6	2	µg/L	----	----	<2	<2	----
^ **Total Xylenes**	----	2	µg/L	----	----	<2	<2	----
^ **Sum of BTEX**	----	1	µg/L	----	----	<1	<1	----
Naphthalene	91-20-3	5	µg/L	----	----	<5	<5	----
EP075(SIM)S: Phenolic Compound Surrogates								
Phenol-d6	13127-88-3	1.0	%	----	----	**18.5**	**18.7**	----
2-Chlorophenol-D4	93951-73-6	1.0	%	----	----	**40.8**	**43.6**	----
2.4.6-Tribromophenol	118-79-6	1.0	%	----	----	**69.3**	**73.7**	----
EP075(SIM)T: PAH Surrogates								

Analytical Results

Sub-Matrix: **WATER** (Matrix: **WATER**)			Client sample ID	**BH104**	**BH112**	**BH209**	**BH207**	**BH217**
			Client sampling date / time	23-Aug-2018 00:00	24-Aug-2018 00:00	23-Aug-2018 00:00	24-Aug-2018 00:00	24-Aug-2018 00:00
Compound	*CAS Number*	*LOR*	*Unit*	**ES1825044-001**	**ES1825044-002**	**ES1825044-003**	**ES1825044-004**	**ES1825044-005**
				Result	Result	Result	Result	Result
EP075(SIM)T: PAH Surrogates - Continued								
2-Fluorobiphenyl	321-60-8	1.0	%	----	----	**66.3**	**81.9**	----
Anthracene-d10	1719-06-8	1.0	%	----	----	**77.3**	**84.7**	----
4-Terphenyl-d14	1718-51-0	1.0	%	----	----	**77.0**	**80.4**	----
EP080S: TPH(V)/BTEX Surrogates								
1.2-Dichloroethane-D4	17060-07-0	2	%	----	----	**93.5**	**89.9**	----
Toluene-D8	2037-26-5	2	%	----	----	**104**	**97.6**	----
4-Bromofluorobenzene	460-00-4	2	%	----	----	**108**	**103**	----

Analytical Results

Sub-Matrix: **WATER** (Matrix: **WATER**)			Client sample ID	**BH301**	**BH302**	**BH223**	**BH145**	**BH202**
			Client sampling date / time	23-Aug-2018 00:00	23-Aug-2018 00:00	22-Aug-2018 00:00	24-Aug-2018 00:00	22-Aug-2018 00:00
Compound	CAS Number	LOR	Unit	**ES1825044-006**	**ES1825044-007**	**ES1825044-008**	**ES1825044-009**	**ES1825044-010**
				Result	Result	Result	Result	Result
EA005P: pH by PC Titrator								
pH Value	----	0.01	pH Unit	**7.21**	----	**7.55**	**7.80**	**7.16**
EA010P: Conductivity by PC Titrator								
Electrical Conductivity @ 25°C	----	1	µS/cm	----	----	**14800**	**3750**	**26400**
EA015: Total Dissolved Solids dried at 180 ± 5 °C								
Total Dissolved Solids @180°C	----	10	mg/L	----	----	**9240**	**2650**	**19500**
EA025: Total Suspended Solids dried at 104 ± 2°C								
Suspended Solids (SS)	----	5	mg/L	----	----	**72**	**39300**	**9**
EA045: Turbidity								
Turbidity	----	0.1	NTU	----	----	**80.1**	**22800**	**12.5**
ED037P: Alkalinity by PC Titrator								
Hydroxide Alkalinity as CaCO3	DMO-210-001	1	mg/L	----	----	<1	<1	<1
Carbonate Alkalinity as CaCO3	3812-32-6	1	mg/L	----	----	<1	<1	<1
Bicarbonate Alkalinity as CaCO3	71-52-3	1	mg/L	----	----	**371**	**725**	**870**
Total Alkalinity as CaCO3	----	1	mg/L	----	----	**371**	**725**	**870**
ED041G: Sulfate (Turbidimetric) as SO4 2- by DA								
Sulfate as SO4 - Turbidimetric	14808-79-8	1	mg/L	**973**	----	**9**	**51**	<1
ED045G: Chloride by Discrete Analyser								
Chloride	16887-00-6	1	mg/L	**10800**	----	**4770**	**730**	**8590**
ED093F: Dissolved Major Cations								
Calcium	7440-70-2	1	mg/L	----	----	**225**	**13**	**568**
Magnesium	7439-95-4	1	mg/L	----	----	**279**	**8**	**843**
Sodium	7440-23-5	1	mg/L	----	----	**2470**	**807**	**3870**
Potassium	7440-09-7	1	mg/L	----	----	**13**	**6**	**42**
EG020F: Dissolved Metals by ICP-MS								
Arsenic	7440-38-2	0.001	mg/L	**0.001**	**0.019**	**0.002**	**0.012**	**0.002**
Cadmium	7440-43-9	0.0001	mg/L	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Chromium	7440-47-3	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001
Copper	7440-50-8	0.001	mg/L	**0.010**	**0.032**	**0.001**	<0.001	**0.012**
Nickel	7440-02-0	0.001	mg/L	**0.014**	**0.008**	**0.004**	**0.033**	**0.006**
Lead	7439-92-1	0.001	mg/L	**0.001**	**0.002**	<0.001	<0.001	**0.002**
Zinc	7440-66-6	0.005	mg/L	**0.025**	**0.057**	**0.014**	<0.005	**0.049**
EG035F: Dissolved Mercury by FIMS								
Mercury	7439-97-6	0.0001	mg/L	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001

Analytical Results

Sub-Matrix: **WATER** (Matrix: **WATER**)			Client sample ID	**BH301**	**BH302**	**BH223**	**BH145**	**BH202**
			Client sampling date / time	23-Aug-2018 00:00	23-Aug-2018 00:00	22-Aug-2018 00:00	24-Aug-2018 00:00	22-Aug-2018 00:00
Compound	*CAS Number*	*LOR*	*Unit*	**ES1825044-006**	**ES1825044-007**	**ES1825044-008**	**ES1825044-009**	**ES1825044-010**
				Result	Result	Result	Result	Result
EK055G: Ammonia as N by Discrete Analyser								
Ammonia as N	7664-41-7	0.01	mg/L	**0.34**	**1.12**	----	----	----
EK057G: Nitrite as N by Discrete Analyser								
Nitrite as N	14797-65-0	0.01	mg/L	<0.01	<0.01	----	----	----
EK058G: Nitrate as N by Discrete Analyser								
Nitrate as N	14797-55-8	0.01	mg/L	<0.01	<0.01	----	----	----
EK059G: Nitrite plus Nitrate as N (NOx) by Discrete Analyser								
Nitrite + Nitrate as N	----	0.01	mg/L	<0.01	<0.01	----	----	----
EK061G: Total Kjeldahl Nitrogen By Discrete Analyser								
Total Kjeldahl Nitrogen as N	----	0.1	mg/L	<0.5	**1.2**	----	----	----
EK062G: Total Nitrogen as N (TKN + NOx) by Discrete Analyser								
^ **Total Nitrogen as N**	----	0.1	mg/L	<0.5	**1.2**	----	----	----
EK067G: Total Phosphorus as P by Discrete Analyser								
Total Phosphorus as P	----	0.01	mg/L	<0.05	<0.02	----	----	----
EK071G: Reactive Phosphorus as P by discrete analyser								
Reactive Phosphorus as P	14265-44-2	0.01	mg/L	<0.01	<0.01	----	----	----
EN055: Ionic Balance								
Total Anions	----	0.01	meq/L	----	----	**142**	**36.1**	**260**
Total Cations	----	0.01	meq/L	----	----	**142**	**36.6**	**267**
Ionic Balance	----	0.01	%	----	----	**0.07**	**0.58**	**1.41**
EP075(SIM)B: Polynuclear Aromatic Hydrocarbons								
Naphthalene	91-20-3	1.0	µg/L	<1.0	<1.0	----	----	----
Acenaphthylene	208-96-8	1.0	µg/L	<1.0	<1.0	----	----	----
Acenaphthene	83-32-9	1.0	µg/L	<1.0	<1.0	----	----	----
Fluorene	86-73-7	1.0	µg/L	<1.0	<1.0	----	----	----
Phenanthrene	85-01-8	1.0	µg/L	<1.0	<1.0	----	----	----
Anthracene	120-12-7	1.0	µg/L	<1.0	<1.0	----	----	----
Fluoranthene	206-44-0	1.0	µg/L	<1.0	<1.0	----	----	----
Pyrene	129-00-0	1.0	µg/L	<1.0	<1.0	----	----	----
Benz(a)anthracene	56-55-3	1.0	µg/L	<1.0	<1.0	----	----	----
Chrysene	218-01-9	1.0	µg/L	<1.0	<1.0	----	----	----
Benzo(b+j)fluoranthene	205-99-2 205-82-3	1.0	µg/L	<1.0	<1.0	----	----	----
Benzo(k)fluoranthene	207-08-9	1.0	µg/L	<1.0	<1.0	----	----	----
Benzo(a)pyrene	50-32-8	0.5	µg/L	<0.5	<0.5	----	----	----
Indeno(1.2.3.cd)pyrene	193-39-5	1.0	µg/L	<1.0	<1.0	----	----	----

Analytical Results

Sub-Matrix: **WATER** (Matrix: **WATER**)			*Client sample ID*	**BH301**	**BH302**	**BH223**	**BH145**	**BH202**
			Client sampling date / time	23-Aug-2018 00:00	23-Aug-2018 00:00	22-Aug-2018 00:00	24-Aug-2018 00:00	22-Aug-2018 00:00
Compound	*CAS Number*	*LOR*	*Unit*	**ES1825044-006**	**ES1825044-007**	**ES1825044-008**	**ES1825044-009**	**ES1825044-010**
				Result	Result	Result	Result	Result
EP075(SIM)B: Polynuclear Aromatic Hydrocarbons - Continued								
Dibenz(a.h)anthracene	53-70-3	1.0	µg/L	<1.0	<1.0	----	----	----
Benzo(g.h.i)perylene	191-24-2	1.0	µg/L	<1.0	<1.0	----	----	----
^ **Sum of polycyclic aromatic hydrocarbons**	----	0.5	µg/L	<0.5	<0.5	----	----	----
^ **Benzo(a)pyrene TEQ (zero)**	----	0.5	µg/L	<0.5	<0.5	----	----	----
EP080/071: Total Petroleum Hydrocarbons								
C6 - C9 Fraction	----	20	µg/L	<20	<20	----	----	----
C10 - C14 Fraction	----	50	µg/L	<50	<50	----	----	----
C15 - C28 Fraction	----	100	µg/L	<100	<100	----	----	----
C29 - C36 Fraction	----	50	µg/L	<50	<50	----	----	----
^ **C10 - C36 Fraction (sum)**	----	50	µg/L	<50	<50	----	----	----
EP080/071: Total Recoverable Hydrocarbons - NEPM 2013 Fractions								
C6 - C10 Fraction	C6_C10	20	µg/L	<20	<20	----	----	----
^ **C6 - C10 Fraction minus BTEX (F1)**	C6_C10-BTEX	20	µg/L	<20	<20	----	----	----
>C10 - C16 Fraction	----	100	µg/L	<100	<100	----	----	----
>C16 - C34 Fraction	----	100	µg/L	<100	<100	----	----	----
>C34 - C40 Fraction	----	100	µg/L	<100	<100	----	----	----
^ **>C10 - C40 Fraction (sum)**	----	100	µg/L	<100	<100	----	----	----
^ **>C10 - C16 Fraction minus Naphthalene (F2)**	----	100	µg/L	<100	<100	----	----	----
EP080: BTEXN								
Benzene	71-43-2	1	µg/L	<1	<1	----	----	----
Toluene	108-88-3	2	µg/L	<2	<2	----	----	----
Ethylbenzene	100-41-4	2	µg/L	<2	<2	----	----	----
meta- & para-Xylene	108-38-3 106-42-3	2	µg/L	<2	<2	----	----	----
ortho-Xylene	95-47-6	2	µg/L	<2	<2	----	----	----
^ **Total Xylenes**	----	2	µg/L	<2	<2	----	----	----
^ **Sum of BTEX**	----	1	µg/L	<1	<1	----	----	----
Naphthalene	91-20-3	5	µg/L	<5	<5	----	----	----
EP075(SIM)S: Phenolic Compound Surrogates								
Phenol-d6	13127-88-3	1.0	%	**18.9**	**17.0**	----	----	----
2-Chlorophenol-D4	93951-73-6	1.0	%	**45.8**	**51.3**	----	----	----
2.4.6-Tribromophenol	118-79-6	1.0	%	**78.4**	**68.5**	----	----	----
EP075(SIM)T: PAH Surrogates								

Analytical Results

Sub-Matrix: **WATER** (Matrix: **WATER**)			Client sample ID	**BH301**	**BH302**	**BH223**	**BH145**	**BH202**
			Client sampling date / time	23-Aug-2018 00:00	23-Aug-2018 00:00	22-Aug-2018 00:00	24-Aug-2018 00:00	22-Aug-2018 00:00
Compound	CAS Number	LOR	Unit	**ES1825044-006**	**ES1825044-007**	**ES1825044-008**	**ES1825044-009**	**ES1825044-010**
				Result	Result	Result	Result	Result
EP075(SIM)T: PAH Surrogates - Continued								
2-Fluorobiphenyl	321-60-8	1.0	%	**75.9**	**77.0**	----	----	----
Anthracene-d10	1719-06-8	1.0	%	**90.7**	**87.0**	----	----	----
4-Terphenyl-d14	1718-51-0	1.0	%	**83.9**	**78.8**	----	----	----
EP080S: TPH(V)/BTEX Surrogates								
1.2-Dichloroethane-D4	17060-07-0	2	%	**102**	**98.6**	----	----	----
Toluene-D8	2037-26-5	2	%	**106**	**110**	----	----	----
4-Bromofluorobenzene	460-00-4	2	%	**110**	**113**	----	----	----

Analytical Results

Sub-Matrix: **WATER** (Matrix: **WATER**)			*Client sample ID*	**QAQC1**	**TB**	**TS**	**----**	**----**
			Client sampling date / time	24-Aug-2018 00:00	17-Aug-2018 00:00	13-Aug-2018 00:00	----	----
Compound	*CAS Number*	*LOR*	*Unit*	**ES1825044-011**	**ES1825044-013**	**ES1825044-014**	**--------**	**--------**
				Result	Result	Result	----	----
EG020F: Dissolved Metals by ICP-MS								
Arsenic	7440-38-2	0.001	mg/L	**0.004**	----	----	----	----
Cadmium	7440-43-9	0.0001	mg/L	<0.0001	----	----	----	----
Chromium	7440-47-3	0.001	mg/L	<0.001	----	----	----	----
Copper	7440-50-8	0.001	mg/L	<0.001	----	----	----	----
Nickel	7440-02-0	0.001	mg/L	**0.004**	----	----	----	----
Lead	7439-92-1	0.001	mg/L	<0.001	----	----	----	----
Zinc	7440-66-6	0.005	mg/L	**0.017**	----	----	----	----
EG035F: Dissolved Mercury by FIMS								
Mercury	7439-97-6	0.0001	mg/L	<0.0001	----	----	----	----
EK055G: Ammonia as N by Discrete Analyser								
Ammonia as N	7664-41-7	0.01	mg/L	**4.47**	----	----	----	----
EK057G: Nitrite as N by Discrete Analyser								
Nitrite as N	14797-65-0	0.01	mg/L	<0.01	----	----	----	----
EK058G: Nitrate as N by Discrete Analyser								
Nitrate as N	14797-55-8	0.01	mg/L	<0.01	----	----	----	----
EK059G: Nitrite plus Nitrate as N (NOx) by Discrete Analyser								
Nitrite + Nitrate as N	----	0.01	mg/L	<0.01	----	----	----	----
EK061G: Total Kjeldahl Nitrogen By Discrete Analyser								
Total Kjeldahl Nitrogen as N	----	0.1	mg/L	**4.5**	----	----	----	----
EK062G: Total Nitrogen as N (TKN + NOx) by Discrete Analyser								
^ **Total Nitrogen as N**	----	0.1	mg/L	**4.5**	----	----	----	----
EK067G: Total Phosphorus as P by Discrete Analyser								
Total Phosphorus as P	----	0.01	mg/L	<0.02	----	----	----	----
EK071G: Reactive Phosphorus as P by discrete analyser								
Reactive Phosphorus as P	14265-44-2	0.01	mg/L	**0.01**	----	----	----	----
EP075(SIM)B: Polynuclear Aromatic Hydrocarbons								
Naphthalene	91-20-3	1.0	µg/L	<1.0	----	----	----	----
Acenaphthylene	208-96-8	1.0	µg/L	<1.0	----	----	----	----
Acenaphthene	83-32-9	1.0	µg/L	<1.0	----	----	----	----
Fluorene	86-73-7	1.0	µg/L	<1.0	----	----	----	----
Phenanthrene	85-01-8	1.0	µg/L	<1.0	----	----	----	----
Anthracene	120-12-7	1.0	µg/L	<1.0	----	----	----	----
Fluoranthene	206-44-0	1.0	µg/L	<1.0	----	----	----	----

Analytical Results

Sub-Matrix: **WATER** (Matrix: **WATER**)			*Client sample ID*	**QAQC1**	**TB**	**TS**	**----**	**----**
			Client sampling date / time	24-Aug-2018 00:00	17-Aug-2018 00:00	13-Aug-2018 00:00	----	----
Compound	*CAS Number*	*LOR*	*Unit*	**ES1825044-011**	**ES1825044-013**	**ES1825044-014**	**--------**	**--------**
				Result	Result	Result	----	----
EP075(SIM)B: Polynuclear Aromatic Hydrocarbons - Continued								
Pyrene	129-00-0	1.0	µg/L	<1.0	----	----	----	----
Benz(a)anthracene	56-55-3	1.0	µg/L	<1.0	----	----	----	----
Chrysene	218-01-9	1.0	µg/L	<1.0	----	----	----	----
Benzo(b+j)fluoranthene	205-99-2 205-82-3	1.0	µg/L	<1.0	----	----	----	----
Benzo(k)fluoranthene	207-08-9	1.0	µg/L	<1.0	----	----	----	----
Benzo(a)pyrene	50-32-8	0.5	µg/L	<0.5	----	----	----	----
Indeno(1.2.3.cd)pyrene	193-39-5	1.0	µg/L	<1.0	----	----	----	----
Dibenz(a.h)anthracene	53-70-3	1.0	µg/L	<1.0	----	----	----	----
Benzo(g.h.i)perylene	191-24-2	1.0	µg/L	<1.0	----	----	----	----
^ **Sum of polycyclic aromatic hydrocarbons**	----	0.5	µg/L	<0.5	----	----	----	----
^ **Benzo(a)pyrene TEQ (zero)**	----	0.5	µg/L	<0.5	----	----	----	----
EP080/071: Total Petroleum Hydrocarbons								
C6 - C9 Fraction	----	20	µg/L	<20	<20	----	----	----
C10 - C14 Fraction	----	50	µg/L	<50	----	----	----	----
C15 - C28 Fraction	----	100	µg/L	<100	----	----	----	----
C29 - C36 Fraction	----	50	µg/L	<50	----	----	----	----
^ **C10 - C36 Fraction (sum)**	----	50	µg/L	<50	----	----	----	----
EP080/071: Total Recoverable Hydrocarbons - NEPM 2013 Fractions								
C6 - C10 Fraction	C6_C10	20	µg/L	<20	<20	----	----	----
^ **C6 - C10 Fraction minus BTEX (F1)**	C6_C10-BTEX	20	µg/L	<20	<20	----	----	----
>C10 - C16 Fraction	----	100	µg/L	<100	----	----	----	----
>C16 - C34 Fraction	----	100	µg/L	<100	----	----	----	----
>C34 - C40 Fraction	----	100	µg/L	<100	----	----	----	----
^ **>C10 - C40 Fraction (sum)**	----	100	µg/L	<100	----	----	----	----
^ **>C10 - C16 Fraction minus Naphthalene (F2)**	----	100	µg/L	<100	----	----	----	----
EP080: BTEXN								
Benzene	71-43-2	1	µg/L	<1	<1	**16**	----	----
Toluene	108-88-3	2	µg/L	<2	<2	**17**	----	----
Ethylbenzene	100-41-4	2	µg/L	<2	<2	**17**	----	----
meta- & para-Xylene	108-38-3 106-42-3	2	µg/L	<2	<2	**16**	----	----
ortho-Xylene	95-47-6	2	µg/L	<2	<2	**17**	----	----
^ **Total Xylenes**	----	2	µg/L	<2	<2	**33**	----	----
^ **Sum of BTEX**	----	1	µg/L	<1	<1	**83**	----	----

Analytical Results

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

			Client sample ID	**QAQC1**	**TB**	**TS**	----	----
			Client sampling date / time	24-Aug-2018 00:00	17-Aug-2018 00:00	13-Aug-2018 00:00	----	----
Compound	CAS Number	LOR	Unit	**ES1825044-011**	**ES1825044-013**	**ES1825044-014**	--------	--------
				Result	Result	Result	----	----
EP080: BTEXN - Continued								
Naphthalene	91-20-3	5	µg/L	<5	<5	**18**	----	----
EP075(SIM)S: Phenolic Compound Surrogates								
Phenol-d6	13127-88-3	1.0	%	**17.6**	----	----	----	----
2-Chlorophenol-D4	93951-73-6	1.0	%	**46.3**	----	----	----	----
2.4.6-Tribromophenol	118-79-6	1.0	%	**60.2**	----	----	----	----
EP075(SIM)T: PAH Surrogates								
2-Fluorobiphenyl	321-60-8	1.0	%	**76.0**	----	----	----	----
Anthracene-d10	1719-06-8	1.0	%	**85.0**	----	----	----	----
4-Terphenyl-d14	1718-51-0	1.0	%	**77.0**	----	----	----	----
EP080S: TPH(V)/BTEX Surrogates								
1.2-Dichloroethane-D4	17060-07-0	2	%	**89.7**	**97.9**	**85.0**	----	----
Toluene-D8	2037-26-5	2	%	**92.1**	**107**	**106**	----	----
4-Bromofluorobenzene	460-00-4	2	%	**98.9**	**110**	**106**	----	----

Surrogate Control Limits

Sub-Matrix: **WATER**

		Recovery Limits (%)	
Compound	*CAS Number*	*Low*	*High*
EP075(SIM)S: Phenolic Compound Surrogates			
Phenol-d6	13127-88-3	10	44
2-Chlorophenol-D4	93951-73-6	14	94
2.4.6-Tribromophenol	118-79-6	17	125
EP075(SIM)T: PAH Surrogates			
2-Fluorobiphenyl	321-60-8	20	104
Anthracene-d10	1719-06-8	27	113
4-Terphenyl-d14	1718-51-0	32	112
EP080S: TPH(V)/BTEX Surrogates			
1.2-Dichloroethane-D4	17060-07-0	71	137
Toluene-D8	2037-26-5	79	131
4-Bromofluorobenzene	460-00-4	70	128

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