Appendix U

Groundwater impact assessment

Groundwater assessment

Woodlawn Advanced Energy Recovery Centre

Prepared for Veolia Environmental Services (Australia) Pty Ltd

August 2022

Groundwater assessment

Woodlawn Advanced Energy Recovery Centre

Veolia Environmental Services (Australia) Pty Ltd

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August 2022

Version	Date	Prepared by	Approved by	Comments
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Executive Summary

ES1 Project overview

Veolia Environmental Services (Australia) Pty Ltd (Veolia) owns and operates the Woodlawn Eco Precinct (the Eco Precinct), located approximately 50 km south of Goulburn and 70 km north of Canberra. The Eco Precinct has provided sustainable and innovative waste management practices since 2004.

The Woodlawn Advanced Energy Recovery Centre (ARC) (the project), an energy recovery facility (ERF), is proposed as the next phase of development at the Eco Precinct. The project is classified as a State significant development (SSD) under the *Environmental Planning and Assessment Act 1979.* The project involves the development of an additional waste management technology at the Eco Precinct, treating a portion of the waste stream which is already approved to be received as part of integrated waste management operations, and recovering energy from the process.

The ARC will generate residual by-products which will be managed within the Eco Precinct, including the construction of an encapsulation cell for the containment of restricted solid waste that will be progressively constructed at the Eco Precinct during operation of the ARC.

ES2 Water resources

Groundwater at the site is associated with the following geological units:

- local, minor groundwater associated with the weathered rock and hillwash sediments and/or unconsolidated colluvial and alluvial sediments; and
- regional groundwater within the fractured hard rock Ordovician and Silurian-Devonian aged volcanic, intrusive and sedimentary units, with groundwater primarily located in the rock fractures and joint spaces.

Both groundwater systems are limited resources owing to low porosity and permeability within the fractured rock units, and the limited extent of the clay rich colluvium. The geology underlying the evaporation dams comprises a sequence of alluvium/colluvium clay up to 20 m in thickness. The base of the clayey alluvium and the weathered bedrock forms an aquitard that separates the overlying colluvial/alluvial groundwater system from the fractured rock groundwater system.

The colluvial/alluvial/weathered bedrock groundwater system is considered unconfined, and the fractured rock groundwater system is considered semi-confined to confined based on measured groundwater elevations. Groundwater yields from the underlying hard rock rely on the interception of fractures.

It is proposed that the colluvium/alluvium near Crisps Creek is hydraulically connected with groundwater migrating from the colluvial/alluvial system to the south in the vicinity of ED1. This watercourse is expected to act as a gaining stream during wet conditions, but could revert to a losing stream in dry conditions, if there is water or ponds along the watercourse (Earth2Water 2010). Allianoyonyiga Creek is also intermittent, with only the first 200 m of the watercourse overlying colluvium, and the remainder overlying the fractured rock, before it joins Willeroo Creek.

Process water supply to the Eco Precinct is via a designated groundwater borefield, named Willeroo, located 6 km west of the Eco Precinct near Lake George. In the vicinity of the Willeroo borefield, the alluvial deposits are more extensive (especially in the palaeochannel areas) and comprise a shallow alluvial aquifer and a deeper alluvial aquifer. These sand and gravel zones are high permeability formations that provide useful supplies for small scale irrigation, mining, industrial, and stock and domestic uses.

Groundwater abstraction and use is low from the fractured rock and does not occur from the colluvium/alluvium at the Eco Precinct. There are 11 registered water bores within 2 km to the south and north of the Willeroo production bores. Within the Eco Precinct area there are no high priority groundwater dependent ecosystems reported in either of the relevant water sharing plans.

ES3 Impact assessment

ES3.1 Hydraulic loading

As part of the project, an encapsulation cell is planned to be constructed in the south-west corner of the existing evaporation dam, ED1. The evaporation dams have been shown to leak via preferential flow pathways to the north-east via the underlying colluvium. Historic artesian conditions have been observed around the perimeters of these dams, suspected to be caused by hydraulic loading from stored water in each of the dams (AECOM 2017).

The applied load from the encapsulation cell on the sediments has the potential to consolidate the clayey sediment, causing the water pressure (groundwater level) to rise and alter the local groundwater flow regime. A qualitative assessment of this effect on groundwater and the potential impacts on receptors during construction and operation was undertaken. During operation of and filling of the encapsulation cell, the following is expected:

- consolidation of the clayey sediments by up to approximately 0.5 m (total), which would occur gradually and consistent with the placement of the APCr;
- gradual and localised increase in water pressure (groundwater level) in the colluvial/alluvial groundwater system in the immediate vicinity of ED1 due to consolidation, in areas where placement is occurring – the localised increase in water pressure would be temporary and would dissipate with time;
- possible discharge of the existing groundwater stored in the clayey sediments at surface, localised in the ED1 and/or encapsulation cell;
- dissipation of the increased water pressure (groundwater level) with time and distance from the encapsulation cell;
- minimal change to the hydraulic gradient of the watertable away from ED1, towards Crisps Creek;
- possible measurable loading effect on the underlying semi-confined fractured rock groundwater system however the increase in water pressure is expected to be small, and hydraulic gradients are unlikely to substantially change; and
- groundwater flow processes are expected to remain relatively unchanged in the Crisps Creek and Spring 2 dam area, as this area will continue to receive water from rainfall and runoff (overland flow) and shallow groundwater discharge from the north.

ES3.2 Groundwater abstraction from Willeroo

The project, coupled with the existing water demand for Veolia's operations has a combined total of approximately 140 ML/yr in normal seasons and potentially up to 300 ML/yr in drought seasons. This maximum demand equates to about 0.8 ML/day of groundwater supply from the Willeroo borefield. Veolia has a Water Access Licence (WAL) for 600 ML (WAL: 28983) linked to four existing production bores.

A preliminary analytical groundwater model was developed to simulate the operation of the bores and estimate the associated drawdown at individual production bores and across the borefield area. The analytical modelling was based on the aquifer parameters derived from a constant rate pumping test undertaken at GW042931 – Bore 3.

The model assumes that the borefield entitlement of 600 ML/yr is extracted from the deep aquifer for the duration of the project. This highly conservative approach equates to a continuous abstraction rate of 20 L/s from the borefield. The preliminary analytical model suggests the Willeroo borefield is capable of continuously supplying 20 L/s with limited drawdown and stress to the shallow and deep alluvial aquifers. The maximum simulated drawdown at each of the production bores after 12 months operation is 6 m or less. The simulated heads in the pumped aquifer show spatially limited drawdown in the vicinity of the production bores compared to the pre-pumping conditions. The predicted drawdown following 25 years of cyclic operation of the borefield is predicted to extend the width of the targeted palaeochannel and is not expected to affect operation of third-party bores.

ES3.3 Inflows to the ARC bunker

A 15 m deep bunker is proposed as part of the ARC. During the construction of the bunker, groundwater within the fractured rock unit is expected to be intersected. The weathered rock overlying the fractured rock is dry, with possible temporary storage of rainfall infiltration. The depth to water, measured at BH3 during drilling, is 2 mbgl noting that the measured groundwater level is considered to be the pressure level in the upper fractured rock system, not the watertable or depth to saturated rock.

In accordance with the Aquifer Interference Policy (AIP), the volume of groundwater likely to be intercepted during construction has been estimated.

The total inflows to the bunker are estimated to be 0.7 ML and assumes the excavation intersects fractures with a similar hydraulic conductivity to those tested on site. Application of a sensitivity analysis performed on the hydraulic conductivity of the lithology, shows the estimated range in total groundwater inflow during construction of the bunker is between 0.3–1.6 ML (0.02–0.1 L/s).

ES4 Assessment conclusions

The potential impacts of the project have been assessed with consideration of the SEARs and relevant regulation, policy and guidelines. The following is a summary of the key conclusions of the groundwater assessment:

- the groundwater supply from the Willeroo borefield is adequate to meet the project water requirements;
- Veolia holds sufficient entitlement for the take associated with operation of the Willeroo borefield;
- excavation of the ARC bunker is expected to intercept groundwater for a short duration during construction and would not impact any groundwater assets;
- water take associated with intercepting groundwater during construction of the ARC bunker is expected to be much less than 3 ML/yr and Veolia is therefore exempt from licensing this take (in accordance with the Water Management (General) Regulation 2018);
- operation of the encapsulation cell is expected to consolidate the underlying clayey sediments of the alluvium/colluvium, causing the water pressure (groundwater level) to rise gradually and locally, which would dissipate with distance and time;
- groundwater flow processes are expected to remain relatively unchanged in the Crisps Creek and Spring 2 dam area, as this area will continue to receive water from rainfall and runoff (overland flow) and shallow groundwater discharge from the north;

- the potential effects of hydraulic loading on the groundwater system or excavation for the ARC bunker (the main water affecting activities in the Goulburn Fractured Rock Groundwater Source[1]) is not expected to have an adverse impact on the water quality of groundwater discharging to Crisps Creek or the greater Sydney drinking water catchment;
- Veolia has adopted several leading practices to produce a project design that avoids and minimises impacts to water assets; and
- the water management strategy for the project is based on a number of water efficiency measures and a commitment to maintain zero process water discharge from the project site.

ES5 Mitigation, monitoring and management

The water management strategy for the project is based on:

- maintaining zero contaminated/process water discharge from the project site;
- retaining water within the existing water storages;
- capturing and re-using rainwater in the operation;
- maintaining 'clean' and 'dirty' water streams;
- implementing a leak detection monitoring and management system at the encapsulation cell; and
- managing construction activities to limit the duration that potentially acid forming material is exposed.

The groundwater monitoring network currently includes 36 project specific monitoring bores. Groundwater monitoring (levels and quality) has been conducted since 1997. The monitoring network will provide an early indication of potential impact to sensitive receptors, including Crisps Creek. Monitoring of the groundwater monitoring network will continue, and the network will be expanded to identify potential impacts from project activities. Triggers and thresholds will be developed to provide context on if, how and when management measures are required as part of the water management plan (WMP) for the project.

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1.1 Overview

Veolia Environmental Services (Australia) Pty Ltd (Veolia) owns and operates the Woodlawn Eco Precinct (the Eco Precinct), located on Collector Road, approximately 6 kilometres (km) west of Tarago, approximately 50 km south of Goulburn and 70 km north of Canberra. The Eco Precinct is located in the Goulburn Mulwaree local government area (LGA). The Eco Precinct has provided sustainable and innovative waste management services since 2004.

The Eco Precinct comprises the following integrated waste management operations, energy recovery technologies and energy generation, and other sustainable land uses:

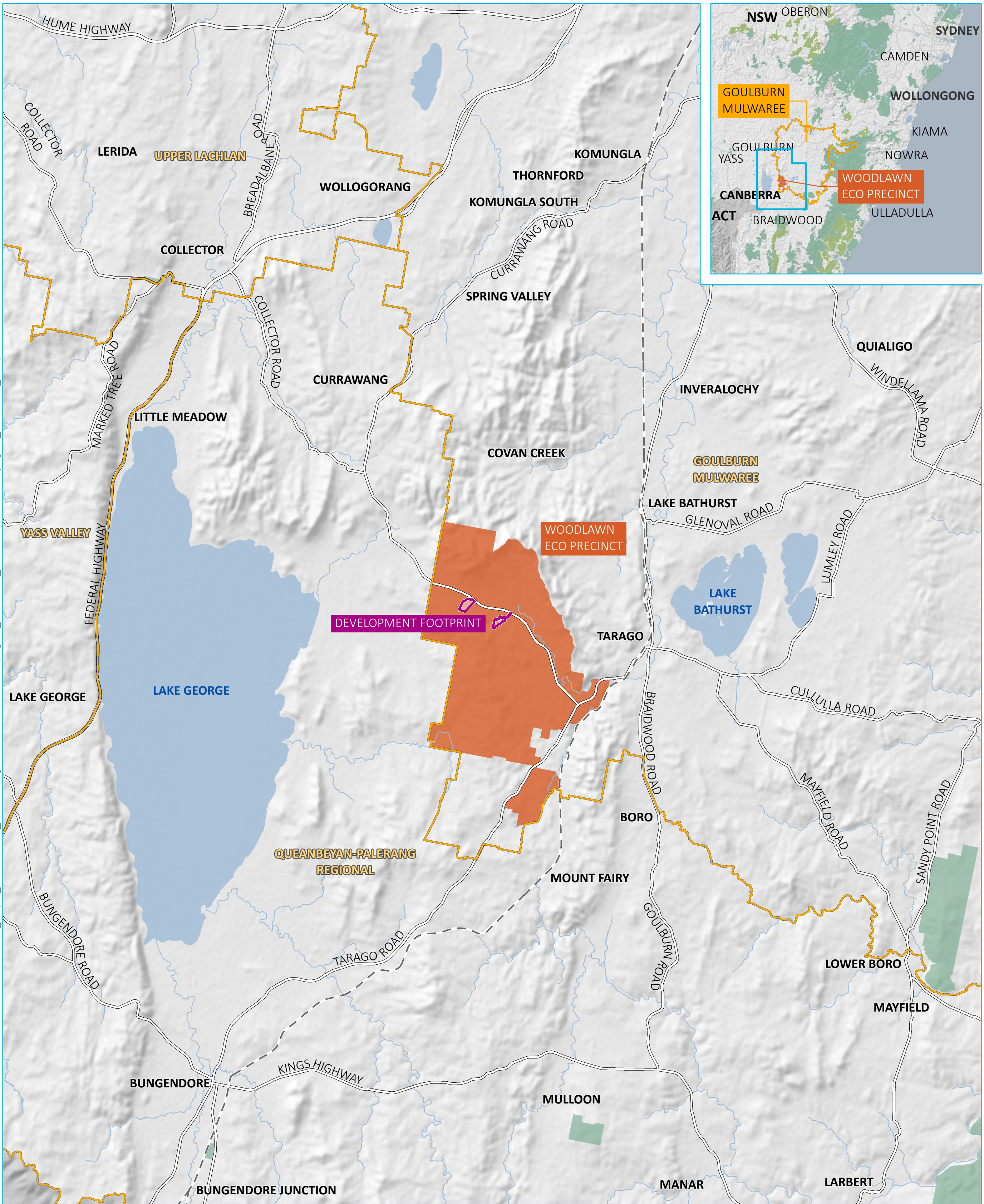
- Woodlawn Bioreactor (the Bioreactor) – a landfill in which leachate is recirculated to help bacteria break down the waste, enhancing the early generation of gas, enabling more efficient capture and extraction of landfill gas, including leachate and landfill gas management systems.
- Woodlawn BioEnergy Power Station – utilises landfill gas from the Bioreactor to generate electricity.
- Woodlawn Mechanical Biological Treatment (MBT) Facility – processes MSW to extract the organic content for use in tailings dam remediation.
- Agriculture – a working farm (sheep and cattle) that applies sustainable management practices.
- Aquaculture and horticulture – operation which uses captured waste heat from the BioEnergy Power Station for use in sustainable fish farming and hydroponic horticulture at the Eco Precinct.
- Renewable energy generation – the Woodlawn Wind Farm (operated by Iberdrola) which has an installed capacity of 48.3 MW, and a solar farm (operated by Veolia) with an installed capacity of 2.3 MW.

The Eco Precinct is served by the Crisps Creek IMF near the village of Tarago. Crisps Creek IMF is approximately 6 km to the east of the Eco Precinct (8.5 km by road), shown in Figure 1.2. Eco Precinct operations are augmented by two waste transfer terminals located in Sydney: the Clyde Transfer Terminal, which commenced operation in 2004 with the Bioreactor and Crisps Creek IMF, and the Banksmeadow Transfer Terminal, which commenced operation in 2016.

Waste is transported from the Sydney waste transfer terminals in purpose-built shipping containers by rail via the Goulburn-Bombala Railway line to the Crisps Creek IMF. The Crisps Creek IMF has an approved throughput of 1.18 million tonnes per annum (tpa). On receipt at the Crisps Creek IMF, containers are loaded on to trucks for delivery to the Eco Precinct. Waste from the regional area is also approved to be transported to the Eco Precinct by road, up to 130,000 tpa (with written consent).

The Eco Precinct also includes two other primary operations leased to other operators, the Woodlawn Wind Farm and the Woodlawn Mine.

Veolia proposes to develop and operate the Woodlawn Advanced Energy Recovery Centre (ARC) (the project), an energy recovery facility (ERF), at the Eco Precinct. This involves the development of an additional waste management technology at the Eco Precinct, processing a portion of the residual waste feedstock received at the site, and generating electricity from the energy recovery process.



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Source: EMM (2022); Veolia (2022); DFSI (2017)

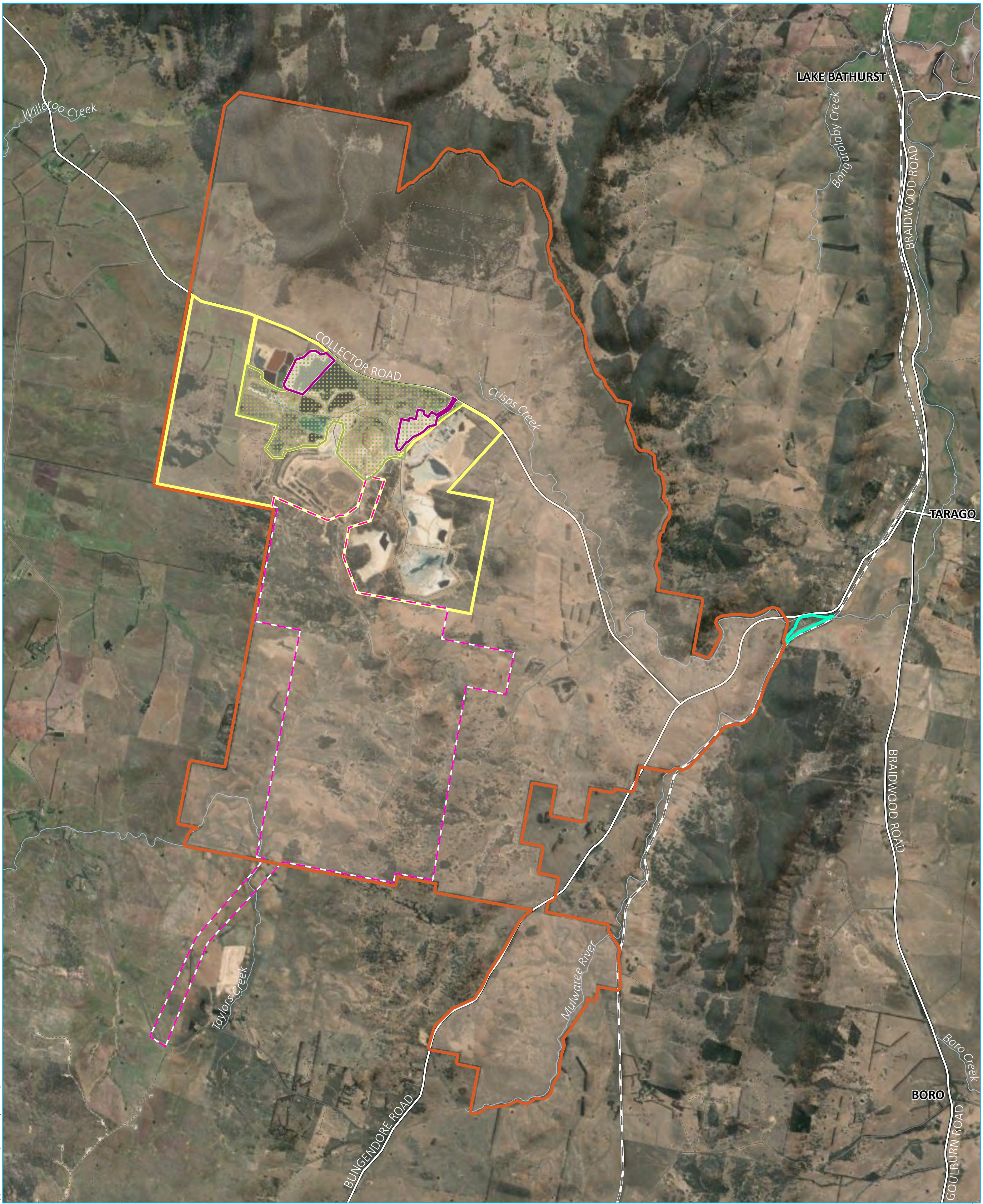
KEY

- Development footprint
- Woodlawn Eco Precinct
- Rail line
- Major road
- Watercourse
- Named waterbody
- NPWS reserve
- Local government area

Regional setting

Woodlawn Advanced Energy Recovery Centre
Groundwater assessment
Figure 1.1

EMM
creating opportunities



Source: EMM (2022); Veolia (2022); DFSI (2017)

KEY

- Development footprint
- Veolia integrated waste management operations
- Woodlawn Eco Precinct
- Crisps Creek Intermodal Facility (IMF)
- Woodlawn Mine operations area
- Woodlawn Wind Farm
- Rail line
- Major road
- Minor road
- Vehicular track
- Watercourse

Local setting

Woodlawn Advanced Energy Recovery Centre
Groundwater assessment
Figure 1.2

EMM creating opportunities

1.2 SEARs

This report has been prepared to address the SEARs (SSD-21184278) for the project, issued by DPIE on 2 July 2021. The requirements that are relevant to groundwater, and where they have been addressed in this report, are summarised in Table 1.1.

Table 1.1 Groundwater SEARs

SEARs	Section addressed
An assessment of potential surface and groundwater impacts associated with the development, including potential impacts on watercourses (Crisps Creek and the Mulwaree River sub-catchment), riparian areas, groundwater, and groundwater dependent communities.	Section 8
Identification of an adequate and secure water supply for the life of the project and details of how the proposal will interact with the existing water management system for the Eco Precinct.	Section 8 and 11
Demonstration of a Neutral or Beneficial Effect on water quality in accordance with State Environmental Planning Policy (Sydney Drinking Water Catchment) 2011.	Section 3 and Surface Water Assessment
Details of all soil and water management, mitigation and monitoring measures.	Section 10

2 Project description

2.1 Project setting

The Eco Precinct is located on Collector Road, approximately 6 km west of the village of Tarago, and 50 km south of Goulburn, NSW. The Eco Precinct includes operational areas used for waste management, energy generation and mining, as well as primary production including sustainable agriculture, aquaculture and horticulture.

The land use zoning of the Eco Precinct under the Goulburn Mulwaree LEP is predominantly IN3 Heavy Industrial, which includes the majority of the waste management, energy generation and mining activities, with the balance zoned RU2 Rural Landscape. Land immediately to the north and south is zoned RU2 Rural Landscape, land to the west is zoned RU1 Primary Production, and land to east, which incorporates the village of Tarago, is zoned a combination of RU5 Village, RU6 Transitional, RU1 Primary Production and E3 Environmental Management.

There are no major National Parks, nature reserves, conservation areas and State forests in close proximity to the Eco Precinct. Land immediately surrounding the operational areas of the Eco Precinct is owned by Veolia, providing a buffer between operations and surrounding private properties.

2.2 Site history

Historically, metalliferous ore minerals were extracted at the Eco Precinct site, and these included sphalerite, galena and chalcopyrite, to produce copper, lead and zinc concentrates. Historic mining at the Woodlawn site was undertaken by Denehurst Limited. Between 1978 and 1987 mining was open cut, and from 1987 to 1998 underground mining was undertaken. The open cut mine void was approximately 200 metres (m) deep and 700 m wide, while underground mining extended 460 m below the base of the pit (Golder 2022a). The former mine workings extend below Evaporation Dam 1 (ED1), at depths of around 690 mAHD (Parsons Brinckerhoff 2012), however the mine is currently in care and maintenance mode.

Veolia (then Collex) purchased the Woodlawn property, now the site of the Woodlawn Eco Precinct, in 2001 following the closure of the mining operations. The property was purchased with the intention of establishing a waste management facility, whilst rehabilitating areas disturbed by prior mining operations.

The Eco Precinct has developed over the last 20 years to become an integrated waste management and resource recovery operation, incorporating the Bioreactor, a landfill, the BioEnergy Power Station operating on landfill gas, a MBT facility, a solar farm and a wind farm. The Bioreactor and Crisps Creek IMF commenced operating in 2004, and the MBT facility commenced operating in 2017.

The MBT Facility is located to the north-west of the Bioreactor and was approved in 2007 to receive up to 280,000 tonnes per annum (tpa) of waste (240,000 tpa of mixed waste and 40,000 tpa of garden waste). The first stage of the MBT completed commissioning in March 2017 and commenced operation in July 2017. Approximately 143,000 tpa of mixed waste is currently accepted from an amalgamation of councils in the Sydney metropolitan area. The incoming waste is processed to extract metals and produce organic output, which is matured on site.

While mining operations ceased in the late 1990s, the rights to Special Mining Lease (SML) 20, were transferred to another operator (Heron Resources Ltd) under an agreement with Veolia to determine responsibilities for the site management and rehabilitation. Mining operations at the Eco Precinct were approved in 2013 and commenced for the area covered by SML 20, although the mine operator went into voluntary administration in July 2021. The mine has recently been acquired by DEVELOP Global Ltd (DEVELOP), who is the current mine operator for SML20.

2.2.1 Evaporation dams

Two evaporation dams (ED1 and ED2) were constructed between 1987 and 1991 in the north-west corner of the Eco Precinct to hold water from the former open cut mine workings, water from underground mining operations, and runoff from the waste rock dumps (AECOM 2017). The evaporation dams are still present and are shown in Figure 2.1. The dams are not lined and are currently still used to store water associated with the mine workings and captured site surface water (AECOM 2017, Golder 2022a). The dams are 3–4 m deep and cover an area of 69 hectares (ha).

The dams were constructed across a broad, shallow drainage gully (Golder 2022a). A clay material, which could be natural or imported, comprises the base of ED1. This has an average thickness of 1.5 m and a hydraulic conductivity of $1x10^{-9}$ m/s (8.6 m/d) (AECOM 2017). There have been no works to treat the floor of these dams (ie compaction or provision of any liners), and historical drying of the dams may have caused surface cracking in the base resulting in possible groundwater migration pathways. In addition, the area underlying ED1 was used for 'borrow pits,' where material was excavated for use and later backfilled and compacted.

AECOM (2017) reports that the water quality of the dams comprises acidic and high salinity water with elevated total metal concentrations including aluminium, cadmium, copper, iron, manganese and zinc. This acid and metalliferous water quality forms due to the exposure of sulfide minerals to air, resulting in their oxidation.

AECOM (2017) assessed the integrity of the dams and found seepage has occurred from both dams, traveling as far as 450 m from ED1 and 900 m from ED2. This leakage has migrated below the dam walls in the underlying colluvium/alluvium to the north and north-east. Despite the low permeability of the dam floors, seepage from ED1 and ED2 has occurred via preferential pathways likely caused by naturally higher permeability sediments (ie areas with more sand), and pathways created by old boreholes and/or borrow pits. Discrete areas of higher permeability material and/or areas of increased saturated porosity have been identified via monitoring bore drilling (Earth2Water 2010) and electromagnetic survey to 6 m deep (AECOM 2017). Seepage from the dams is influenced by hydraulic head within the dams, and results in slow migration from the dams.

Review of historic bore data indicated multiple bores immediately adjacent to the dams in the colluvium/alluvium and weathered rock have been artesian, resulting in shallow groundwater and dam seepage potentially presenting at surface. AECOM (2017) propose these were artificial artesian conditions that originated in response to hydraulic loading and/or induced recharge when the evaporation dam levels were high.

2.3 Project description

Veolia proposes to develop and operate the ARC project, an ERF, at the Eco Precinct. This involves the development of an additional waste management technology at the Eco Precinct, treating a portion of the waste stream which is already approved to be received as part of integrated waste management operations, and recovering energy from the process.

The project will involve construction and operation of the following key components comprising the ARC:

- construction of the ARC, comprising an ERF for the thermal treatment of residual municipal solid waste (MSW) and commercial and industrial (C&I) waste (referred to as waste feedstock) that would otherwise be disposed to landfill;
- thermal treatment in the ARC of up to 380,000 tonnes per annum (tpa) of residual waste feedstock;
- installed capacity of up to 30 megawatts (MW) of electricity (generation of up to 240,000 megawatt hours (MWh) of electricity per annum);
- on-site management of residual by-products generated by the ARC, including construction of an encapsulation cell; and
- construction of ancillary infrastructure to facilitate construction and operation of the project, including a new access road.

The project life is anticipated to be in excess of 25 years, however, will be dependent on a range of factors, which may include future changes in waste policy and legislation, advances in technology, and availability and suitability of waste feedstock sources in the future.

2.3.1 The ARC

The ARC will be housed within a fully enclosed building and the waste handling system consists of a tipping hall for receiving residual waste, a waste storage bunker and two overhead grab cranes. The waste bunker extends 15 metres below ground level (mbgl) to a maximum depth of 762 metres Australian Height Datum (mAHD).

2.3.2 By-product handling and treatment

The ARC process will generate residual by-products including incinerator bottom ash (IBA) and air pollution control residues (APCr).

IBA will be matured onsite and either disposed of in the Bioreactor, beneficially reused within the Eco Precinct (eg used as daily cover for the Bioreactor), or transported offsite for beneficial reuse. The proposed disposal and/or use of IBA at the Bioreactor is not expected to result in groundwater quality impacts. The IBA will be processed and stored at the IBA area before being either disposed of, or reused. Maturation of the IBA is the process by which the IBA is exposed to the atmosphere for an extended period and results in stabilisation of the IBA. The IBA area will have an impermeable floor and will be bunded, and will have a leachate collection system. This design means the potential risk to shallow groundwater is negligible, and all surface runoff will be captured and reused in the maturation process.

The APCr will be stabilised and disposed of in an encapsulation cell which will be progressively constructed within the western portion of ED1. The encapsulation cell will have a final footprint of 11.9 Ha and the current extent of ED1 will be reduced to accommodate the cell. The encapsulation cell will be designed in accordance with the NSW EPA's *Environmental Guidelines Solid Waste Landfill Second Edition 2016* (Landfill Guidelines) (NSW EPA 2016), meaning the final form will be lined (with a dual barrier lining system) and capped with low permeability materials to deflect rainfall and minimise infiltration. The encapsulation cell will be progressively filled and constructed. Temporary geomembrane partitions and capping will be used, meaning during construction only rainfall generated leachate will be produced. However, in accordance with the Landfill Guidelines the encapsulation cell will have a leachate barrier and collection system, inclusive of a secondary leak detection layer, to capture and contain this leachate, thus preventing leakage and potential contamination of groundwater (Golder 2022b).

Leachate evaporation via a dedicated evaporation pond is proposed as the primary leachate disposal method from the encapsulation cell. The leachate evaporation pond is shown on Figure 2.1. The pond will be lined and will also include a leachate barrier and detection system. Ongoing generation of leachate is unlikely to occur once the encapsulation cell is full and sealed with an impermeable cap, however the leachate system will still be monitored and maintained.

2.3.3 Water supply and demand

Existing process water supply to the Eco Precinct is via a designated groundwater borefield, named Willeroo, located 6 km west of the Eco Precinct near Lake George. Groundwater take is via four production bores 47–57 m in depth and screened opposite deep sand and gravel aquifers. The borefield targets a palaeochannel, a buried Quaternary Alluvium system that drains into Lake George.

Veolia has a Water Access Licence (WAL) for 600 ML (WAL: 28983) linked to the four production bores (GW042931, GW042932, GW042933 and GW042934) that make up the Willeroo borefield. The location of these bores is shown in Figure 2.2. Groundwater take is licensed under the NSW Murray Darling Basin Fractured Rock Groundwater Sources Water Sharing Plan (WSP), (2020), specifically the Lachlan Fold Belt Murray Darling Basin Groundwater Source.

The typical annual groundwater take is around 56 ML, although this can be higher during drought conditions (ie up to 168 ML in the first half of 2019). Operational water is currently used for the following activities:

- wheel wash facility;
- container wash down;
- potable water use;
- dust control on roads; and
- aquaponics project.

During operation, the project will require process water, equivalent to 7.4 megalitres per month (ML/month) (EMM 2022a). The additional annual demand is 90 megalitres per year (ML/yr) for the project, combined with the existing average demand for the Eco Precinct, the new annual demand is around 150 ML/yr in an average year, and up to 300 ML/yr in severe drought years. This water will be sourced from stormwater harvesting (when available) and groundwater from the Willeroo Borefield (when stormwater is not available) via existing pipeline infrastructure at the Eco Precinct which connects the ARC development footprint to the Willeroo Borefield. During drought conditions, it is anticipated that the Willeroo Borefield will meet the projects full water supply requirements for extended periods of time. The full water demand is proposed to be met via groundwater and captured stormwater, with 60%−100% of supply being sourced from groundwater.

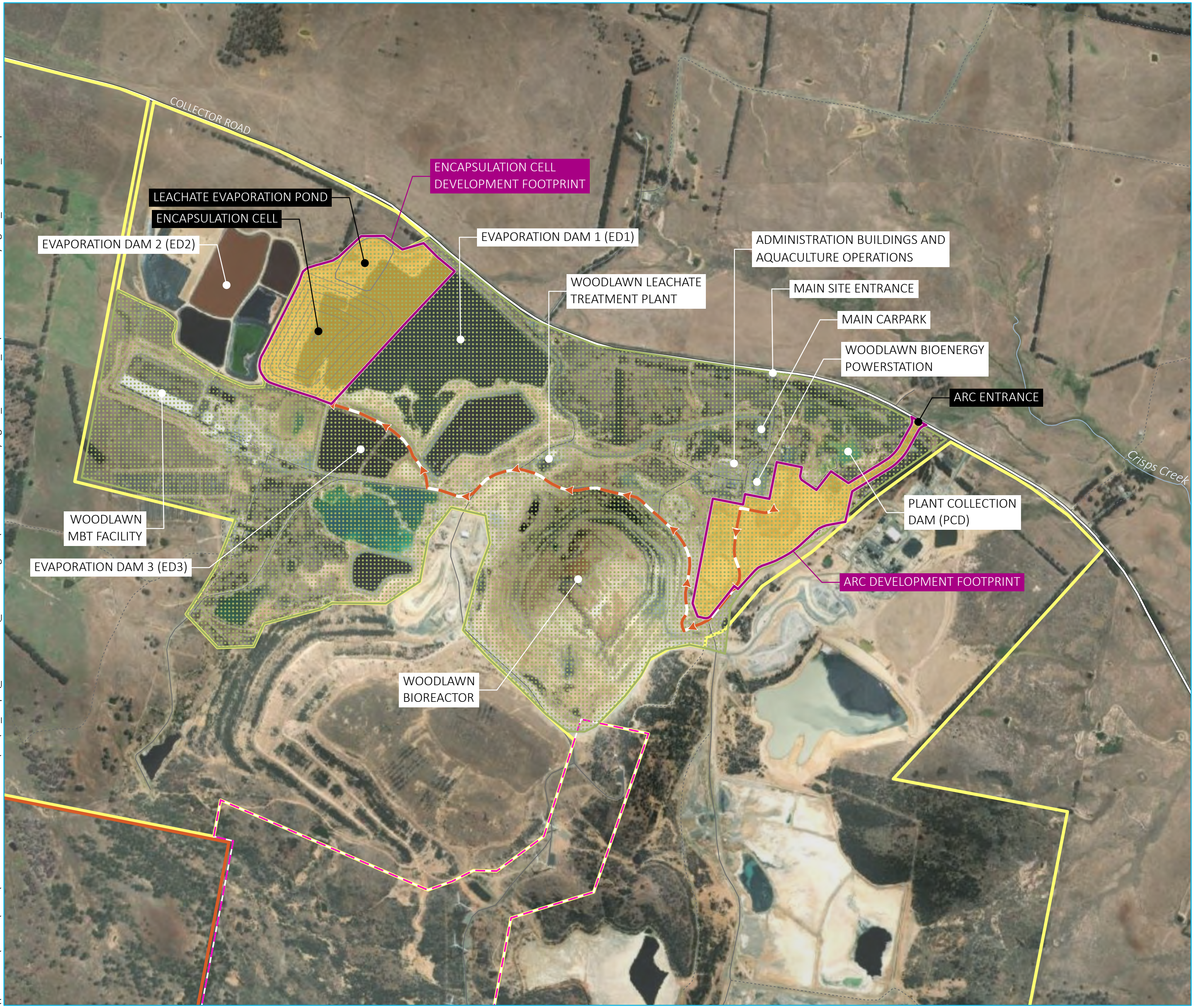
2.3.4 Water management

A water management system will be developed for the project to manage stormwater runoff during construction and operations, supply water to the project and manage contaminated water streams and wastewater (ie sewage). Further details can be found in the *Surface Water Assessment* (EMM 2022a).

The water management systems include controls that separate clean and dirty water. Dirty water and leachate are managed using in a designated system that includes evaporation ponds to manage the build-up during wet periods. The process water system will utilise potentially contaminated stormwater runoff captured in the IBA area stormwater system and recycled process water that could comprise a mixture of raw water, brine and return water from the wash down and steam cycle systems. Under certain circumstances (such as extended wet weather) there may be surplus process water that requires management via dewatering to ED1. This contingency arrangement will ensure that all contaminated stormwater or recycled process water is managed in either the process water system or ED1, with no discharges to the stormwater system expected. The proposed evaporation pond will be double lined with a leak detection layer.

The existing Plant Collection Dam (PCD) will capture run off from the ARC, and is shown onFigure 2.3. The PCD was originally established to manage water from the ore processing plant. The PCD currently has a contributing catchment area of 31.3 ha that comprises: the former processing plant area, Woodlawn BioEnergy Power Station, the site administration complex and various roads and unused areas. Water collected in the PCD dam is Acid Mine Drainage (AMD) affected and is known to have a low pH and elevated salinity levels and metal concentrations. Currently all water collected in the PCD is pumped to ED1. Veolia have not observed the PCD to overflow during the 20 years that they have operated the site.

Stormwater settling ponds are proposed to be constructed at the ARC and will be used for the storage of the 'clean' water stream.



KEY
- Development footprint
- Veolia integrated waste management operations
- Woodlawn Eco Precinct
- Woodlawn Mine operations area
- Woodlawn Wind Farm
- APCr transport route
- Major road
- Minor road
- Vehicular track
- Watercourse

Source: EMM (2022); Veolia (2022); DFSI (2017)

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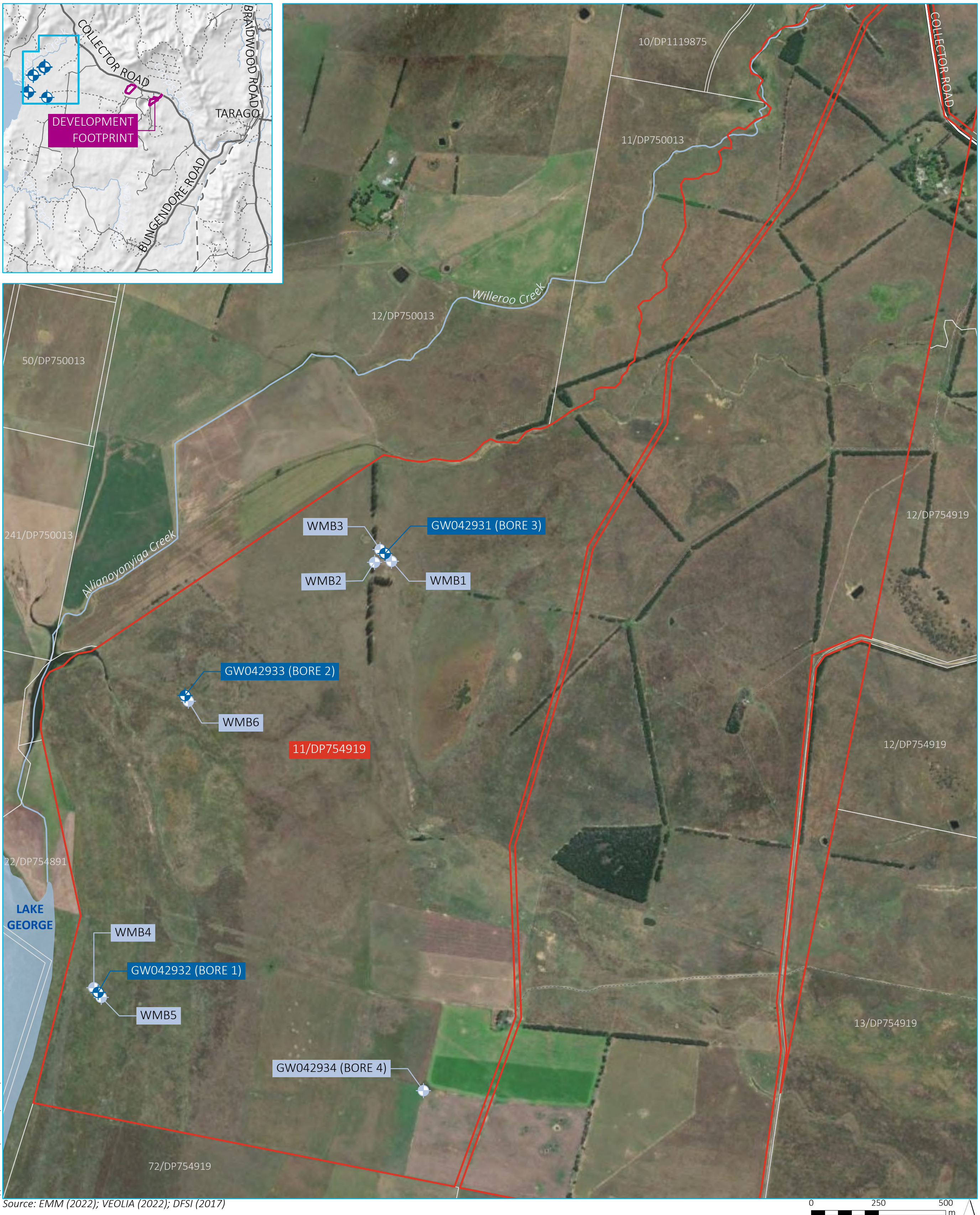
Project layout

Woodlawn Advanced Energy Recovery Centre
Groundwater assessment
Figure 2.1

EMM creating opportunities



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Source: EMM (2022); VEOLIA (2022); DFSI (2017)

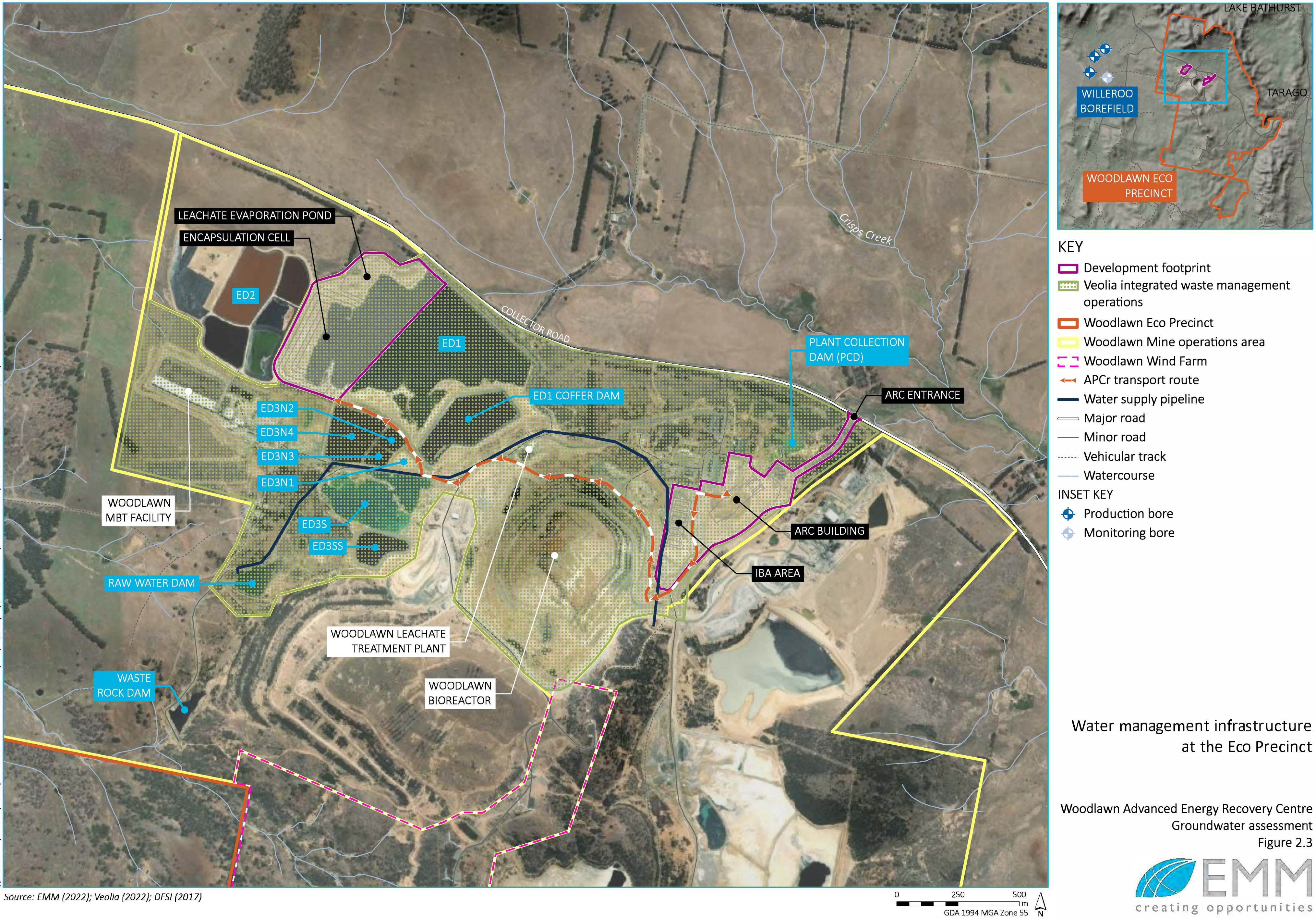
KEY

- Development footprint (see inset)
- Production bore
- Monitoring bore
- Major road
- Minor road
- Vehicular track
- Named watercourse
- Named waterbody
- Willeroo borefield lot boundary
- Lot boundary

Willeroo borefield

Woodlawn Advanced Energy Recovery Centre
Groundwater assessment
Figure 2.2

EMM
creating opportunities



Source: EMM (2022); Veolia (2022); DFSI (2017)

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Water management infrastructure at the Eco Precinct

Woodlawn Advanced Energy Recovery Centre
Groundwater assessment
Figure 2.3

EMM creating opportunities

3 Regulatory and policy context

3.1 Overview

The primary water related statutes that apply to the project are the *Water Act 1912* (Water Act), *Water Management Act 2000* (WM Act) and *Protection of the Environment Operations Act 1997* (POEO Act). The provisions of each Act are applied in accordance with their attendant regulations.

The requirements of the applicable legislation and policies and the assessments of the project against these key policy requirements are given in the following sections. The relevant Water Sharing Plans (WSPs) and the AIP (DPI Water 2012a) are key documents dictating the assessment of the potential impacts of the project on groundwater resources.

3.2 Water Act 1912

The Water Act has been largely superseded by the WM Act with WSPs developed for all water sources across NSW. However, some aspects of the Water Act are still operational such as licences for monitoring bores. Monitoring bores will continue to be licensed under the Water Act.

3.3 Water Management Act 2000

The WM Act is based on the principles of ecologically sustainable development and the need to share and manage water resources for future generations. The WM Act recognises that water management decisions must consider economic, environmental, social, cultural and heritage factors.

The WM Act provides for water sharing between different water users including environmental, basic rights and all consumptive users including industry. In addition, the WM Act provides security to holders of WALs.

The licensing provisions of the WM Act apply to those areas where a WSP has commenced; it has progressively been enacted across NSW since July 2004. The licensing provisions of the WM Act become effective for any water source once a WSP for that water source commences.

One of the key components of the WM Act is the separation of the water licence from the land; this facilitates opportunities for licence holders to trade water. The WM Act outlines the requirements for taking and trading water through WALs, water supply works, and water use approvals.

The WM Act is the primary legislation governing water management and licensing relevant to the project. The licensing requirements for industrial use are similar to other consumptive licensing requirements.

3.3.1 Water sharing plans

WSPs are statutory documents dictating the management and sharing of water sources. The WSPs set the water management vision and objectives, management rules for WALs, what water is available within the various water sources, and procedures for dealing in licences and water allocations, water supply works approvals and the extraction of water. WSPs are designed to establish sustainable use and management of water resources and are periodically reviewed (every 10 years).

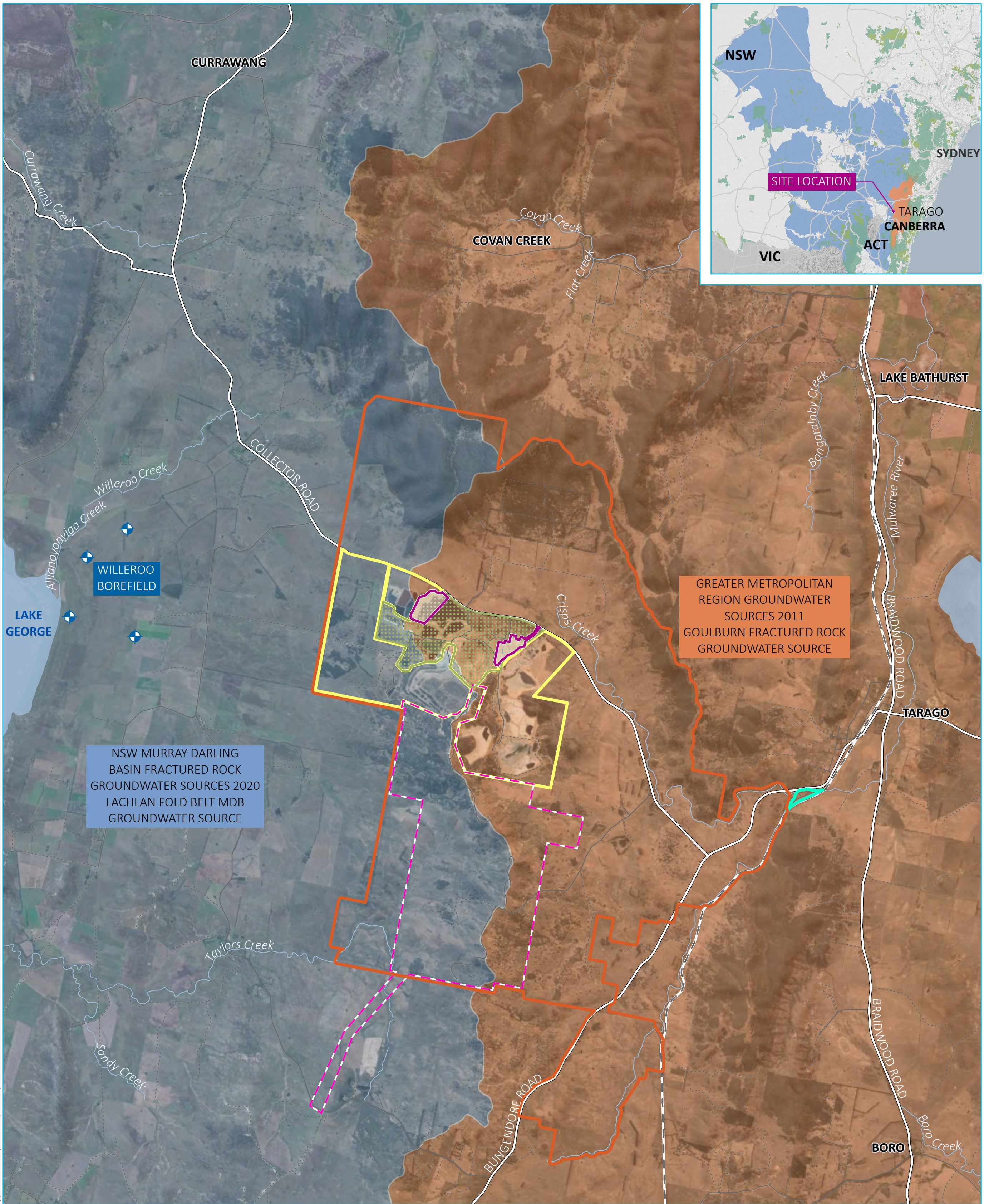
Each WSP documents the water available and how it is shared between environmental, basic rights, and other consumptive uses. The WSPs outline the water availability for extractive uses within different categories, such as: local water utilities, domestic and stock, basic rights, and access licences.

The development footprint overlies two water sharing plan (WSP) areas that relate to the regional fractured rock groundwater units, namely:

- *WSP for the Greater Metropolitan Region Groundwater Sources* (2011), Goulburn Fractured Rock Groundwater Source in the eastern half of the development footprint; and

- *WSP for the NSW Murray Darling Basin Fractured Rock Groundwater Sources Order* (2020), Lachlan Fold Belt MDB Groundwater Source in the western half of the development footprint (which includes the Quaternary Alluvium associated with the Willeroo borefield).

The shallow groundwater in the colluvium/alluvium and weathered rock at the Eco Precinct is part of the Goulburn Fractured Rock groundwater source. The Willeroo borefield area (although in an alluvial groundwater system) is not within the mapped area of the Bungendore Alluvial groundwater source that is regulated under the WSP for the Murrumbidgee Alluvial Groundwater Sources Order (2020).



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Source: EMM (2022); VEOLIA (2022); DPIE (2021); DFSI (2017)

0 2.5 5 km

GDA 1994 MGA Zone 55

N

Water sharing plan boundaries

KEY

- Development footprint
- Veolia integrated waste management operations
- Woodlawn Eco Precinct
- Crisps Creek Intermodal Facility (IMF)
- Woodlawn Mine operations area
- Woodlawn Wind Farm
- Groundwater bore

Water sharing plan and water source

- Greater Metropolitan Region Groundwater Sources 2011/Goulburn Fractured Rock Groundwater Source
- NSW Murray Darling Basin Fractured Rock Groundwater Sources 2020/ Lachlan Fold Belt MDB Groundwater Source

- Rail line
- Major road
- Minor road
- Vehicular track
- Watercourse

Woodlawn Advanced Energy Recovery Centre
Groundwater assessment
Figure 3.1

EMM
creating opportunities

3.3.2 NSW Aquifer Interference Policy

The AIP is the policy with respect to groundwater interference activities (DPI Water 2012). The policy explains the role and requirements of the Minister in determining applications for aquifer interference activities. The WM Act (under Section 91) defines an 'aquifer interference activity' as an activity involving:

- penetration of an aquifer;
- interference with water in an aquifer;
- obstruction of the flow of water in an aquifer;
- taking of water from an aquifer in the course of carrying out mining, or any other activity prescribed by the regulations; or
- disposal of water taken from an aquifer in the course of carrying out mining or any other activity prescribed in the regulations.

This project has the potential to interfere with water in an aquifer (both the ARC building waste bunker and the encapsulation cell); the other activities are not relevant.

Section 91(3) of the WM Act 2000 relates to aquifer interference approvals. The requirement to obtain an aquifer interference approval under Section 91(3) is triggered only when a proclamation has been made under Section 88A of the WM Act that the particular type of approval is required. To date, no proclamation has been made specifying that an aquifer interference approval is required in any part of NSW.

In the meantime, the AIP sets the policy with respect to aquifer interference. Typically, projects need to meet the minimal impact considerations relating to water levels, water pressures and water quality for either a highly productive groundwater source or a less productive groundwater source. This project is underlain by a less productive groundwater source. DPI Water's assessment framework for aquifer interference is included (and completed) in Appendix A. The AIP:

- clarifies the requirements for licensing water intercepted during aquifer interference activities (such as mining, quarrying, dewatering for construction); and
- defines and establishes 'minimal impacts' for water related assets (such as existing bores and groundwater dependent ecosystems (GDEs)).

For this project there is no incidental take of groundwater from a natural groundwater system that exceeds 3 ML/yr, therefore no access licence is required for construction. A water access licence to take and recycle leachate that is collected from the encapsulation cell is also not required as volumes are small and don't exceed the threshold of 3 ML/yr.

The encapsulation cell and the associated evaporation pond could be considered a high-risk activity as it is:

- an activity with the potential to contaminate groundwater or result in unacceptable loss of storage or structural damage to an aquifer.

The encapsulation cell and ARC building waste bunker have been assessed in this impact assessment on the basis of the risks to the underlying colluvial/alluvial weathered rock and fractured rock groundwater systems.

i Assessment criteria

The AIP defines water sources as being either 'highly productive' or 'less productive' based on levels of salinity and average yields from bores. The AIP further defines water sources by their lithological character, being one of: alluvium, coastal sand, porous rock, or fractured rock. The colluvium/alluvium and fractured rock groundwater systems at the project site are considered to be 'less productive' based on the low yields and high salinity.

The minimal impact considerations have been developed for impacts on groundwater sources, connected water sources, and their dependent ecosystems, culturally significant sites and water users. For each category, the AIP identifies thresholds for minimal impact considerations. These thresholds relate to impacts on the watertable, water pressure and water quality, and are ranked as being either 'level 1 minimal impact' or 'level 2 exceeding minimal impact'. The definition of 'minimal impact' and the aspects applicable for the project have been reproduced in Table 3.1 (for fractured rock water sources) and Table 3.2 (for alluvial water sources).

The AIP minimal impact considerations process is shown in Figure 3.2.

Table 3.1 Minimal impact criteria for 'less productive' porous and fractured rock water sources

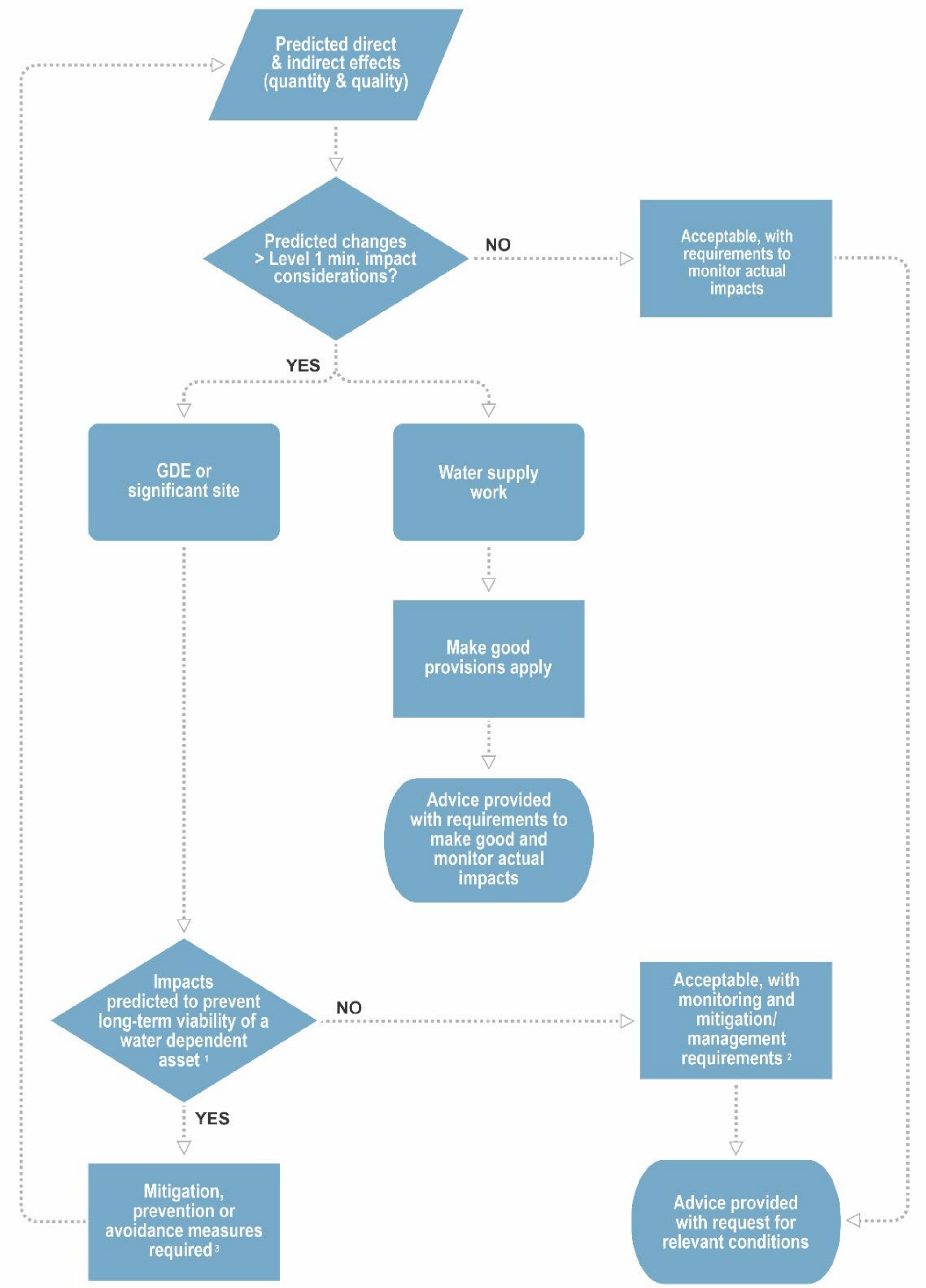
Watertable	Water pressure	Water quality
1. Less than or equal to 10% cumulative variation in the watertable, allowing for typical climatic 'post-water sharing plan' variations, 40 m from any: a) high priority groundwater dependent ecosystem; or b) high priority culturally significant site; listed in the schedule of the relevant water sharing plan. A maximum of a 2 m decline cumulatively at any water supply work. 2. If more than 10% cumulative variation in the watertable, 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 2 m decline cumulatively at any water supply work then make good provisions should apply.	1. A cumulative pressure head decline of not more than a 2 m decline, at any water supply work. 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.	1. Any change in the groundwater quality should not lower the beneficial use category of the groundwater source beyond 40 m from the activity. 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.

Note: Sourced from NSW Aquifer Interference Policy (DPI Water 2012a)

Table 3.2 Minimal impact criteria for 'less productive' alluvial water sources

Watertable	Water pressure	Water quality
1. Less than or equal to 10% cumulative variation in the watertable, 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 2 m decline cumulatively at any water supply work unless make good provisions should apply. 2. If more than 10% cumulative variation in the watertable, 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 then appropriate studies will need to 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 2 m decline cumulatively at any water supply work then make good provisions should apply.	1. A cumulative pressure head decline of not more than 40% post water sharing plan pressure head above the base of the water source to a maximum of a 2 m decline, at any water supply work. 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.	1(a) Any change in the groundwater quality should not lower the beneficial use category of the groundwater source beyond 40 m from the activity. 1(b) No increase of more than 1% per activity in long-term average salinity in a highly connected surface water source at the nearest point to the activity. Redesign of a highly connected surface water source that is defined as a reliable water supply is not an appropriate mitigation measure to meet considerations 1(a) and 1(b) above. 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. If condition 1(b) is not met then appropriate studies are required to demonstrate to the Minister's satisfaction that the River Condition Index category of the highly connected surface water source will not be reduced at the nearest point to the activity.

Note: Sourced from NSW Aquifer Interference Policy (DPI Water 2012a), with reference to mining related works removed



1. *Assessment as per Serov et al 2012, with consideration of uniqueness, ecological/cultural value and timeframe of the impact.*
2. *Conditions of approval may include requirements for adaptive management to monitor and mitigate or remediate impacts that exceed level 1 thresholds.*
3. *Where there are no suitable or practical mitigation or prevention options, the proponent may be asked to avoid impacts by modifying the proposed activity.*

Figure 3.2 AIP minimal impact considerations process (adapted from DPI Water 2012a)

3.4 NSW Protection of the Environment Operations Act

The POEO Act is the key piece of environment protection legislation administered by the NSW EPA. The POEO Act enables the government to set protection of the environment policies that provide environmental standards, goals, protocols, and guidelines. The POEO Act also establishes a licensing regime for pollution generating activities in NSW. Under Section 48, an environment protection licence (EPL) is required for 'scheduled activities'. This project is not planning to discharge to or impact groundwater, however, revised conditions are envisaged under a new or amended EPL for the site activities.

3.5 NSW policies and guidelines

Several policies and guidelines are relevant to this Groundwater Assessment. They are discussed in the following sections.

3.5.1 State Groundwater Policy Framework Document

The NSW State Groundwater Policy Framework Document (DLWC 1997) aims to manage the groundwater resources of the State so they can sustain environmental, social, and economic outcomes for the people of NSW. The policy will be considered in resource management decisions made in NSW.

The document is a framework for the following three policies:

- NSW State Groundwater Quantity Management Policy (2001 (unpublished));
- NSW State Groundwater Quality Protection Policy (DLWC 1998); and
- NSW State Groundwater Dependent Ecosystem Policy (DLWC 2002).

This policy establishes the overarching principle for the management of groundwater in NSW, which remains valid 19 years after its inception. The principles of sustainability across the three environmental, social, and economic aspects are still referenced in modern water policies released by the NSW Government.

The NSW State Groundwater Quantity Management Policy and NSW State Groundwater Dependent Ecosystem Policy have little relevance to this project and are not discussed further.

3.5.2 State Groundwater Quality Protection Policy

The NSW State Groundwater Quality Protection Policy requires that water quality within groundwater systems is managed in accordance with the management principles given in Table 3.3.

Table 3.3 State Groundwater Quality Protection Policy (1998) principles

Groundwater quality management principles	Consideration of the principle
The most sensitive identified beneficial use (or environmental value) is maintained.	The beneficial uses of local groundwater sources is irrigation, industrial, domestic and stock. Groundwater quality impacts of the project will be negligible, and the beneficial use category will not change as a result of the project.
Town water supplies are afforded special protection against contamination.	There are no nearby town water supply bores.
Groundwater pollution should be prevented.	Groundwater chemistry has been assessed and groundwater pollution will not occur.
For new developments, the scale and scope of work required to demonstrate adequate groundwater protection shall be commensurate with the risk the development poses to a groundwater system and the value of the groundwater resource.	The project is a State Significant Development, and as such a thorough impact assessment has been made. Baseline environmental monitoring and assessment of the project's potential impacts has been occurring continuously for over two years.
Groundwater dependent ecosystems are afforded protection.	There are no High Priority GDEs within the project development area.
Groundwater quality and quantity management is integrated.	The baseline groundwater quantity and quality data has been integrated in the groundwater assessment and the impact assessment.
The cumulative impacts of developments on groundwater quality should be recognised.	Groundwater quality changes as a result of the project are anticipated to be negligible. As such, cumulative groundwater quality impacts are also not anticipated as a result of the project.
Where possible and practical, environmentally degraded areas should be rehabilitated and their ecosystem support functions restored.	The former mine site is degraded and this project includes some rehabilitation activities including the repurposing and relining of ED1 to control leachate and leakage.

3.5.3 State Environmental Planning Policy (Biodiversity and Conservation) 2021

The Eco Precinct is located within the Sydney Drinking Water Catchment, meaning clauses 9(1), 9(2) and 10(1) of the *State Environmental Planning Policy (Biodiversity and Conservation) 2021* (the SEPP) apply. This means the development is required to have a Neutral or Beneficial Effect (NorBE) on water quality released or migrating from site. The Neutral or Beneficial Effect on Water Quality Assessment Guideline (WaterNSW 2015) outlines the assessment and approval process developed by the WaterNSW in applying the principles of NorBE. A neutral or beneficial effect on water quality means any water introduced to an offsite water source will be comparable to or will have better quality than the receiving water body, thereby having no identifiable negative impact on the receiving water quality.

Achieving NorBE has not been relevant for the Eco Precinct to date as the site has zero offsite discharge, having undertaken detailed consideration in the water infrastructure and management. However the project will require a NorBE assessment and this is detailed in the Surface Water Assessment (EMM 2022a). The NorBE assessment on receiving water quality is achieved via a water management system that meets the following objectives:

- a water management system that separates potentially contaminated water and recycled process water from stormwater runoff;
- a stormwater management system that is consistent with industry best practice for an industrial area, and the ARC stormwater system can be integrated into a future stormwater system in the PCD catchment that overflows to the receiving environment and achieves a NorBE on receiving water quality; and
- commitment to a new wastewater (ie sewage) management system that is designed and operated in accordance with the methods described in *Designing and Installing On-Site Wastewater Systems (WaterNSW 2019b).*

3.5.4 Risk assessment guidelines for groundwater dependent ecosystems

The Risk Assessment Guidelines for Groundwater Dependent Ecosystems (Serov et al 2012) (GDE Risk Assessment Guidelines) are the NSW requirements for assessment and management of GDEs under the WM Act.

The GDE Risk Assessment Guidelines provide that GDEs:

- explicitly include any ecosystem that uses groundwater at any time or for any duration in order to maintain its composition and condition.

An ecosystem's dependence on groundwater can be variable, ranging from partial and infrequent dependence, ie seasonal or episodic (facultative), to total continual dependence (entire/obligate) (Figure 3.3).

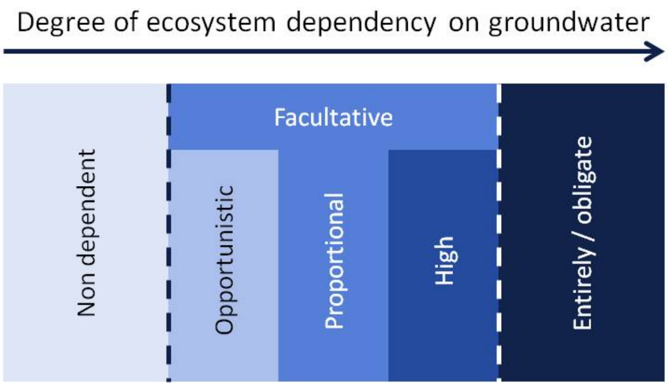


Figure 3.3 Groundwater dependent ecosystem level of dependence on groundwater

A GDE assessment has been conducted for the project (EMM 2022b), which considered variations in available water and ecosystem types, with assessment methods based on the GDE Risk Assessment guidelines.

3.6 Relevant Commonwealth guidelines

3.6.1 Australian and New Zealand Guidelines for Fresh and Marine Water Quality

The *Australian and New Zealand Guidelines for Fresh and Marine Water Quality* (ANZG), Agriculture and Resource Management Council of Australia and New Zealand and the Australian and New Zealand Environment and Conservation Council (ANZECC & ARMCANZ) 2000 describe the water quality objectives for marine and freshwater environments, aquatic ecosystems, primary industries, and recreational water.

An environmental and community value is defined in the national water quality guidelines (ANZG 2018) as a particular value or use of the environment that is important for a healthy ecosystem or for public benefit, health, safety or welfare, and requires protection from the effects of stressors. For groundwater systems, the term 'beneficial use' is also often used to describe environmental and community values. For each catchment in NSW, the Government has endorsed the community's environmental values for water, known as 'Water Quality Objectives'.

Environmental and community values recognised by the national water quality guidelines (ANZG 2018) are listed in Figure 3.4 below.

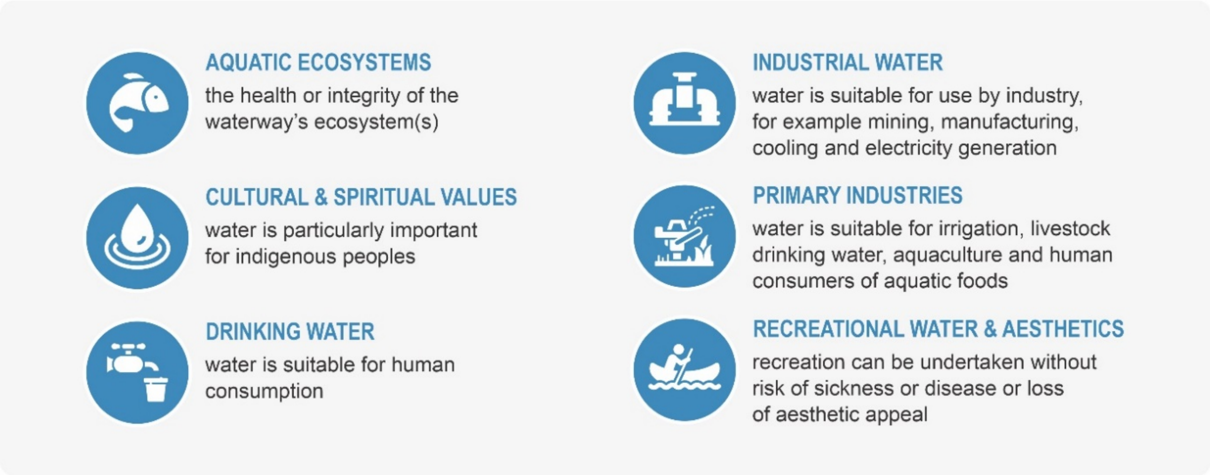


Figure 3.4 Environmental and community values

The groundwater at the project site supports the following values:

- aquatic ecosystems, where groundwater discharges as baseflow to permanent streams there is the potential for facultative reliance on groundwater;
- drinking water systems, groundwater discharge into Crisps Creek is part of the Sydney drinking water catchment;
- industrial water, alluvial groundwater from the Willeroo borefield is used for operations at the Eco Precinct and will be used for the proposed operations; and
- primary industries, as groundwater is used for stock, domestic and limited irrigation purposes across the local area.

4 Project setting

4.1 Climate

Prior to February 2015, rainfall data has been obtained from the Bureau of Meteorology (BoM) weather station 070036 (Lake Bathurst) located 8 km north-west of the site (BoM 2021). Onsite rainfall monitoring was undertaken between February 2015 and December 2020.

The average yearly rainfall from 1998 onwards is 614 millimeters (mm). There are minor seasonal fluctuations with wetter summers and drier winters. November to March are the wettest months with an average monthly rainfall of 60 mm, between April to July average monthly rainfall is 35 mm.

Figure 4.1 illustrates monthly rainfall and the cumulative deviation from the mean over a 22 year timeframe. Monthly cumulative deviation from the mean shows whether rainfall trends are above average (trending upwards) or below average (trending downwards). The average rainfall trend is typically cyclical within two to four year periods. Severe drought conditions prevailed from 2017 to February 2020 after which rainfall has been above average.

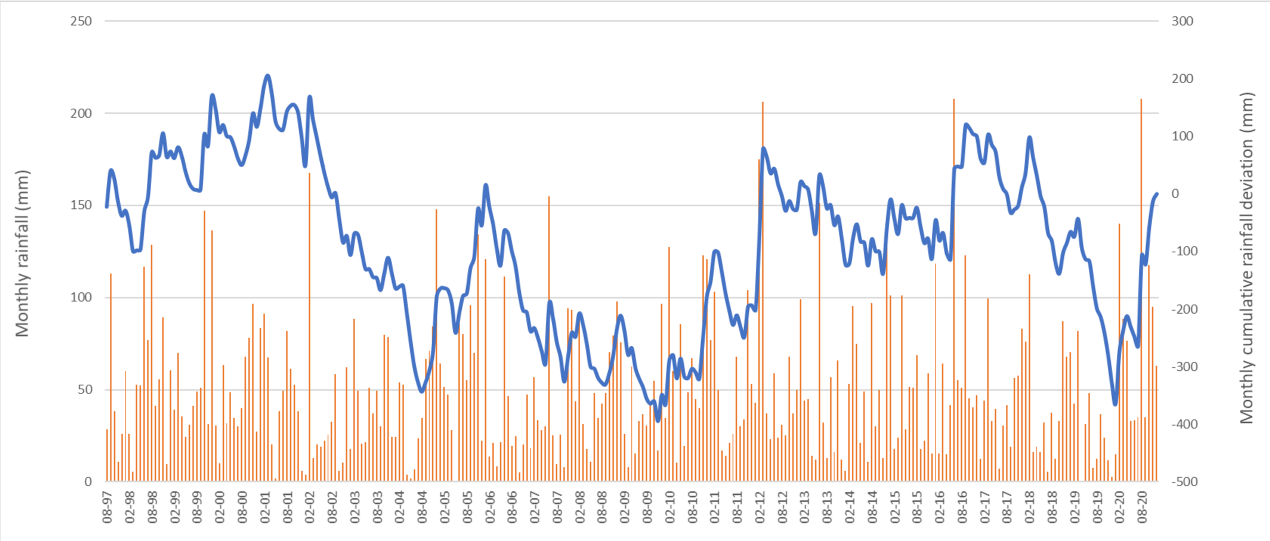


Figure 4.1 Monthly cumulative rainfall deviation

Average annual evaporation obtained from the site monitoring station is 726 mm (spanning 2015 to 2020), which is lower than that documented in Eath2Water (2010) 1,420 mm/yr. Both measurements exceed average monthly rainfall.

4.2 Topography

The Eco Precinct has an average elevation of approximately 800 mAHD across the site with a maximum of 1,000 m AHD in the north-eastern corner along the ridgeline of the Great Dividing Range (GDR). The region is characterised by undulating plains with the GDR running through the Eco Precinct in a north-south alignment. The original topography has been altered by the excavation of the mine void, emplacement of waste rock dumps, and construction of evaporation and storage dams.

4.3 Surface water

The Eco Precinct is situated in the headwaters of both the Lake George and Wollondilly River catchments with Allianoyonyiga Creek flowing to the west, and the Mulwaree River catchment via Crisps Creek flowing to the east. The GDR ridgeline separates the catchments. Other prominent water features include the ephemeral Lake George approximately 7.5 km to the west and Lake Bathurst approximately 9 km to the north-east of the Eco Precinct (see Figure 1.2).

Roughly one-third of the Eco Precinct (western side of the GDR) forms part of the Lake George Catchment while the remainder on the eastern side of the GDR is part of the Wollondilly catchment. The Wollondilly catchment forms part of the Warragamba Dam catchment, which contributes to Sydney's drinking water supply and is thus a WaterNSW regulatory area.

Typically both Allianoyonyiga and Crisps Creek are intermittent, with flow predominantly in the summer. Earth2Water (2010) hypothesise that Crisps Creek is hydraulically connected with the colluvial groundwater system, and is a gaining stream during wet conditions, but reverts to a losing stream in dry conditions, if there is water in the watercourse. Allianoyonyiga Creek is predominately incised into the weathered bedrock but is likely to be a gaining stream in its lower reaches towards Lake George.

4.4 Geology

The project site is situated over the Lachlan Fold Belt, a massive geological structure in south-eastern Australia. The Lachlan Fold Belt is a 700 km wide belt of deformed, Palaeozoic deep and shallow marine sedimentary rocks, cherts, and mafic volcanic rocks (Grey 1997). The bedrock across the development footprint consists primarily of volcanic geological units that have undergone metamorphism, faulting and folding.

Reference to the Braidwood 1:100,000 Geological Sheet (2017) indicates the site overlies Siluro-Devonian aged Woodlawn Volcanics, Covan Creek Formation and older Ordovician Adaminaby Group, Abercrombie Formation. There are minor intrusions of Silurian-Devonian aged pink granite and Currawang Basalt. The outcropping geology at the site is shown in Figure 4.2. The geological sequences includes lithified volcanics, volcaniclastics as well as sedimentary shales and sandstones. Review of the site bore logs show dolerite, shale, tuff, siltstone and rhyolite are commonly intersected.

Quaternary colluvium is mapped overlying the Woodlawn Volcanics, adjacent to Collector Road, comprising clay rich alluvium/colluvium from old fluvial deposits and hillwash sediments. Parsons Brinckerhoff (2012) report the thickness of the colluvium ranges from 1 m at the top of hills to 5 m within valleys. Clay rich colluvium/alluvium underlies the evaporation dams, ED1 and ED2, comprising clays of medium to high plasticity with traces of fine sand and gravel. The maximum recorded thickness of the colluvial sediments underlying ED1 is 19.5 m, with thinner colluvium/alluvium under ED2. This is likely a local depositional environment, possibly controlled by geological structure.

Further west, at the Willeroo borefield, Quaternary alluvium is deposited along the eastern margin of Lake George and adjacent to watercourses. This alluvium comprises an alluvial sand and gravel palaeochannel deposit, an old bedrock channel that has been filled with unconsolidated sediments.

The ARC overlies colluvium/alluvium, which was described as silty residual soil and weathered rock by Golder (2021) during drilling investigations. The colluvium is approximately 2 m in thickness. The underlying competent fractured rock comprises predominately siltstone, with a dolerite intrusion in the south.

Major, mapped faults and thrusts trending north-south are present in the development footprint and surrounds associated with the Captains Flat/Goulburn Synclinorial zones (Parsons Brinckerhoff 2012). Specifically, the Fairy Meadow Thrust Fault runs north-west to south-east through the site (Braidwood 1:100,000 Geological Sheet 2017). Regional faults and joints form a synclinorial-anticlinorial fold pattern, which results in a significant lack of continuity in the horizontal plane (AECOM 2017). Pers coms with Dino Parisotto (Earth2Water, Director) on 12 August reported an unnamed fault running east-west under ED1, whereby Allianoyonyiga Creek is a possible surface expression of this fault. There is a presumed throw associated with this fault, and to the immediate north of the fault are the thickest deposits of clay.

4.4.1 Soil acid potential

Golder tested the soil acid generation potential from the ARC and various fill sites across the Eco Precinct. The majority of fill, sediments and some natural soils were considered to be acid-forming or potentially acid-forming (PAF) via the oxidation of pyrite and pyrrhotite. A low acid neutralising capacity is noted owing to a lack of carbonates, calcite and dolomite in the host rock (Golder 2021).

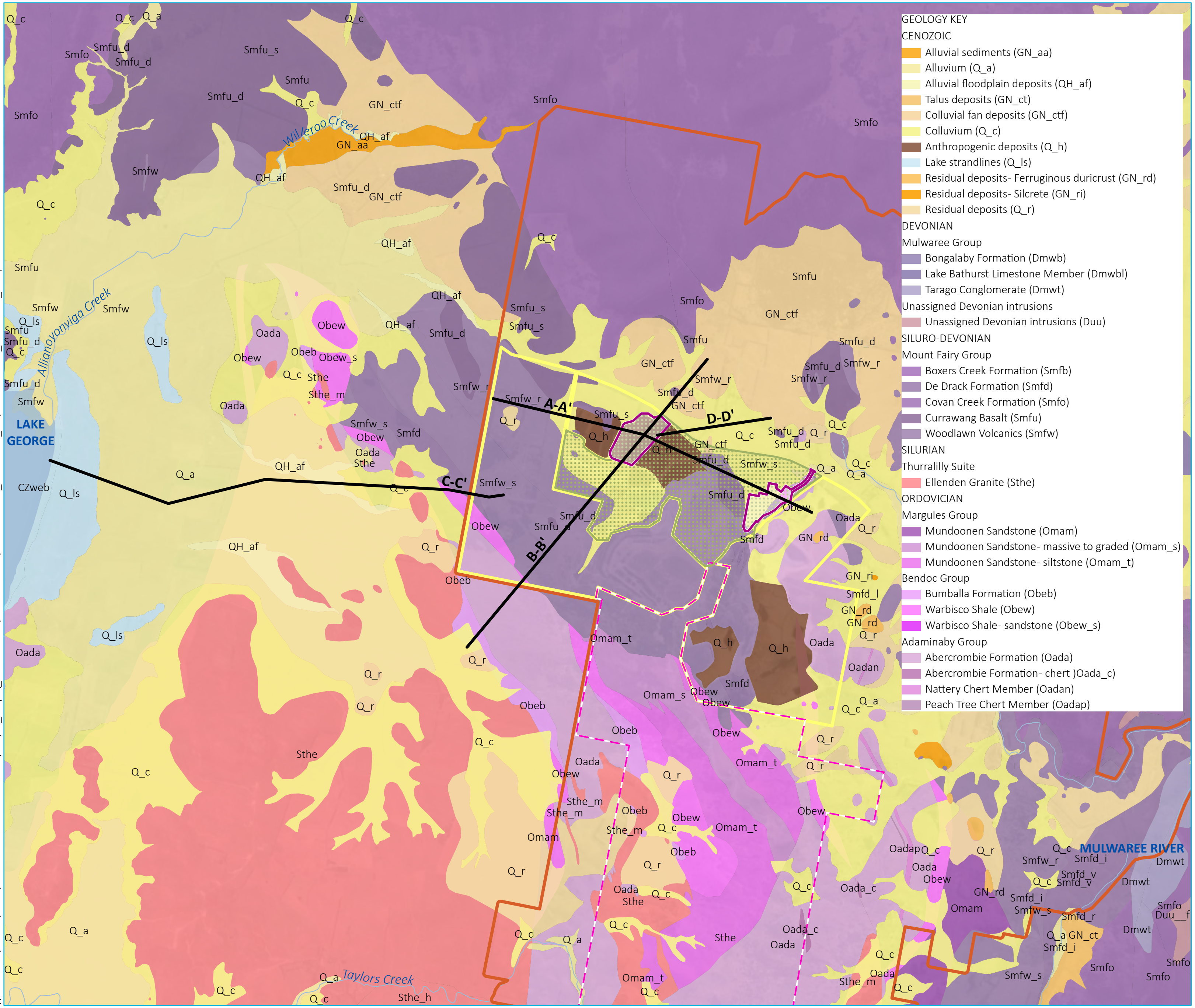
4.5 Groundwater

Groundwater at the site is associated with the following geological units:

- local, minor groundwater associated with the weathered rock and hillwash sediments and/or unconsolidated colluvial and alluvial sediments; and
- regional groundwater within the fractured hard rock Ordovician and Silurian-Devonian aged volcanic, intrusive and sedimentary units, with groundwater primarily located in the rock fractures and joint spaces.

Both groundwater systems are limited resources owing to low porosity and permeability within the fractured rock units, and the limited extent of the clay rich colluvium. Groundwater yields from the underlying hard rock rely on the interception of fractures.

In the vicinity of the Willeroo borefield, the alluvial deposits are more extensive (especially in the palaeochannel areas) and comprise a shallow alluvial aquifer and a deeper alluvial aquifer. These sand and gravel zones are high permeability formations that provide useful supplies for small scale irrigation, mining, industrial, and stock and domestic uses.



KEY

- Development footprint
- Veolia integrated waste management operations
- Woodlawn Eco Precinct
- Crisps Creek Intermodal Facility (IMF)
- Woodlawn Mine operations area
- Woodlawn Wind Farm
- Cross section location
- Watercourse
- Named waterbody

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Source: EMM (2022); DFSI (2017); GA (2011)

Geology

Woodlawn Advanced Energy Recovery Centre
Groundwater assessment
Figure 4.2

EMM
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5 Local hydrogeology

As outlined in Section 4.5 there are two groundwater systems at the immediate development footprint: a local, minor shallow system associated with unconsolidated colluvium/weathered rock and in parts alluvium, and the deeper, regional fractured rock groundwater system. The extent of the local groundwater system is limited, owing to the distribution of colluvium/alluvium.

Underlying the evaporation dams the alluvium/colluvium is clay rich and is observed to be thicker on northern half of ED1, presumably associated with a fault running west-east under ED1. The base of the clayey alluvium and the weathered bedrock forms an aquitard that separates the overlying colluvial/alluvial groundwater system from the fractured rock groundwater system. The colluvial/alluvial/weathered bedrock groundwater system is considered unconfined, and the fractured rock groundwater system is considered semi-confined to confined based on measured groundwater elevations.

Groundwater flow in the regional fractured rock groundwater system is dominated by secondary porosity, comprising structural features such as joints, fractures, faults, shear zones and bedding planes. Groundwater flow in the local colluvial/alluvial groundwater systems occurs via primary porosity, ie flow within the colluvial sediments, particularly any sand and gravel lenses, but is constrained by clay.

5.1 Groundwater monitoring

Veolia conducts regular groundwater level and quality monitoring across the Eco Precinct at 52 groundwater monitoring bores, of which 38 are regularly monitored (ie every quarter). These bores target the shallow colluvium, colluvium/alluvium and fractured rock. Their location is shown in Figure 5.1 and an overview of the bore construction data for the active monitoring bores is included in Table 5.1 (all bore details are included in Appendix B). Seventeen groundwater monitoring bore target the weathered bedrock and 16 bores alluvial/colluvial groundwater systems, the target for the remaining bores is unknown.

Groundwater levels and groundwater quality are assessed every three months, with sampling details included in *Soil and Water Management Plan for Woodlawn Bioreactor* (Veolia 2018). Monitoring commenced at different intervals, with the earliest starting in 1996. An overview of the monitoring network and the sampling period is included in Appendix B.

Table 5.1 Overview of active groundwater monitoring network

Monitoring point	Depth (mbgl)	Screen (mbgl)	Target unit	Target formation	Location
MB1	32.2	26–32.2	Dolerite	Fractured rock	Evaporation dam
MB2	13.2	7–13.2	Clay/dolerite (weathered)	Alluvium/colluvium	Evaporation dam
MB3	25.8	20.8–25.8	Clay/gravel	Colluvium/alluvium	North of Crisps Creek
MB4	25.8	20.8–25.8	Shale	Fractured rock	Bioreactor
MB5	25.8	20.8–25.8	Tuff	Fractured rock	Waste rock dam
MB6	25.8	20.8–25.8	Shale	Fractured rock	Evaporation dam
MB7	29	26–29	Shale/tuff	Fractured rock	Evaporation dam
MB8	25.9	Unknown	Unknown	Unknown	Collector Road
MB10	20.8	19.8–20.8	Gravel/dolerite (weathered)	Alluvium/colluvium	Evaporation dam
MB10S	9.1	Unknown	Tuff	Fractured rock	Evaporation dam
MB11	5.3	2.3–5.3	Dolerite/shale (weathered)	Alluvium/colluvium	Evaporation dam
MB12	13.2	10.2–13.2	Dolerite	Fractured rock	Evaporation dam
MB13	13.2	10.2–13.2	Dolerite	Fractured rock	Allianoyonyiga Creek
MB14	12.5	9.5–12.5	Dolerite	Fractured rock	Evaporation dam
MB15	23.7	17–23.7	Rhyolite	Fractured rock	Waste rock dam
MB16	7.3	3–6	Clay, gravel, dolerite	Alluvium/colluvium	Waste rock dam
MB17	15.4	9.4–15.4	Volcanics, tuff	Fractured rock	Waste rock dam
MB28	9	6–9	Gravely clay	Colluvium/alluvium	Evaporation dam
MB33	Unknown	Unknown	Unknown	Unknown	Bioreactor
MB34	Unknown	Unknown	Unknown	Unknown	Bioreactor
MB35	Unknown	Unknown	Unknown	Unknown	Bioreactor
MW-FRC1	5.2	2.2–5.2	Siltstone (weathered), clay	Alluvium/colluvium	Evaporation dam
SP2-MW1	4.5	1.5–4.5	Clay	Colluvium/alluvium	Spring 2
ED3B	5.9	Unknown	Unknown	Unknown	Evaporation dam
MW8D	10.4	7.4–10.4	Tuff/Siltstone	Fractured rock	Evaporation dam
MW8S	6.5	7.4–10.4	Tuff/Siltstone	Fractured rock	Evaporation dam
MW9S	7	4–7	Siltstone	Fractured rock	Evaporation dam
MW10S	9.1	6–9	Siltstone	Fractured rock	Evaporation dam
WM1	115	Unknown	Dolerite	Fractured rock	Bioreactor
WM5	6	Unknown	Clay/tuff	Unknown	Evaporation dam
WM6	6	Unknown	Tuff/volcanics	Unknown	Evaporation dam
WMBT11 [1]	Unknown	Unknown	Unknown	Unknown	Unknown

1. Location unknown, not shown on Figure 5.1

Source: EMM (2022); VEOLIA (2022); DFSI (2017)

KEY
- Development footprint
- Veolia integrated waste management operations
- Woodlawn Eco Precinct
- Crisps Creek Intermodal Facility (IMF)
- Woodlawn Mine operations area
- Woodlawn Wind Farm
- Major road
- Minor road
- Vehicular track
- Watercourse

Groundwater monitoring bore- sampled (formation)
- Colluvium/alluvium
- Fractured rock
- Surface water
- Unknown

Groundwater monitoring bore- not sampled (formation)
- Colluvium/alluvium
- Fractured rock
- Unknown

Groundwater monitoring bores

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Groundwater assessment
Figure 5.1

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5.2 Groundwater levels and flow

An overview of the groundwater levels measured across the Eco Precinct is provided in Table 5.2.

Table 5.2 Overview of measured groundwater levels at the Eco Precinct

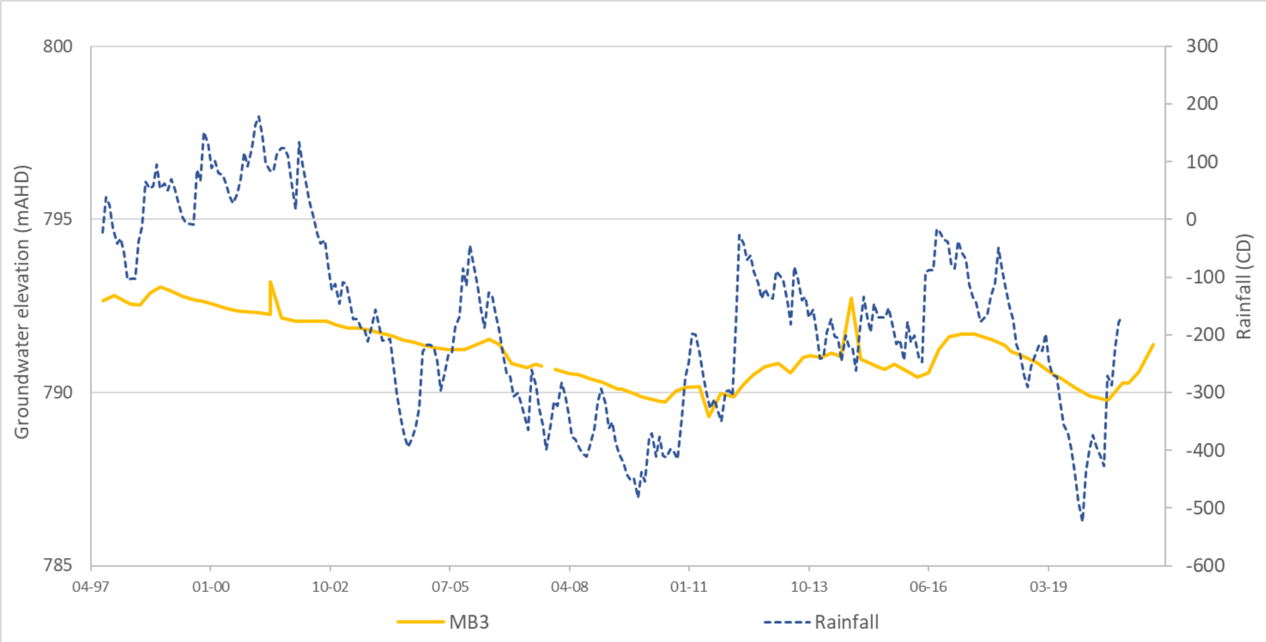
Groundwater unit	Depth (mbgl[1])			Elevation (mAHD[2])		
	Minimum	Maximum	Average	Minimum	Maximum	Average
Shallow alluvium/colluvium/ weathered bedrock	0.2	9.3	2.6	678.31	793.2	770.0
Fractured rock	0.03	46.9	8.7	734.3	793.3	772.3

Notes: 1. mbgl = metres below ground level
2. mAHD = metres Australian Height Datum

The average depth to groundwater within the shallow alluvium/colluvium is around 3 mbgl. The groundwater elevation in the fractured rock is deeper, at around 9 mbgl, and this represents the pressure head of the confined/semi-confined system, not the depth to groundwater. At some locations (such as in the vicinity of ED1) the water levels in the deep fractured rock groundwater system are higher than the water levels in the shallow colluvial/alluvial/weathered rock groundwater system.

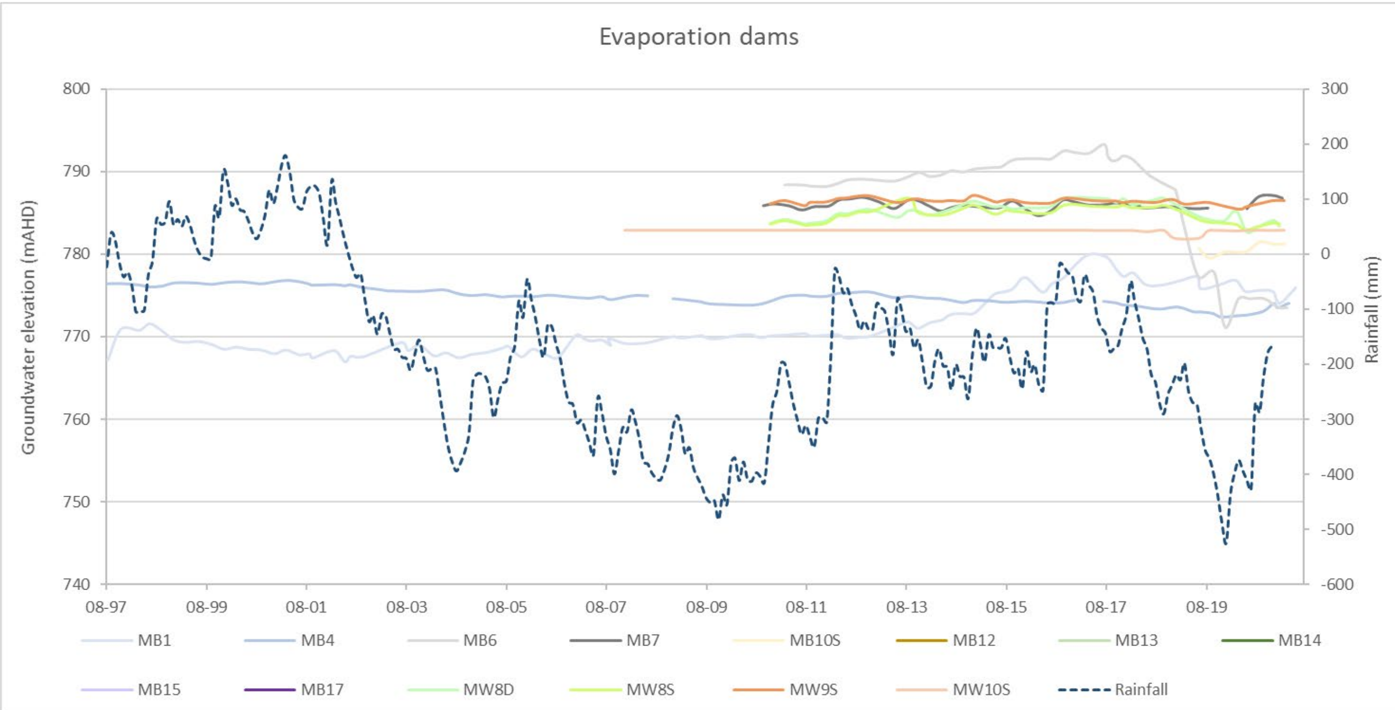
Hydrographs included in Figure 5.2 and Figure 5.3 show groundwater levels trends from a bore targeting the alluvium/colluvium and the numerous site monitoring bores targeting the fractured rock respectively, plotted with monthly cumulative deviation rainfall data. Long term trends for the alluvium/colluvium are presented from a bore not impacted by leakage from ED1 (monitoring bore MB3).

Groundwater elevations in the alluvium/colluvium (Figure 5.2) are comparable to the long term rainfall trends, with a decline in groundwater level seen between 2002 and mid-2011 and gain from 2017 to early 2020, consistent with largely below average rainfall. Groundwater levels in the fractured rock are mostly stable (Figure 5.3), with some increasing/decreasing trends associated with site operations (ie mining, infilling of pits, etc). Some fractured rock monitoring bores (MB8s and MB8d) show declining groundwater elevations consistent with long term rainfall trends.



Notes: 1. CD = cumulative deviation rainfall, taken from site data and BoM site 070036

Figure 5.2 Shallow groundwater hydrograph



Notes: 1. CD = cumulative deviation rainfall, taken from site data and BoM site 070036

Figure 5.3 Fractured rock groundwater hydrograph

5.2.1 Spatial trends

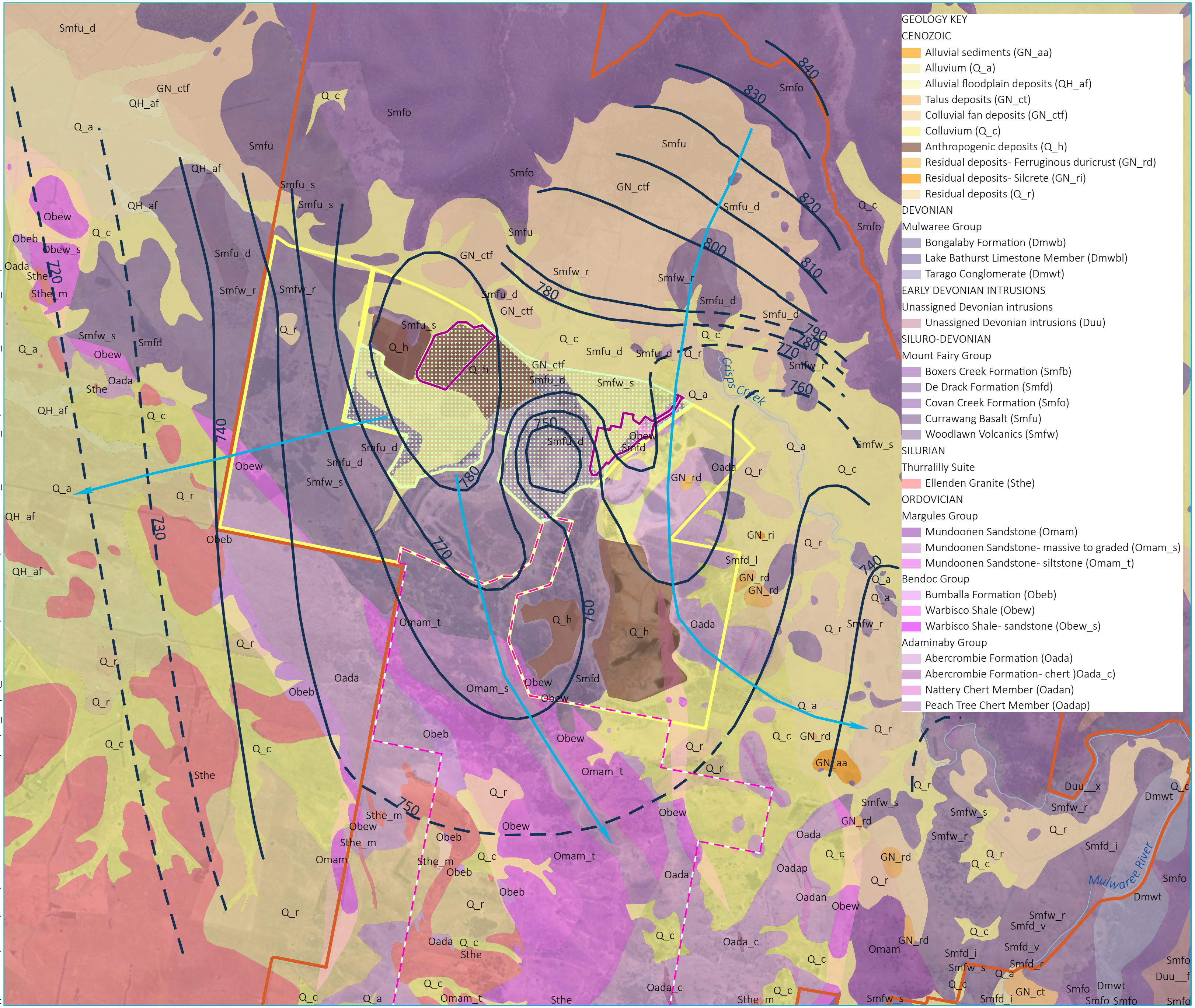
Groundwater elevations have been plotted as contours showing groundwater flow directions for the deep fractured rock groundwater system (Figure 5.4) and the shallow alluvium/colluvium system (Figure 5.5).

Groundwater in the regional fractured rock flows away from the GDR feature, with regional groundwater flow to both the east and west from the development footprint. Based on the topography and the available water level data, the water level contours wrap around Crisps Creek suggesting that the creek is a potential groundwater discharge feature for the fractured rock groundwater system. Localised groundwater flow towards the Bioreactor mine void also occurs; this feature forms a 'groundwater sink' whereby a hydraulic gradient is generated towards the void. This cone of depression represents a lowering of the water levels in the vicinity of the void, inferring that the mine void has led to dewatering of groundwater in the surrounding bedrock area.

Groundwater in the alluvium/colluvium and weathered rock around the evaporation dams mimics surface topography, flowing towards watercourses and other low points in the topography. The contours are strongly influenced by leakage from the two evaporation dams, ED 1 and ED2. The shallow groundwater flow direction is towards both Crisps Creek to the north-east and Allianoyonyiga Creek to the west.

5.3 Groundwater yield and hydraulic conductivity

Reported yields from the site bores indicate groundwater inflows are very low, ranging from 0 to 0.5 litres per second (L/s). The frequent lack of groundwater ingress observed during historic drilling through both the shallow unconsolidated and fractured rock units is indicative of the very low groundwater hydraulic conductivities and permeability. Field based tests of hydraulic conductivity (ie rising/falling head slug tests) report extremely low values, with some monitoring bores taking a week or more to recover after purging a single well volume (Earth2Water 2010).



KEY

- Development footprint
- Veolia integrated waste management operations
- Woodlawn Eco Precinct
- Crisps Creek Intermodal Facility (IMF)
- Woodlawn Mine operations area
- Woodlawn Wind Farm
- Watercourse
- Named waterbody
- Groundwater flow direction

Fractured rock

- Groundwater contour (m AHD)
- Inferred groundwater contour (m AHD)

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Source: EMM (2022); DFSI (2017); GA (2011)

Fractured rock groundwater contours

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Groundwater assessment
Figure 5.4

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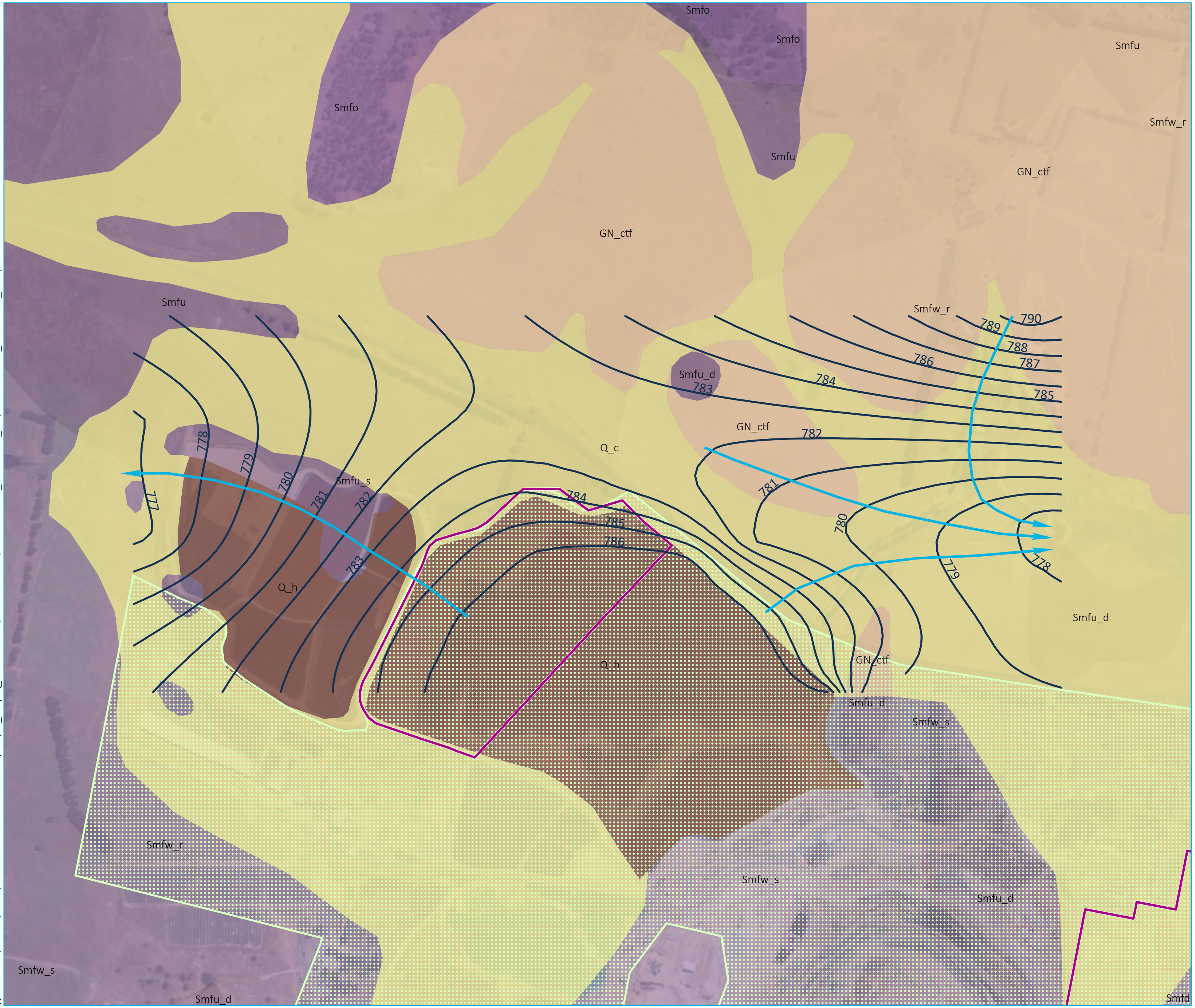

KEY

Development footprint
Veolia integrated waste management operations
Colluvial groundwater contour (m AHD)
Groundwater flow direction

GEOLOGY

CENOZOIC

Colluvial fan deposits (GN_ctf)
Colluvium (Q_c)
Anthropogenic deposits (Q_h)

SILURO-DEVONIAN

Mount Fairy Group

De Drack Formation (Smfd)
Covan Creek Formation (Smfo)
Currawang Basalt (Smfu)
Woodlawn Volcanics (Smfw)

Source: EMM (2022); DFSI (2017); GA (2011)

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Alluvial/Colluvial groundwater contours

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Groundwater assessment
Figure 5.5

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5.4 Recharge and discharge

Groundwater recharge to the two groundwater systems is via direct rainfall infiltration. Rainfall recharge to the deeper fractured rock occurs on upper slopes, ridgelines and hilltops of the landscape where the rock sub-crops or outcrops and is greatest where open fractures (secondary porosity) occur in the rock matrix. Both the NSW Office of Water (NOW) (2011) and the Department of Primary Industries, Water (DPIW) (2012) report the infiltration rate for the outcropping areas of the Goulburn Fractured Rock Groundwater Source and the Lachlan Fold Belt MDB Groundwater Source as 4% of annual average rainfall.

The bulk of groundwater flow away from the recharge areas in the fractured rock system is via through flow. Groundwater discharge points from the fractured rock system comprise the former mine pit and water bores, and natural locations such as springs, spring fed dams, watercourses and the relatively lower lying areas like gullies where open fracture conduits could exist.

There are two known groundwater discharge locations associated with the shallow colluvium. The closest feature is a seep on Allianoyonyiga Creek, located at the contact between the fractured rock and the colluvium. The seep was observed within the channel of Allianoyonyiga Creek for approximately 20–50 m (Niche 2018). Surface water quality analysis suggests a groundwater contribution from Allianoyonyiga Creek in the vicinity of ED2 (Niche 2018). There is also a spring to the north of Collector Road 750 m from site, adjacent to Crisps Creek (AECOM 2017). The spring is within the colluvium, but is dammed and presumably comprises water from both groundwater and overland flow.

5.5 Groundwater quality

Due to historical use of the Eco Precinct as a mine and current use as a waste management facility, there are a number of activities that affect groundwater quality. Historic stockpiling, acid mine drainage, underground storage tanks, sediments ponds, tailings dams and evaporation dams have impacted groundwater quality on a local scale (Golder 2022a).

In general, groundwater from the fractured rock has a natural acidic to neutral pH, with a brackish salinity (~3,000 microsiemens per centimetre (µS/cm)) and high concentrations of sulfate, copper, zinc and lead are common (AECOM 2017). Review of the fractured rock groundwater shows exceedances of the 95% ecological species protection levels reported in ANZG (2018) for arsenic, cadmium, copper, lead, manganese and zinc. The fractured rock groundwater quality is influenced by the host rock minerology and exceedances of the ANZG criteria is not unusual for groundwater from low permeability fractured rock groundwater systems.

Regional groundwater quality was assessed from bores within 10 km of the site, outside of the site boundary. Salinity data was obtained for these bores through the WaterNSW (2021) real-time water database. Electrical conductivity values for these bores, which are screened within the fractured rock system, ranged between 600 and 4,000 µS/cm, with a median value of 1,740 µS/cm, which is slightly brackish.

Groundwater in the alluvium/colluvium from monitoring bore MB3 (ie not impacted by leakage from ED1) is neutral and slightly brackish (averaging 2,048 µS/cm). Salinities are comparable to the underlying fractured rock groundwater system, indicative of the clayey matrix of the colluvium, possible discharge from the underlying fractured rock, and low rainfall recharge rates. Metal results are typically an order or two magnitude lower that results seen in the fractured rock, although the zinc result frequently exceeds the ANZG 95% ecosystem protection trigger value.

5.6 Groundwater receptors

5.6.1 Third-party bores

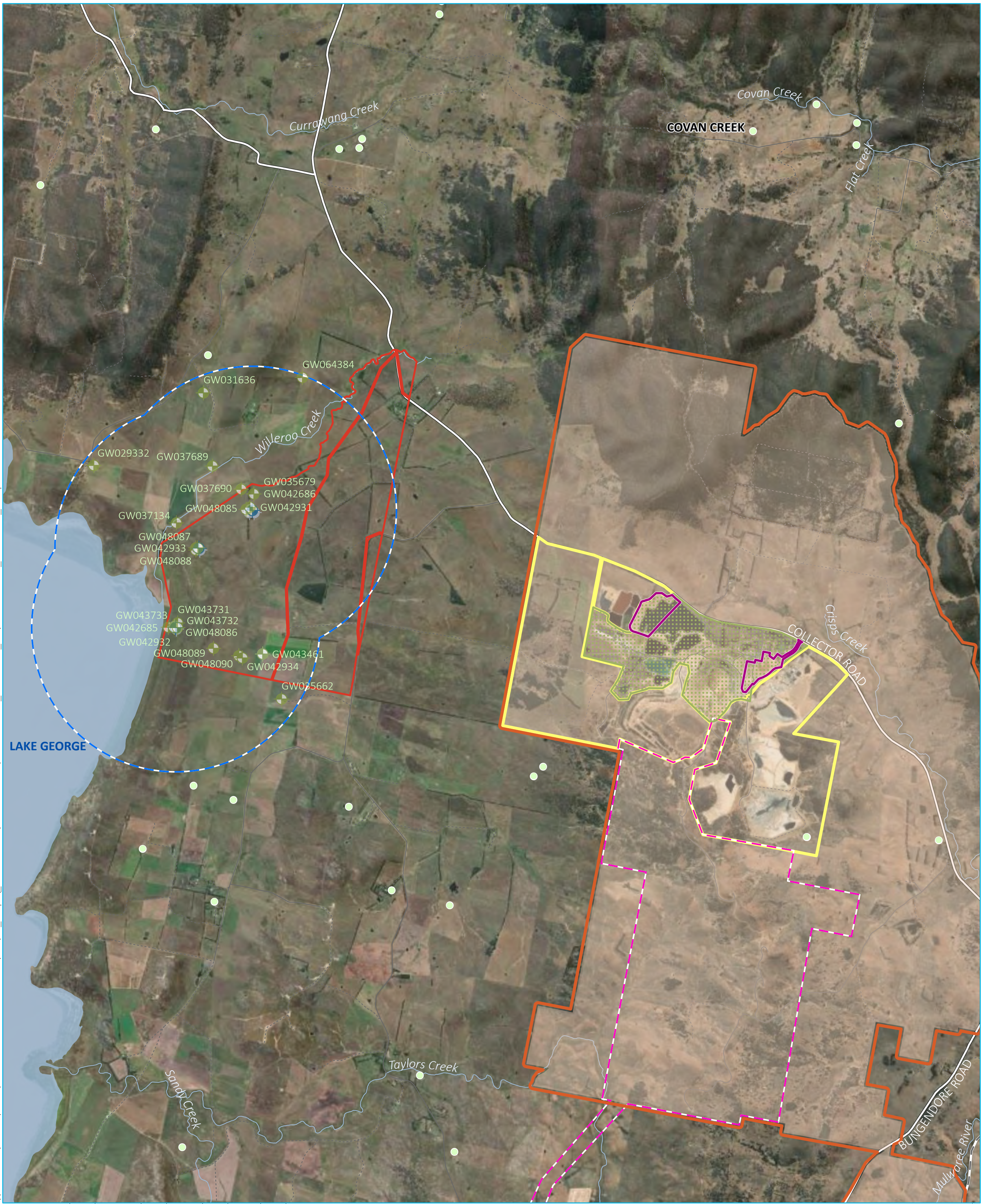
There are no registered groundwater users within 2 km of the proposed ARC and the encapsulation cell. The closest registered bore is 2.5 km to the south-west, GW405046. This bore is reportedly used for stock purposes, targeting the fractured rock unit (dolerite) with a yield of 0.9 L/s.

The Willeroo borefield is within Lot 11, DP 754919 and is located 6 km west of the ARC in the Lake George catchment. Within 2 km to the south and north of the production bores, are 7 registered water bores. Details of these bores are provided in Table 5.3, and the majority are licensed for stock and domestic use. Registered third-party bores are shown in Figure 5.6.

Table 5.3 Registered water bores within 2 km of Willeroo borefield

ID	Easting	Northing	Year drilled	Depth	Yield (L/s)	Bore use
GW037134	726924	6119217	1972	58.5	-	Stock
GW037690	727823	6119688	1972	57.9	-	Stock
GW037689	727425	6120007	1972	21.3	-	Stock
GW029332	725777	6120017	1968	44.2	0.2	Household
GW031636	727299	6121027	1968	18.3	1.52	Irrigation
GW064384	728673	6121239	1987	30.5	0.4	Household
GW035662	728384	6116776	1934	6.0	-	Stock

Notes: L/s = litres per second
Notes: * = currently not in use



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Source: EMM (2022); VEOLIA (2022); BOM (2021); DFSI (2017)

0 1 2 km
GDA 1994 MGA Zone 55
N

KEY

- Development footprint
- Veolia integrated waste management operations
- Woodlawn Eco Precinct
- Crisps Creek Intermodal Facility (IMF)
- Woodlawn Mine operations area
- Woodlawn Wind Farm
- Rail line
- Major road
- Minor road
- Vehicular track
- Watercourse

Third-party bore
- Within 2 km Willeroo borefield
- Outside 2 km Willeroo borefield

Willeroo borefield
- Production bore
- Monitoring bore
- Willeroo borefield lot boundary
- Willeroo borefield 2 km buffer

Third-party bores

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Figure 5.6

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5.6.2 Groundwater dependent ecosystems

Within the Eco Precinct there are no high priority groundwater dependent ecosystems reported in either of the WSPs.

Reference to the BoM groundwater dependent ecosystem atlas shows there are no mapped GDEs (aquatic and/or terrestrial) within the Eco Precinct (Figure 5.7). The BoM atlas shows low potential terrestrial GDEs 1 km to the north of ED1 comprising eastern tableland dry shrubs, grasses and forests. Aquatic GDEs in the vicinity of the development footprint may be indirectly impacted to a small degree by the project, however these ecosystems are likely to be dependent primarily on surface water flow.

The *Biodiversity Development Assessment Report* (EMM 2022b) for the project noted an existing wetland area to the north of the ARC that comprises with grasslands and planted buffers that provides both visual amenity and habitat connectivity. It is likely that part of this wetland is a natural feature and part an anthropogenic feature caused by alteration to local hydrology initiated by the construction of Collector Road and infrastructure within the Eco Precinct.

Crisps and Allianoyonyiga Creeks are considered to have moderate potential for aquatic GDEs according to the BoM atlas. There is a seep 1.3 km to the west on Allianoyonyiga Creek and spring 1.3 km to the north-east on Crisps Creek; the spring is down hydraulic gradient of ED1. The spring, which has been dammed, is thought to receive water contribution from overland flows based on the water quality. The creeks are intermittent, and are therefore only occasional groundwater discharge features, but they could support facultative ecosystems. The *Biodiversity Development Assessment Report* (EMM 2022b) noted the vegetation species around the spring on Crisps Creek comprise Juncus grasses and buffalo grass cover.

5.7 Conceptual hydrogeological model

Groundwater at the Eco Precinct is associated with shallow colluvium/alluvium/weathered bedrock, and the underlying volcanic fractured rock units. The alluvium/colluvium predominately comprises weathered rock but is rich in clay and alluvium around ED1. The extent of the alluvium/colluvium is local and the sediments have low permeability. Groundwater flow in the competent fractured rock occurs via secondary permeability, fracture flow. The groundwater elevation in the fractured rock is pressurised, meaning groundwater in the fractured rock unit rises above the aquifer zone and is semi-confined to confined.

The groundwater flow direction in the fractured rock is to the east and west, the site is located on a groundwater divide which is the same as the topographic divide. The groundwater flow direction in the alluvium/colluvium is a muted reflection of topography, with flow generally towards local watercourses.

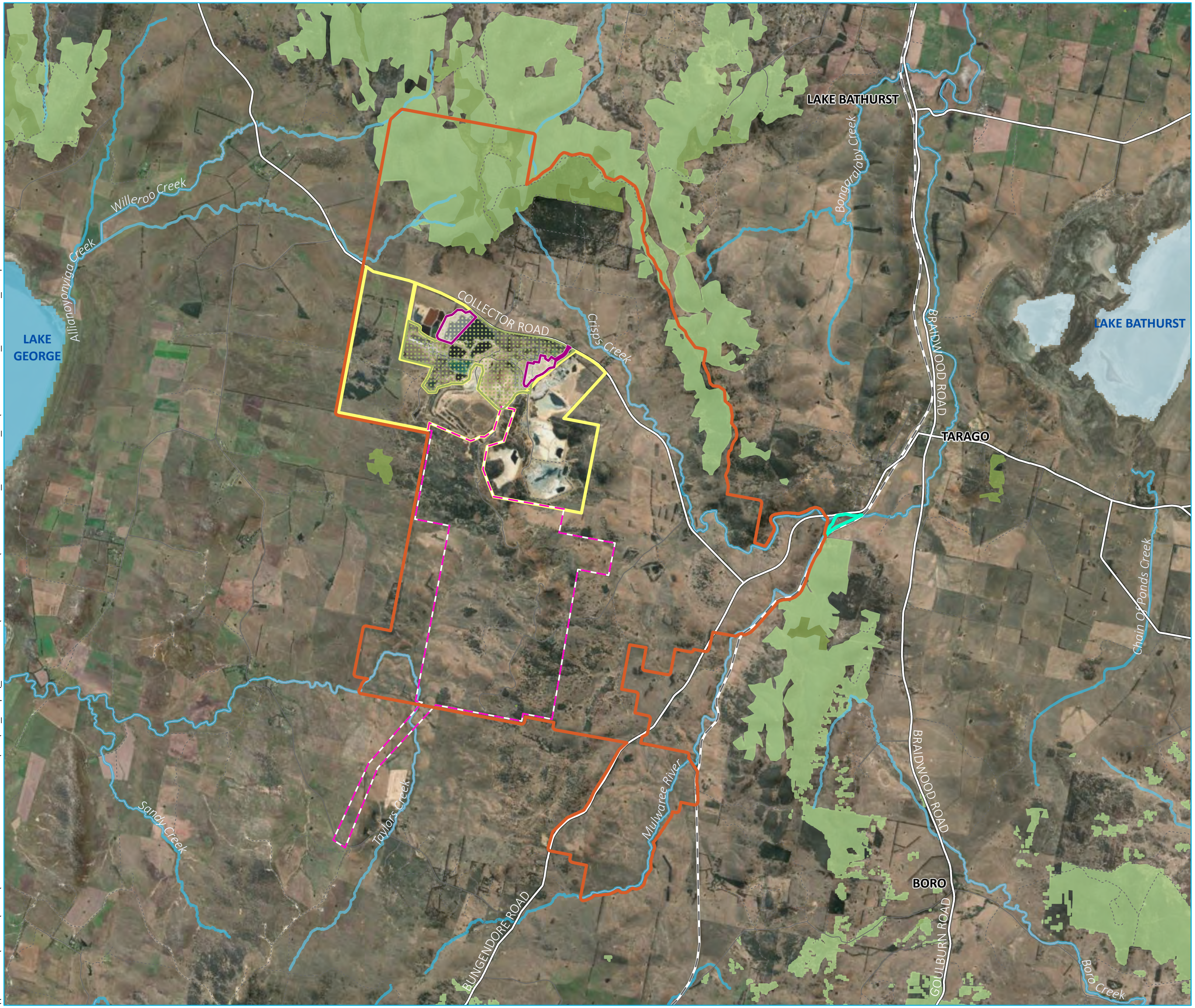
Groundwater abstraction and use is low from the fractured rock and does not occur from the colluvium/alluvium across the Eco Precinct.

Recharge to both the colluvium/alluvium and fractured rock groundwater systems occurs via rainfall recharge at outcrop, however this is only expected following heavy and sustained rainfall noting annual average evaporation exceeds annual average rainfall. The bulk of groundwater discharge from the fractured rock comprises flows to the former mine pit and water bores, and natural locations such as springs, spring fed dams, watercourses and the relatively lower lying areas like gullies where open fracture conduits may exist. There are no known discharge locations across the main project site. There are two groundwater discharge location from the colluvium, a seep on Allianoyonyiga Creek, near the contact with the fractured rock, and a spring near Crisps Creek. The spring near Crisps creek is dammed and is expected to comprise both groundwater and overland flow.

The evaporation dams have been shown to leak via preferential flow pathways to the north-east via the colluvium. Historic artesian conditions have been observed around the perimeters of these dams, suspected to be caused by hydraulic loading from stored water in each of the dams (AECOM 2017).

It is proposed that the colluvium/alluvium near Crisps Creek is hydraulically connected with groundwater migrating from the colluvial/alluvial system to the south in the vicinity of ED1. This watercourse is expected to act as a gaining stream during wet conditions, but could revert to a losing stream in dry conditions, if there is water or ponds along the watercourse (Earth2Water 2010). Allianoyonyiga Creek is also intermittent, with only the first 200 m of the watercourse overlying colluvium, and the remainder overlying the fractured rock, before it joins Willeroo Creek.

A conceptual west-east hydrogeological cross section in shown in Figure 5.8 with another south-west to north-east cross section to Crisps Creek shown in Figure 5.9.



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Source: EMM (2022); DFSI (2017); GA (2011)

Groundwater dependent ecosystems

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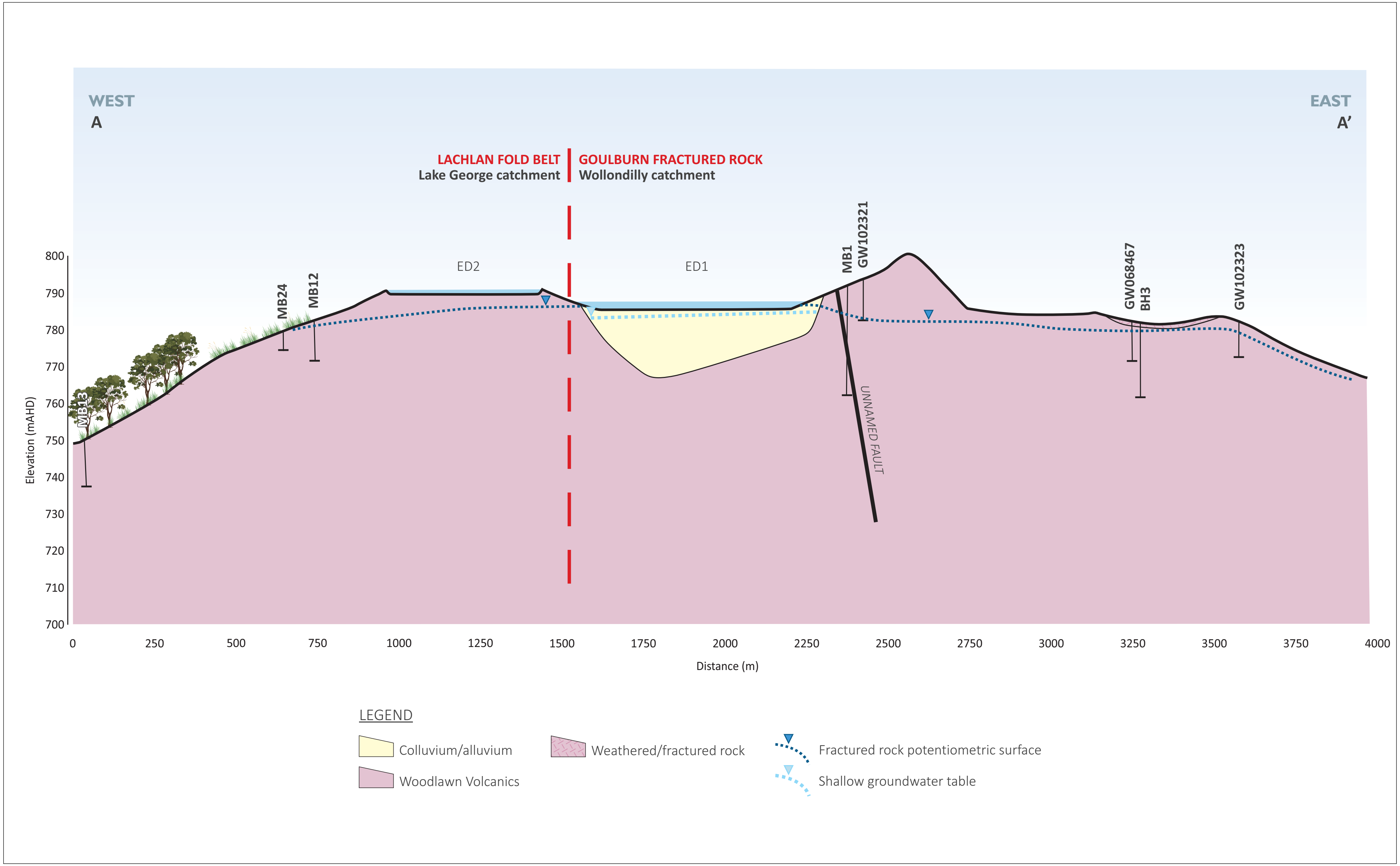
Groundwater assessment
Figure 5.7

creating opportunities



EMM creating opportunities

West–east conceptual cross section

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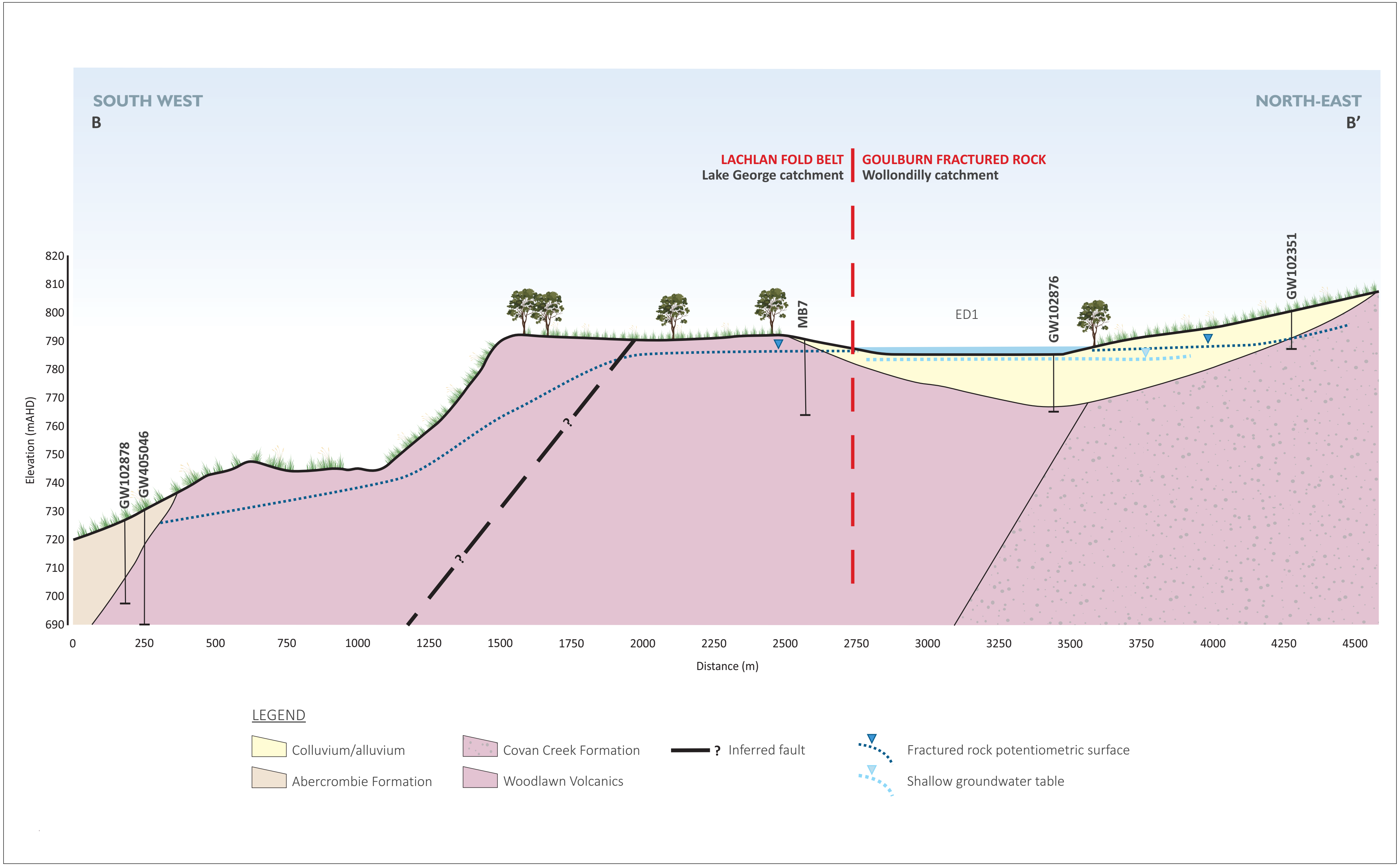
Groundwater assessment

Figure 5.8



Southwest–northeast conceptual cross section

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Groundwater assessment

Figure 5.9

6 Site hydrogeology

This section discusses the main areas of interest to the Groundwater Assessment and the works undertaken to further inform the conceptual hydrogeological understanding of these areas, including: the proposed encapsulation cell and current ED1 area, the proposed ARC and the Willeroo borefield.

The following works were undertaken by EMM for this Groundwater Assessment:

- groundwater level monitoring, comprising singular manual measurements of groundwater levels from select bores;
- groundwater quality sampling, comprising the collection of representative groundwater samples from select locations, with field measurement of physicochemical parameters and laboratory analysis;
- hydraulic conductivity testing in the form of rising and falling head ‘slug’ tests at three bores;
- analytical assessment of potential inflows to the ARC bunker during construction; and
- completion of a constant rate pumping test at a bore in the Willeroo borefield, with analytical modelling to estimate groundwater drawdown associated with operation of the borefield.

6.1 Evaporation dams

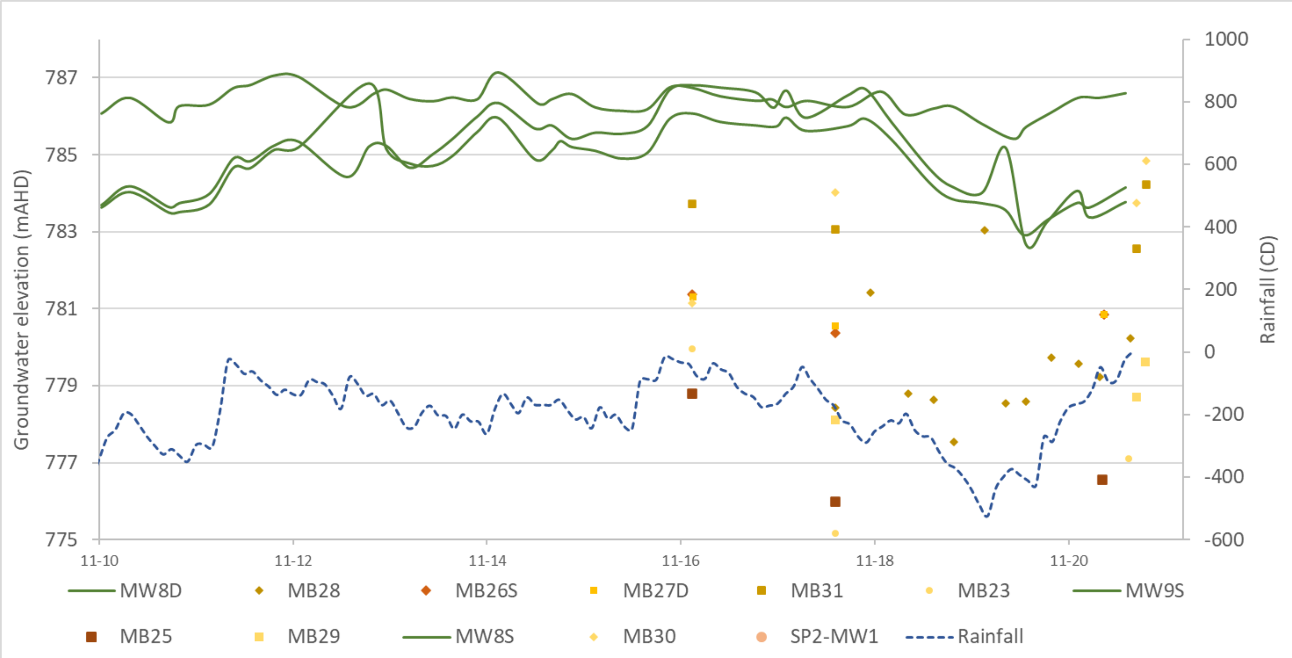
6.1.1 Groundwater levels and flow

Locally, the watertable is elevated in the area of the evaporation dams, due to long-term seepage from the dams to the watertable in the colluvium/alluvium. As seen in Figure 5.5, the shallow groundwater flow direction in the colluvium/alluvium in the dam area flows radially from the dams to the north-east, towards Crisps Creek, or to the west, towards Allianoyonyiga Creek.

Groundwater level measurements for the monitoring bores around the evaporation dams are presented in a hydrograph, shown in Figure 6.1.

Groundwater measurements in the colluvium/alluvium fluctuate in response to both infiltration of rainfall and discharge/leakage from the dams. There is also some fluctuation in the fractured rock groundwater levels owing to rainfall recharge.

Available groundwater monitoring data indicates there is an upward hydraulic gradient and the potential for upward vertical flow from the fractured rock to the colluvium/alluvium.



Notes: 1. CD = cumulative deviation from mean rainfall, taken from site data and BoM site 070036
2. Green bores target fractured rock, yellow/orange bores target colluvium/alluvium

Figure 6.1 Groundwater hydrograph, bores near evaporation dams

6.1.2 Hydraulic conductivity

Falling head ('slug') tests were conducted at two monitoring bores near ED1 to estimate the local horizontal hydraulic conductivity of the colluvium/alluvium in this area. These tests are achieved by introducing a 'slug' device to displace the water column within the monitoring bore, causing the water level to rise quickly and water to flow from the bore into the screened lithology (Butler 1998). The water level decay is recorded until the water level has returned to, or is close to, the pre-test level. The test data was analysed using the Hvorslev (1951), and Bouwer and Rice (1976) methods for analysis in unconfined and confined aquifers using the software AQTESOLV (Duffield 2007).

The results are presented in Table 6.1, with further details of the analysis included in Appendix C. The calculated hydraulic conductivity is within the textbook ranges as reported by Domenico and Schwartz (1990) for gravel and clay.

Table 6.1 Hydraulic conductivity test results

Bore	Screened lithology	K range (m/day)	K average (m/day)
MB10	Sand and gravel, minor clay	1.2–1.3	1.3
MB26s	Clay, minor gravels	0.007–0.009	0.008

Notes: K = hydraulic conductivity

6.1.3 Groundwater quality

Veolia conducts regular water sampling at the Eco Precinct for laboratory water quality analysis. This includes the evaporation dams, monitoring bores and surface water monitoring locations. To further inform the hydrogeological understanding of the ED1 area, EMM collected additional water samples for field and laboratory water quality analysis.

The water stored in the evaporation dams is typically acidic, saline and has high levels of dissolved metals and sulfate (AECOM 2017). Subsequently, groundwater quality near the evaporation dams has similar water quality.

Box and whisker diagrams (using log scales) are provided in Figure 6.2 to Figure 6.8 showing the concentration ranges and median concentrations for EC, sulfate, pH, copper, iron, lead, zinc, respectively, for the following monitoring sites:

- ED1;
- alluvium/colluvium bores;
- fractured rock bores in the ED1 area;
- Spring 2 monitoring site; and
- Crisps Creek.

The following provides a summary of the data presented in Figure 6.2 to Figure 6.8:

- EC:
  - water sampled from ED1 is saline;
  - fractured rock groundwater varies from brackish to saline; and
  - alluvium/colluvium groundwater is generally brackish.
- pH:
  - water sampled from ED1 is strongly acidic;
  - groundwater sampled from fractured rock bores and the Spring 2 site ranges from acidic to alkaline, however the median is neutral; and
  - groundwater sampled from alluvium/colluvium bores generally has a higher pH and shows less variability (range) in the data.
- Sulfate:
  - sulfate (and heavy metal) concentrations are high in ED1 and cover a large range;
  - fractured rock groundwater is naturally high in sulfate, with data showing a large range in concentrations, however the median is generally lower than concentrations in ED1; and
  - sulfate concentrations in the alluvium/colluvium aquifer, Spring 2 site and Crisps Creek are generally low.

Water quality laboratory data has been compared to the Australia and New Zealand guidelines for fresh water and marine water quality (ANZG 2018) (95% protection levels):

- Water quality at SP2-MW1, Spring 2 site and Crisps Creek generally exceeds the default guideline values for copper, lead (however sometime samples collected from Crisps Creek are below the guideline value) and zinc.

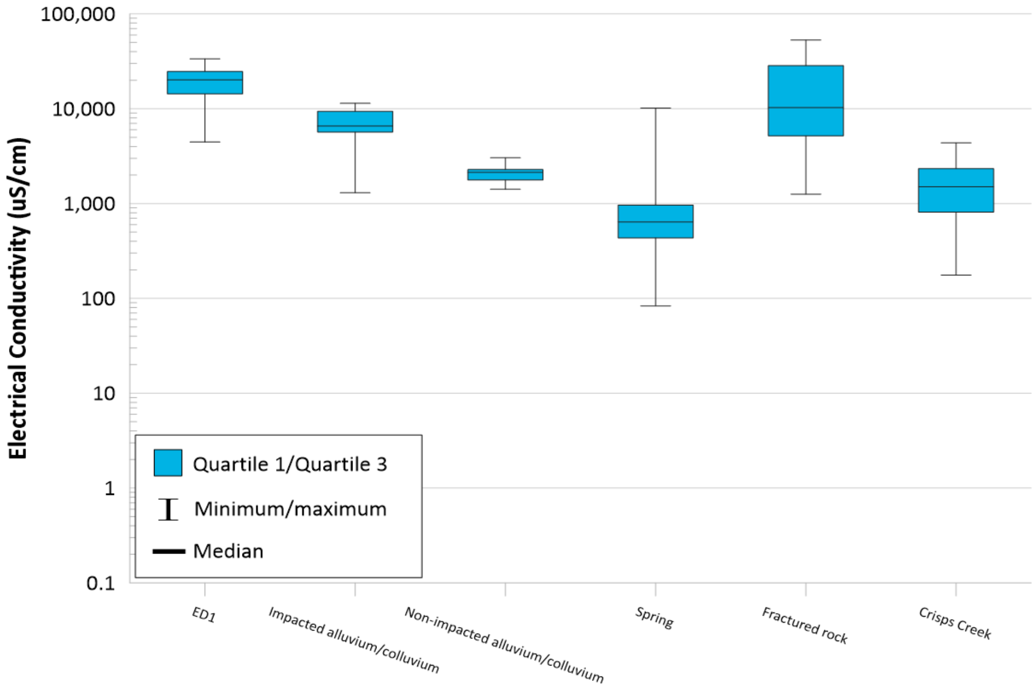


Figure 6.2 Box and whisker plot – electrical conductivity

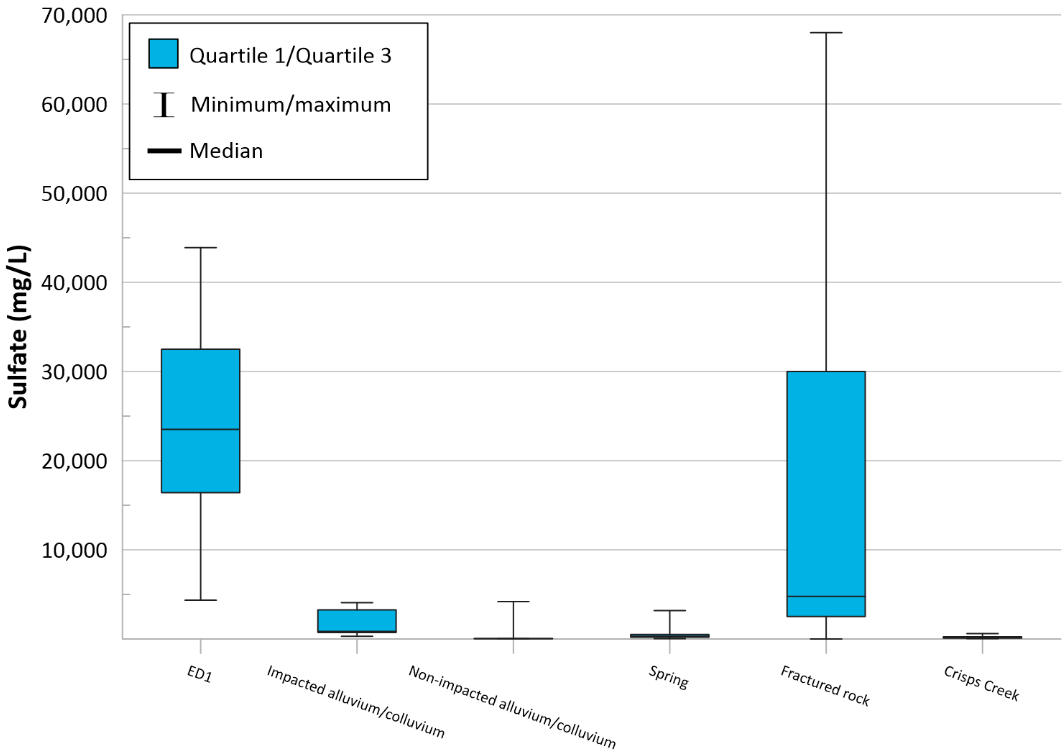


Figure 6.3 Box and whisker plot - sulfate

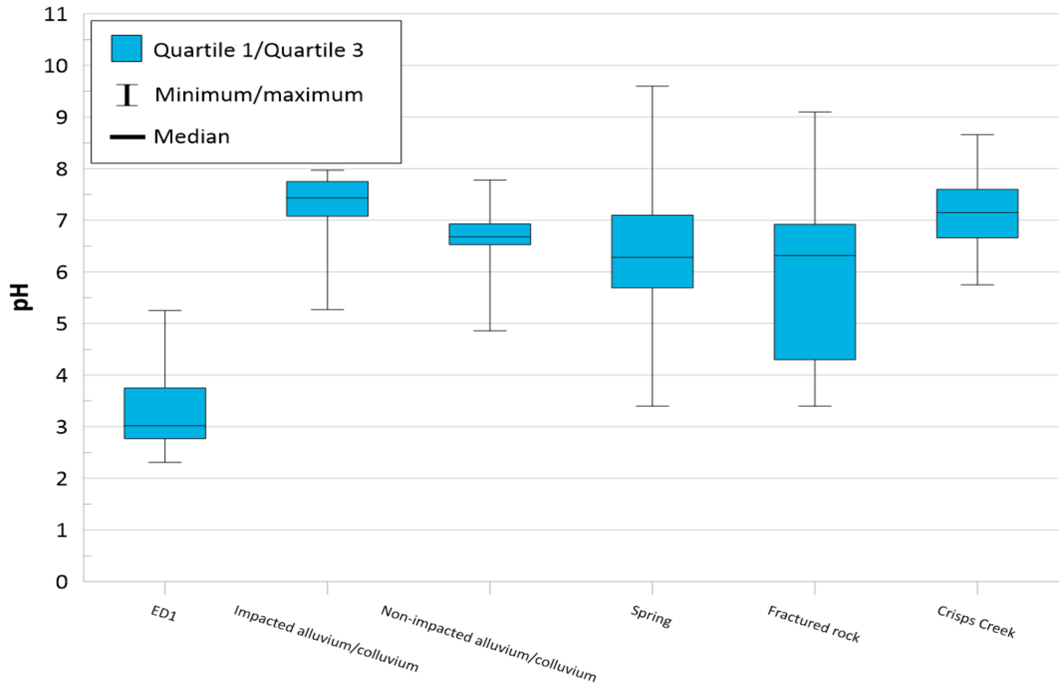


Figure 6.4 Box and whisker plot - pH

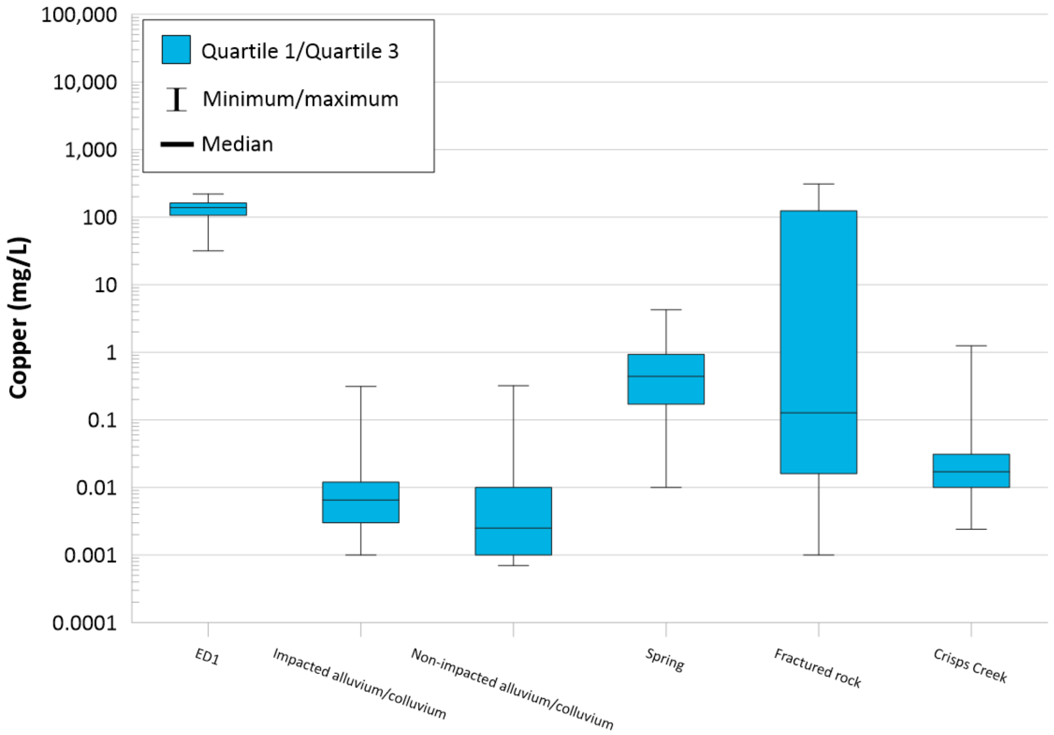


Figure 6.5 Box and whisker plot – copper

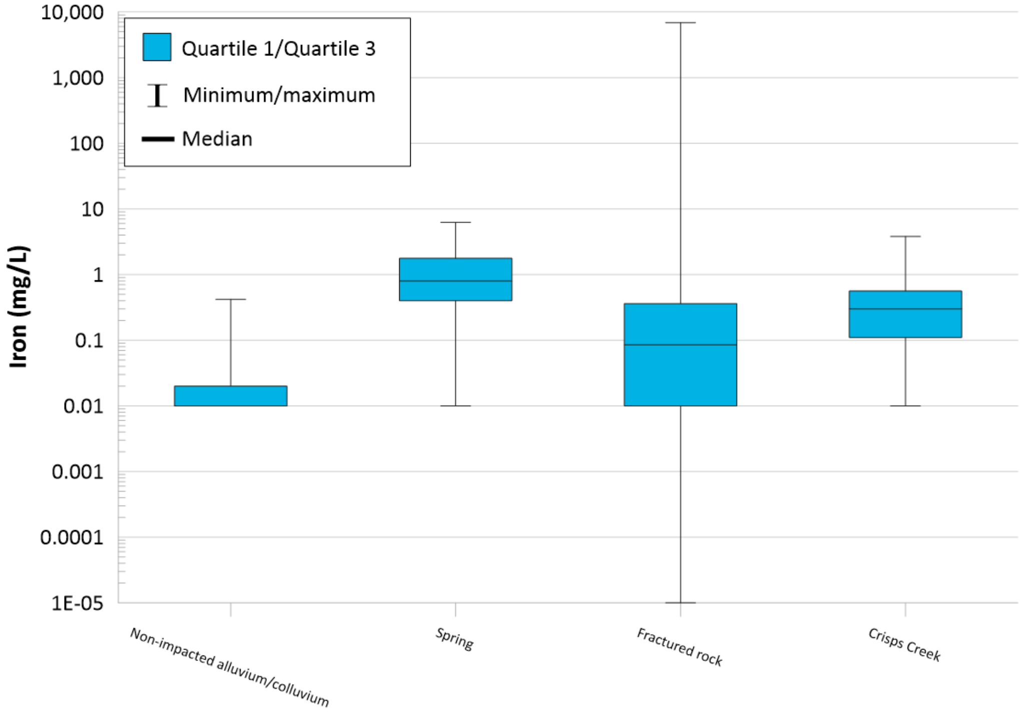


Figure 6.6 **Box and whisker plot – iron**

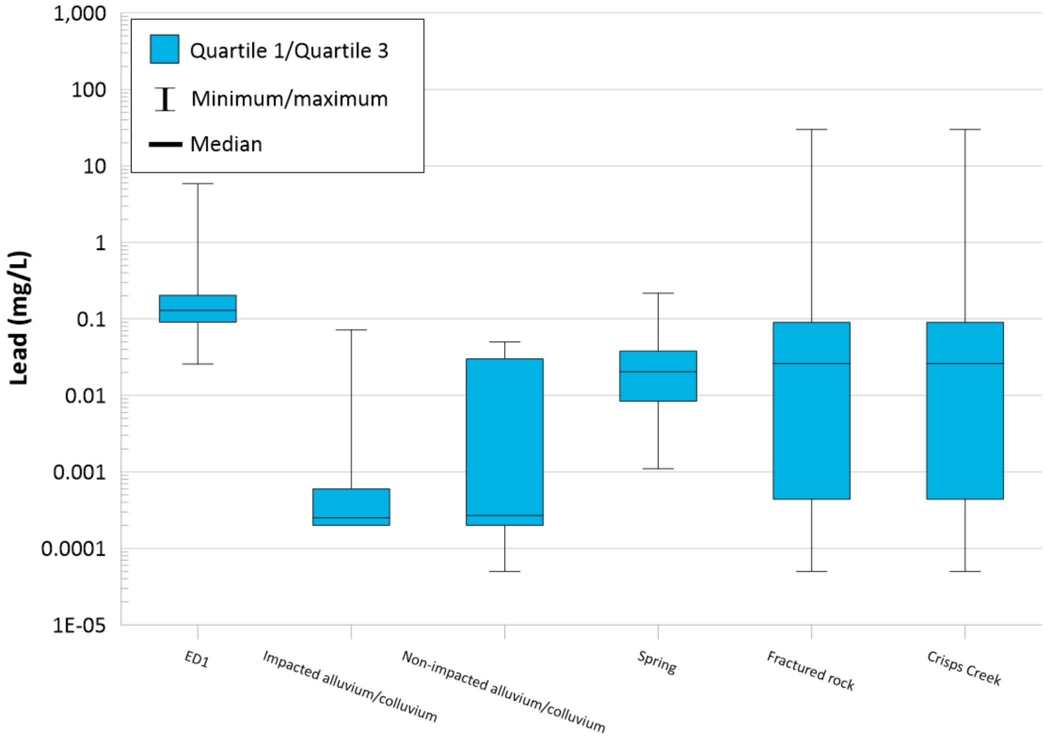


Figure 6.7 **Box and whisker plot – lead**

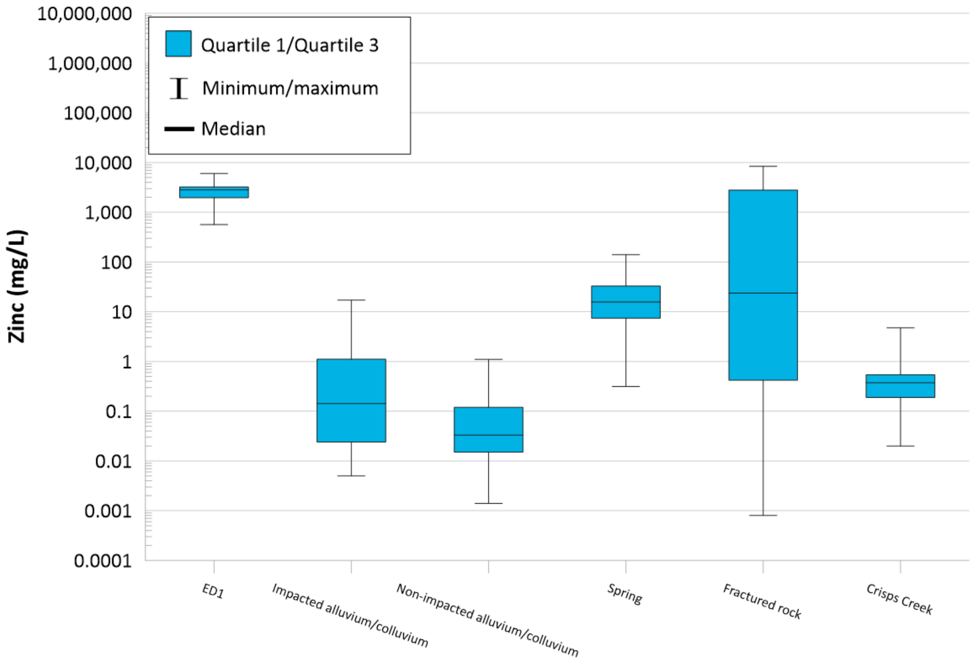


Figure 6.8 Box and whisker plot - zinc

Stiff diagrams for recent (August 2021) laboratory water quality results for select sites are presented in Figure 6.9. The diagrams show water quality at SP2-MW1 and the Spring 2 dam is very different to the water quality at ED1 and MB10. Water quality at SP2-MW1 is very similar to MB3 (located to the north of Crisps Creek) groundwater quality. The Spring 2 water quality is different to the other sites presented in Figure 6.9. These observations are supported by the Piper diagram provided in Figure 6.10.

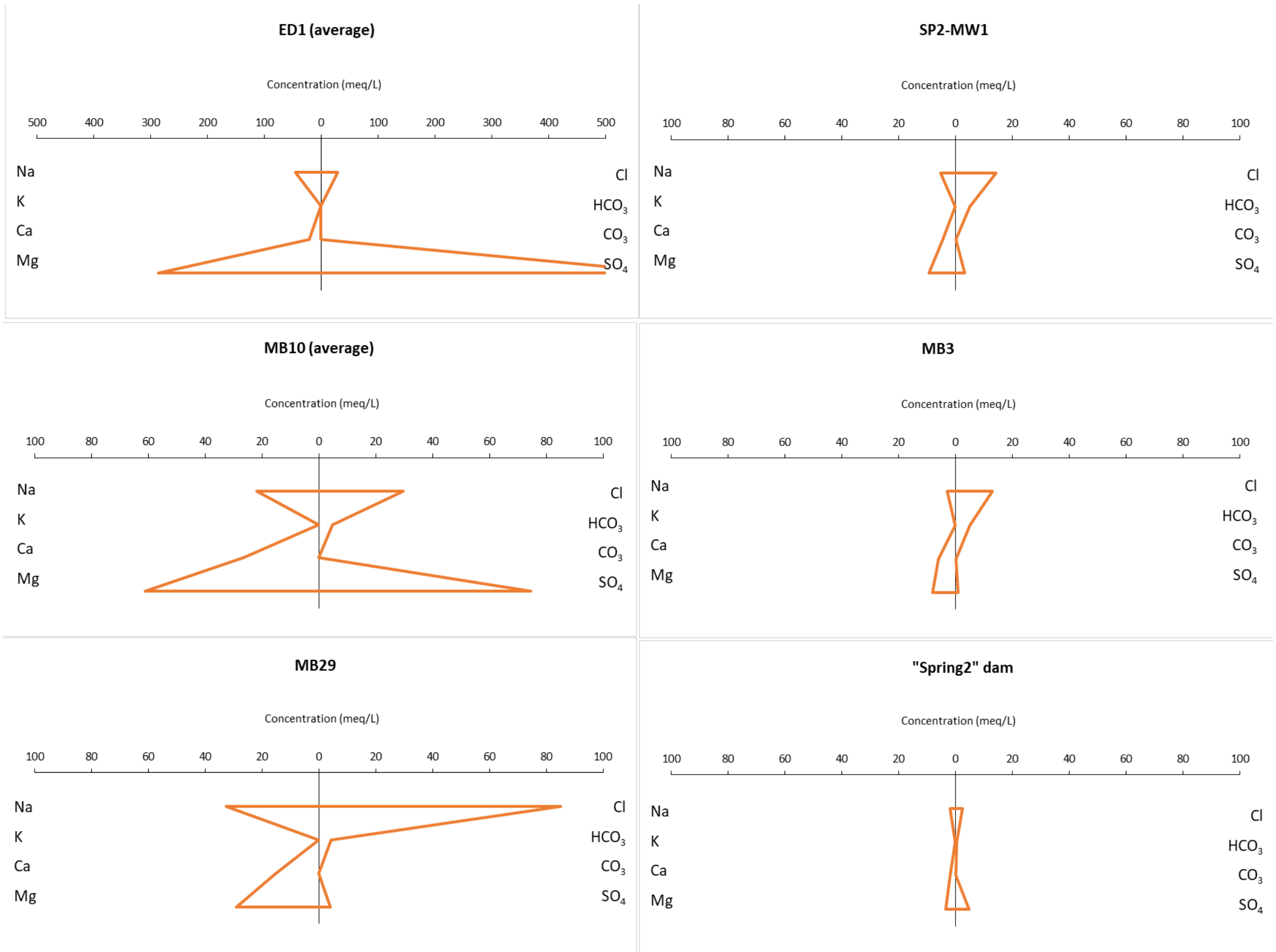


Figure 6.9 Stiff diagrams for water within evaporation dam area

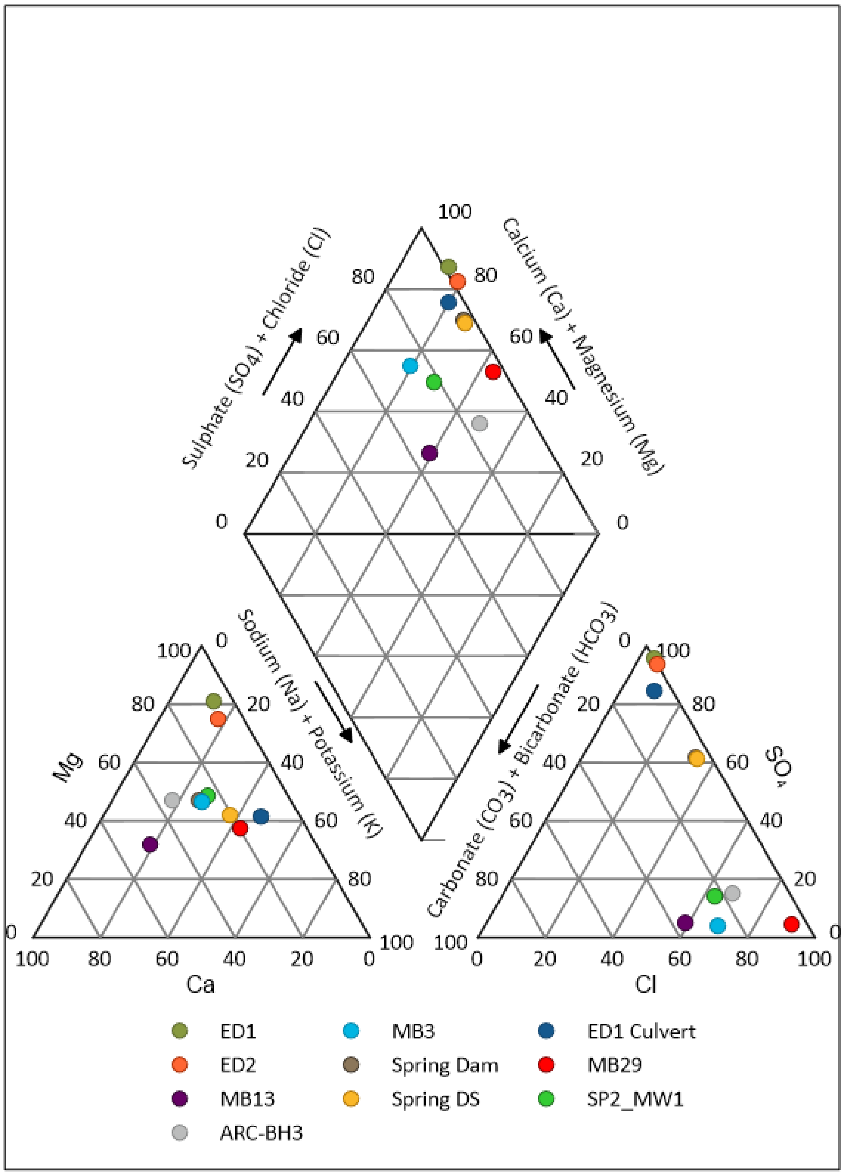
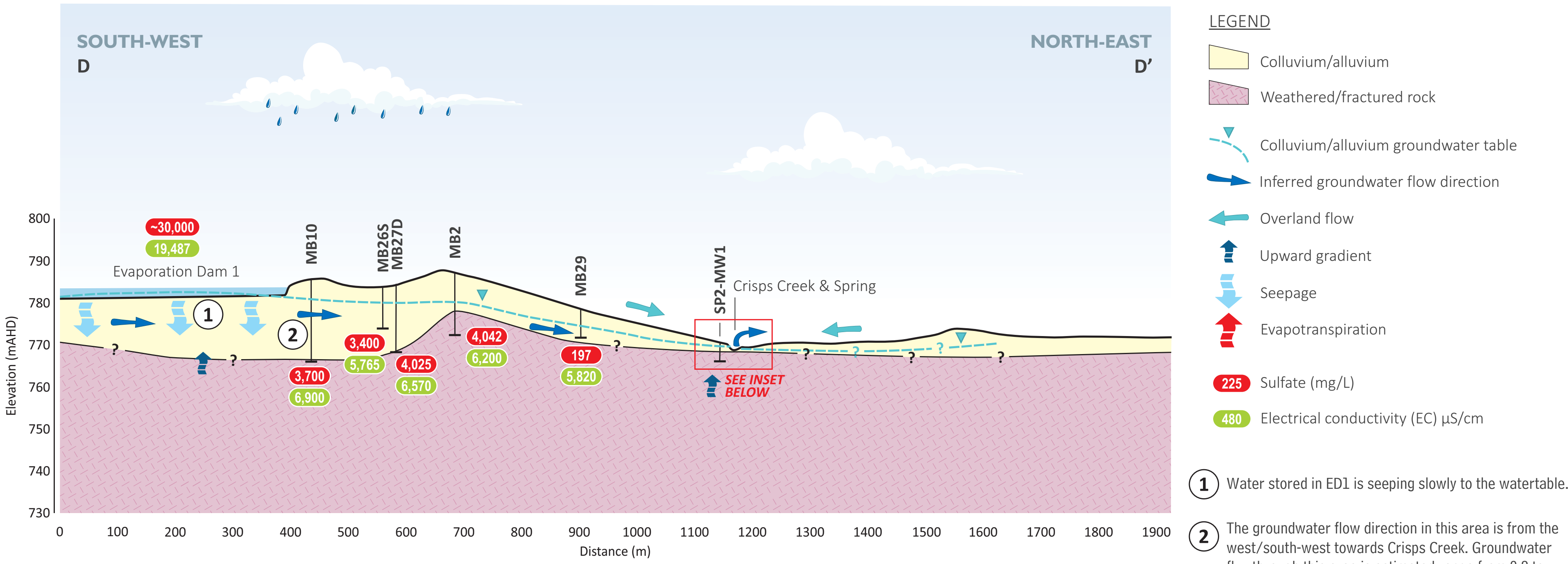


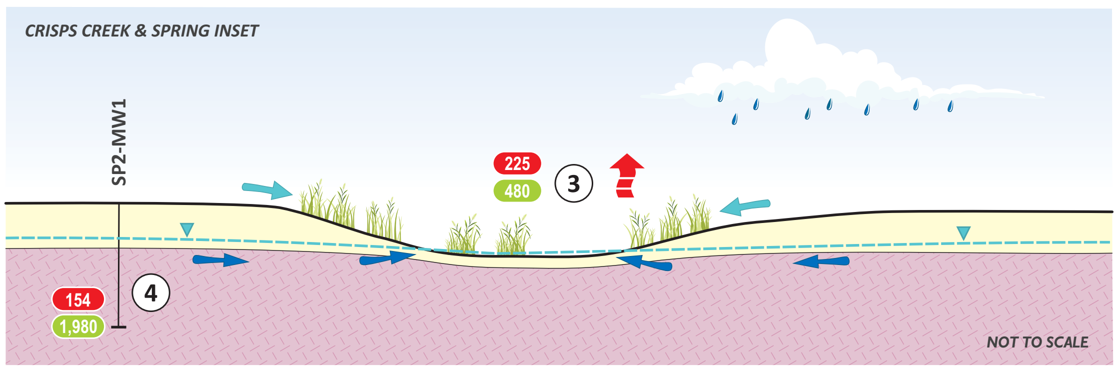
Figure 6.10 Piper diagram – evaporation dam area

6.1.4 Site conceptual hydrogeology

The following provides a summary of the information presented above and a conceptual hydrogeological understanding of the ED1 area, extending north/north-east towards Crisps Creek. A conceptual hydrogeological diagram illustrated the conceptual understanding of the “existing situation”, ie pre-project, is provided in Figure 6.11:

- water stored in ED1 is seeping slowly to the watertable, which is elevated in the ED1 area;
- local lithology comprises clayey sediments with generally low hydraulic conductivity;
- the groundwater flow direction in this area is from the south/south-west (ED1) towards Crisps Creek. Groundwater flux through this area is estimated to range from 100 kL/yr (assuming low hydraulic conductivity lithology such as that intercepted at MB26S) to 1,100 kL/yr (assuming higher hydraulic conductivity material such as that intercepted at MB10);
- the watertable in the SP2-MW1 area is located within the top of the weathered bedrock; however, under wet conditions, the watertable rises into the alluvium;
- groundwater salinity and sulfate concentrations reduce with distance from ED1;
- groundwater quality at SP2-MW1 is very different to ED1 and surrounding monitoring bores, and is more similar to the groundwater quality at MB3, located to the north of Crisps Creek;
- Crisps Creek is thought to receive surface water runoff (overland flow) and some shallow groundwater discharge from the north and the south/south-west; and
- the Spring 2 site is a dam constructed on a tributary to Crisps Creek and is thought to intercept shallow groundwater, as well as receiving overland flow, which is supported by the results of laboratory water quality analysis.





1. Water stored in ED1 is seeping slowly to the watertable.
2. The groundwater flow direction in this area is from the west/south-west towards Crisps Creek. Groundwater flux through this area is estimated range from 0.2 to 23 kL/yr per metre.
3. Crisps Creek is thought to receive surface water runoff (overland flow) and some shallow groundwater discharge from the north and the south/south-west. This water is being captured via a dam constructed on the watercourse and has been sampled and named 'Spring2'. This dam is thought to intercept shallow groundwater and receive overland flow.
4. The watertable at SP2-MW1 (drilled in 2019) was intercepted in the weathered bedrock. The alluvium in this area varies from being unsaturated in dry conditions to saturated at the base of the alluvium in wet/high rainfall periods.

(this diagram is a conceptual representation only)

ED1 area conceptual diagram – existing situation

Woodlawn Advanced Energy Recovery Centre

Groundwater assessment

Figure 6.11

EMM creating opportunities

6.2 The ARC

6.2.1 Groundwater levels and flow

Historic groundwater investigations report the groundwater elevation is between 2−7 mbgl, or between 767−772 mAHD at 3 geotechnical boreholes drilled to a maximum 15 m in the centre of the ARC (Golder 2021). The intersected geology comprises weathered to competent siltstone, with some minor overlying colluvium. EMM recorded a groundwater level of 1.9 metres below top of casing (mbtoc) (772.7 mAHD) at BH3 on 20 August 2021, consistent with Golder's (2021) observations. The groundwater level is considered to be the pressure level in the fractured rock system, not the watertable or depth to saturated rock. The depth to the watertable was not recorded during drilling. The groundwater flow direction in the fractured rock at the ARC is south-west towards the open cut void or to the east, consistent with the regional groundwater flow direction.

6.2.2 Hydraulic conductivity

Falling head ('slug') tests were conducted at BH3 to estimate the horizontal hydraulic conductivity of the screened lithology, as per the method described in Section 6.1.1. The results are presented in Table 6.2, with further details of the analysis included in Appendix C. The calculated hydraulic conductivity is within the textbook ranges as reported by Domenico and Schwartz (1990) for siltstone.

Table 6.2 Hydraulic conductivity test results

Bore	Screened lithology	K range (m/day)	K average (m/day)
BH3 (ARC)	Siltstone	0.03	0.03

6.2.3 Groundwater quality

A groundwater quality sample was collected from monitoring bore BH3 on 20 August 2021, and was assessed for physicochemical and laboratory parameters. The laboratory results are included in Appendix E. The groundwater conditions are neutral (pH 6.65) and brackish (3,860 µS/cm). The total zinc result was 1.31 milligrams per litre (mg/L) and the total nitrogen result was 0.7 mg/L. The major ions are presented on a Piper diagram in Figure 6.10. As the groundwater is up hydraulic gradient of the Bioreactor void and with no reported groundwater contamination in the area (Golder 2022a), the groundwater quality is expected to be representative of background conditions for the fractured rock, with low potential for groundwater contamination.

6.3 Willeroo borefield

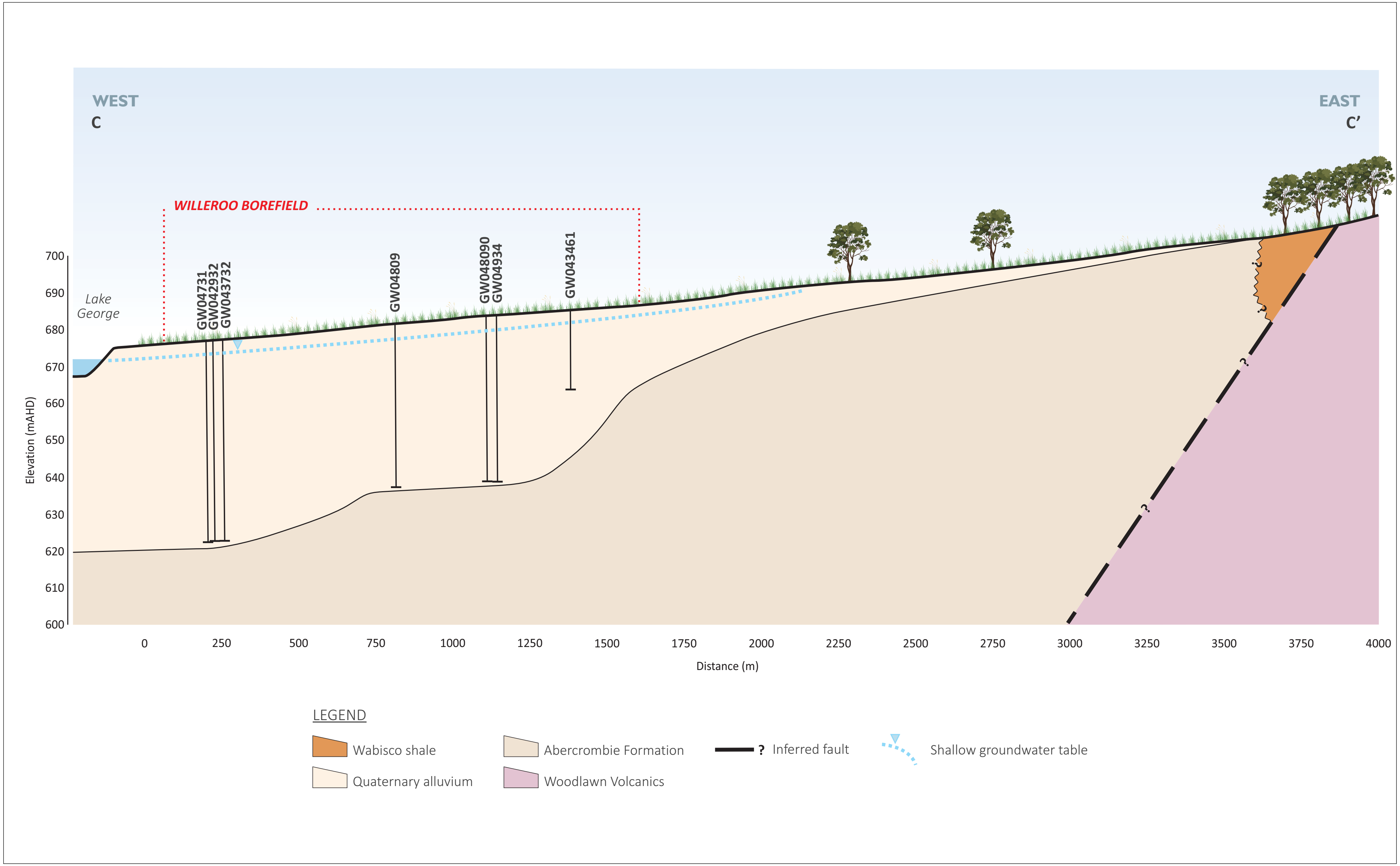
6.3.1 Hydrogeology

The borefield targets an alluvial palaeochannel, a buried Quaternary Alluvium erosional channel that drains into Lake George. The alluvium comprises a sand and gravel unit underlying a clay lens. The alluvium is approximately 50 m thick near Lake George with the production bores targeting the aquifer at the base of the alluvium, which is semi-confined owing to overlying clay.

The Willeroo borefield production and monitoring bores are shown in Table 6.3. A west-east cross section showing conceptual geology and hydrogeology is provided in Figure 6.12. This shows the erosional channel within the fractured rock.

Table 6.3 Willeroo borefield

ID	Easting	Northing	Year drilled	Depth	Yield (L/s)	Bore use
GW042931 (bore 3)	727944	6119439	1977	38.1	11.3	Production
GW042933 (bore 2)	727219	6118871	1977	43.0	11.3	Production*
GW042932 (bore 1)	726888	6117769	1976	56.7	15.6	Production*
GW042934 (bore 4)	727840	6117344	1977	46.5	10.0	Production*
GW048090	727791	6117377	1977	46	–	Monitoring
GW048089	727438	6117478	1976	44	3.8	Monitoring
GW043731	726812	6117771	1974	60.1	–	Exploration
GW042685	726888	6117769	1974	56.9	–	Industry
GW048086	726938	6117768	1976	57	1.7	Monitoring
GW043732	726938	6117768	1974	35.9	–	Exploration
GW043733	726940	6117829	1974	34.6	4.4	Exploration
GW048087	727194	6118871	1977	41	2.3	Monitoring
GW048088	727193	6118841	1974	36	1.3	Monitoring
GW042686	727999	6119622	1973	39.9	–	Monitoring
GW035679	727999	6119622	1972	36.8	8.8	Exploration
GW048085	727892	6119409	1977	45	3.8	Monitoring



Willeroo borefield conceptual cross section

Woodlawn Advanced Energy Recovery Centre

Groundwater assessment

Figure 6.12

6.3.2 Borefield operation

The Willeroo borefield was constructed in the 1970s and provides groundwater supply to the Eco Precinct (via pipeline) and has historically been used to supply water to the mine operator. As mentioned in Section 2.3.3, Veolia have a WAL for 600 ML (WAL: 28983) linked to the four production bores (GW042931, GW042932, GW042933 and GW042934) that make up the Willeroo borefield.

There are three production bores that are capable of being pumped, however only one bore is currently operational (GW042931 – Bore 3). The fourth production bore (GW042934) has been abandoned. Currently, Veolia operate GW042931 (Bore 3) on an approximate 4-hour cycle, pumping at approximately 15 L/s.

Abstraction from the borefield increased significantly in 2019 due to increased water demand for the Woodlawn Mine and drought conditions. During this higher abstraction period, anecdotal information suggests the production bores remained reliable. Historical groundwater abstraction from the borefield, along with measured depth to groundwater at each production bore is provided in Figure 6.13.

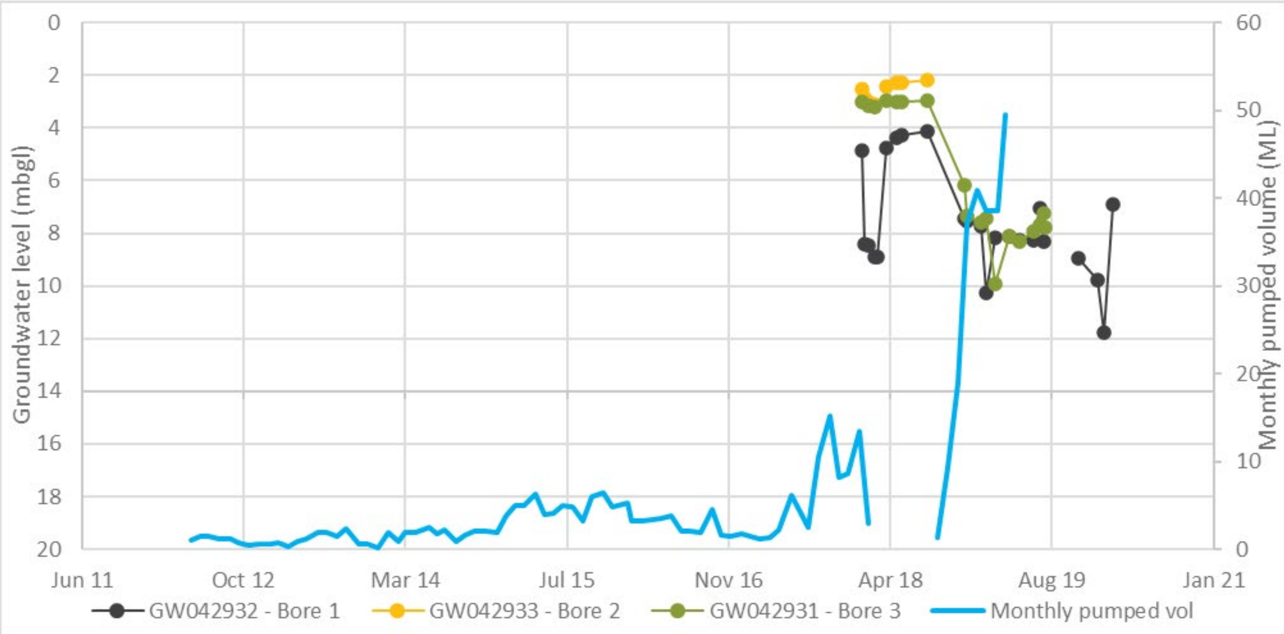


Figure 6.13 Willeroo borefield historical pumped volumes and groundwater level response

6.3.3 Hydraulic conductivity and bore yield

The borefield was visited on 19 August 2021. A constant rate pumping test (CRT) was conducted to assess the performance of the operational bore (GW042931 – bore 3), at a pumping rate that is close to the proposed long-term pumping rate. The groundwater level drawdown and recovery data collected from the CRT was used to estimate aquifer hydraulic properties, including transmissivity (T), hydraulic conductivity (K) and storativity (S) (or storage coefficient). The extent of drawdown and a safe yield for the production bore was also assessed.

The CRT commenced on 20 August and ran for approximately 74 hours, with recovery commencing on 23 August. The test pumping rate fluctuated between 14.5 and 15.5 L/s and was unable to be kept at a constant rate. Drawdown data was only obtained for the first 2 hours and 40 minutes of the CRT, as the data logger was unable to be set any lower, due to proximity of the pump intake. It is predicted that after 16 hours, the groundwater level was at or below the pump intake and the bore would have been cavitating. Consequently, a safe yield of 15 L/s cannot be maintained long term and hence only the early drawdown data was used to predict the safe yield of this production bore. The recovery test data was unable to be recorded. Due to COVID restrictions and access constraints, manual measurements of depth to groundwater could not be recorded during the pumping test.

Groundwater level monitoring was undertaken during the CRT and aquifer recovery periods using a pressure transducer data logger (Solinst^{TM} M100 dataloggers). The frequency of groundwater level and quality measurements were made in accordance with the *Minimum Requirements for Pumping Tests on Water Bores in New South Wales* (DPIE 2019). Groundwater level changes were recorded in the test production bore, with back-up manual measurements also recorded via an electric Solinst^{TM} water level dip meter at the commencement of the test. The groundwater levels in adjacent monitoring bores were also continuously monitored with down hole pressure transducers.

Field data, including drawdown data recorded via the dataloggers is included in Appendix D. Drawdown results were analysed using AQTESOLV (Duffield 2007) and the AQTESOLV summary sheets are also included in Appendix D. Aquifer properties are estimated by fitting mathematical models (type curves) to drawdown data via curve matching. The solutions found to be the best fit for the data was the Hantush-Jacob type curve solution for semi-confined aquifers. A summary of the CRT details is provided below in Table 6.4. The production bore and observation bores fully penetrate the alluvium.

Table 6.4 Pumping test summary – GW042931 - Bore 3

Summary	CRT details
Duration	74 hours, 20–23 August 2021
Discharge (pumping) rate	14.5–15.5 L/s
Formation	Quaternary Alluvium, sand and gravel
Production bore	GW042931 - Bore 3, screened from 25.9–38.1 mbgl targeting sand and gravel, with overlying clay lenses. Pump intake is at ~21 mbgl/mbtoc (from anecdotal reports), screened interval is approximately 12 m.
Monitoring bore, WMB1	Screen interval unknown, bore is assumed to be targeting sand and gravel based on total depth of 27.8 mbgl. The bore is 36 m from the production bore.
Monitoring bore, WMB2	Screen interval unknown, bore is assumed to be targeting sand and gravel based on total depth of 37.02 mbgl. The bore is 51 m from the production bore.

Note: mbgl = metres below ground level; mbtoc = metres below top of casing

An overview of the aquifer parameters derived from analysis for the available CRT data is provided below in Table 6.5.

Table 6.5 GW042931 - Bore 3 aquifer parameters

Solution	Transmissivity (m^2/d)	Hydraulic conductivity (K) (m/d)	Storativity (S)
Hantush-Jacob	128	8.0	5×10^{-4}

There was a slight increase in the rate of drawdown observed after approximately 10 minutes of pumping, suggesting that a barrier boundary may exist in the deep alluvial aquifer within tens of metres of the production bore. This is not unexpected as the aquifer comprises channel alluvium, that is the system is heterogeneous and does not have the same aquifer characteristics in all directions. The slightly steeper drawdown rate has been used to estimate the preliminary safe yield of GW042931 - Bore 3. It should also be noted that there is a large initial drawdown in the bore which is attributable to well loss and inefficiencies in transmitting water from the aquifer into the bore.

Safe yield estimates are described by Fetter (1994) as the amount of water that can be withdrawn from an aquifer on a sustained basis, without impairing groundwater quality or creating undesirable effects such as environmental damage. For this project, this term is used to describe the predicted yield for a production bore in its current configuration and pumping in isolation of other bores that may be operational within the borefield. The yield estimate does not include any allowance for seasonal variations in groundwater levels or interference effects from nearby pumping bores.

Safe yield estimates for the production bore have been calculated using a method from Fetter (1994) using aquifer characteristics recorded during the CRT pumping tests. The following equation was applied to calculate safe yield and a summary of the results is provided in Table 6.6.

$$DDL = SWL + (S100 + 2.2\Delta S)(\frac{Q}{Qtest})$$

Equation 1 Safe yield solution

Where DDL is the maximum drawdown level, SWL is the static water level, ΔS is the drawdown per log cycle, S100 is the drawdown after 100 minutes, Q_{test} is the pumping rate used during the CRT and Q is the safe yield. A 2.2ΔS is equivalent to 14 days.

Table 6.6 Safe yield estimates for production GW042931 - Bore 3 (after Fetter 1994)

Bore	SWL (mbgl)	Test pumping rate (L/s)	Maximum drawdown level (mbgl)	Drawdown per log cycle (Δs) (m)	S100 (m)	Safe yield (L/s)	Safe yield (ML/d)
GW042931 – Bore 3	3.87	15.5	20	4	17	9.7	0.84

Notes: SWL = static water level, mbgl = metres below ground level, L/s = litres per second, ML/d = megalitres/day

A pumping rate of 9.7 L/s for up to 14 days continuous pumping is estimated to be the safe yield for GW042931 - Bore 3 (operating in isolation of other production bores). The pumping test analysis indicates that the current pumping rate of approximately 15 L/s is not sustainable, as after approximately 16 hours groundwater level is predicted to reach the pump intake.

6.3.4 Groundwater quality

A groundwater sample was collected from a sample tap located on the headworks of the production bore, approximately one hour into the CRT. Physicochemical parameters were measured in the field with a calibrated YSI water quality meter and samples underwent laboratory analysis at Australian Laboratory Service (ALS). The field parameters are presented in Table 6.7 and the laboratory report is included in Appendix E.

Physicochemical parameters indicate the groundwater is slightly acidic and slightly brackish. The dissolved copper, nickel, zinc and manganese concentrations were above the laboratory limits of reporting (LOR) and the highest concentration was zinc (0.01 mg/L). The total nitrogen concentration was 1.2 mg/L and the total phosphorus concentration was 0.01 mg/L.

Table 6.7 GW042931 - Bore 3 field parameters

Value	Units	Measurement
pH	pH units	6.48
Electrical conductivity (EC)	µS/cm	1,560
Temperature	°C	15.7
Dissolved oxygen	mg/L	4.31
Oxidation reduction potential	mV	107

7 Assessment approach

7.1 Overview

The assessment of potential project-related impacts on water resources and water users considers the requirements of the WM Act, relevant WSPs and the AIP (for some activities).

The National Water Commission developed guidelines and a risk framework for assessing local and cumulative effects of mining activities on groundwater systems (Moran et al 2010). While this is not a mining project, the framework remains applicable and defines the following four possible direct groundwater effects arising from a project:

- altered groundwater quantity (groundwater levels, pressures and fluxes);
- altered groundwater quality (concentration of salts and other important water quality constituents);
- altered surface water – groundwater interaction; and
- physical disruption or removal of aquifers (excavation for tunnelling, mine pits or underground works).

Direct effects encompass the changes to physical and/or quality aspects of groundwater due to water affecting activities, or the changes to the physical characteristics of aquifers affected by these activities.

Indirect effects of water affecting activities are those that arise in response to direct effects (Moran et al 2010). The potentially sensitive receptors that have been identified include:

- third-party bores (licensed or unlicensed) used for irrigation, stock and domestic purposes;
- ecosystems that potentially rely on groundwater (terrestrial vegetation and aquatic ecosystems); and
- watercourses, drainage lines, creeks and springs that receive baseflow.

The potential for cumulative impacts should also be considered, noting the development footprint is located within a former mine site.

7.2 Avoidance and mitigation measures

Veolia has adopted several leading practices to produce a project design that avoids and minimises impacts to water assets. The key leading practices adopted to minimise impacts to water related assets includes:

- double lining the encapsulation cell to prevent seepage from the encapsulation cell to surface water or groundwater;
- leak detection and collection system built into the foundation of the encapsulation cell to prevent seepage to surface water or groundwater;
- isolating the encapsulation cell from ED1;
- concrete sealing of the ARC bunker;
- commitment to a nil discharge site; and
- utilisation of rainwater and associated runoff captured within the development footprint and recirculating excess water within the water management system to limit the demand on the Willeroo borefield groundwater supply.

7.3 Potential impacts

As listed above, Veolia has adopted several leading practices to produce a project design that avoids and minimises impacts to water assets. Table 7.1 presents a brief description of the water affecting activities and the potential effects. Further description of the water affecting activities related to the project is provided in Section 8.

Table 7.1 Potential groundwater impacts from Project activities

Effect	Water affecting activity	Potential effect	Receptors potentially impacted	Assessment criteria
Quantity	Excavation of the ARC bunker and groundwater interception in fractured rock aquifer	Localised watertable drawdown, aquifer depressurisation, localised changed groundwater flow path	None, but intercepted water to be assessed against WM Act and AIP (via licensing)	AIP
	Stockpiling during construction (excavation of the ARC bunker)	Altered recharge Hydraulic loading	None	AIP
	Wastewater ponds and water storage	Perched watertable, seepage	None	Not applicable for this project, see below
	Groundwater take for project use in alluvial aquifer	Watertable drawdown, aquifer depressurisation	Third-party bores	Bore dealing impact assessment
	Built infrastructure (roads, buildings, plant, encapsulation cell, general civil works)	Reduction in groundwater recharge Loading impact of encapsulation cell causing localised increase in water pressures and hydraulic gradient	None Colluvial/alluvial and fractured rock groundwater systems	Not applicable, see below AIP
Quality	Encapsulation cell causing hydraulic loading of the underlying clay	Leachate loss from collection system Enhanced groundwater flow rates	Colluvial/alluvial groundwater system Crisps Creek catchment (springs)	AIP WQOs, comparison to baseline
	Stockpiling during construction (excavation of the ARC bunker)	Acid generation and leakage	None	AIP WQOs, comparison to baseline
	Wastewater ponds and water storage	Leaching of solutes	Crisps Creek catchment	Not applicable, see below
	Built infrastructure (roads, buildings, plant)	Solutes in runoff	None	Not applicable, see below
Groundwater-surface water interaction	Encapsulation cell causing hydraulic loading of the underlying clay	Enhanced groundwater flow rates and discharge	Crisps Creek catchment (springs)	AIP
	Wastewater ponds and water storage	Perched watertable, seepage	Crisps Creek catchment	Not applicable, see below
Aquifer disruption	Excavation and construction of ARC bunker	Removal of part of the fractured rock groundwater system	None, but potential licensing requirement	AIP

Table 7.1 Potential groundwater impacts from Project activities

Effect	Water affecting activity	Potential effect	Receptors potentially impacted	Assessment criteria
	Encapsulation cell causing hydraulic loading of the underlying clay	Localised increase in water pressure and hydraulic gradient Enhanced groundwater flow rates and discharge	Crisps Creek catchment (springs)	AIP

7.4 Groundwater affecting activities with no potential impact to sensitive receptors

As detailed in Table 7.1 project activities with potential effects may or may not impact potential groundwater receptors. The activities with a potential effect to groundwater receptors are assessed further in Section 8. The activities that are not expected to have any impact to potentially receptors include:

- stockpiling material excavated from the ARC bunker during project construction;
- wastewater ponds and water storage; and
- built infrastructure (roads, buildings, plant).

The potential impacts from these activities may result in very localised impacts to the groundwater system, with no potential impact to groundwater receptors, such as third-party bores and /or ecological systems. The potential for these activities to have an impact on receptors has been considered as part of project design and/or proposed management measures. This is discussed below.

In addition to the above activities, excavation for the ARC bunker requires assessment under the requirements of the WM Act and AIP. However, as the activity will be of short duration (construction only), the effect on the groundwater systems is expected to localised and of short duration. This is discussed further in Section 7.4iv.

i Stockpiling

During construction, Veolia will excavate the ARC bunker area, prior to lining it for operations. Temporary stockpiling of the excavated material will occur during construction, which has the potential to alter the rate of rainfall recharge to the watertable. Depending on the hydraulic properties of the stockpile, rainfall infiltration may give rise to a perched watertable within the landform and possible seepage at the toe, and if left to pond, may seep to the watertable. Site investigations have identified the potential for rock at the site to be PAF (Golder 2021). The project will include water management measures to capture any runoff from the new landforms and seepage that may present at the toe of stockpiles will be captured and directed into the water management system to ensure no off site discharge.

ii Wastewater ponds and water storage

Water storage facilities have the potential for stored water to seep through to the watertable. As part of construction of new water storages/facilities, all ponds will be lined and bunded prior to construction to reduce water seepage.

Existing water storages, such as the evaporation dams and PCD, will continue to be used for water management purposes. These activities are unchanged from the current development and are not considered separately in this assessment. The Eco Precinct operates as a nil off site discharge site, and this will remain unchanged.

iii Built infrastructure

Runoff from areas within the ARC (including roads, plant, other buildings and hazard goods storage areas) has the potential to pick up contaminant solutes that have the potential to enter the surface water and/or groundwater system. The project will include runoff containment systems and other features to restrict surface water runoff within the development footprint. Clean runoff will be captured for re-use.

Dedicated storage areas for fuel and reagent, and runoff containment systems will be developed during the construction phase and maintained over the operational period while potential pollutants remain on site.

iv Groundwater inflows at the ARC bunker

During the construction of the 15 m deep ARC building waste bunker, groundwater within the fractured rock unit is expected to be intersected. The weathered rock overlying the fractured rock is dry, with possible temporary storage of rainfall infiltration. The depth to water, measured at BH3 during drilling, is 2 mbgl (noting that the measured groundwater level is considered to be the pressure level in the upper fractured rock system, not the watertable or depth to saturated rock. Therefore, use of this shallow depth to estimate inflows to the bunker is conservative.

In accordance with the AIP, the volume of groundwater to be intercepted during construction has been estimated.

An analytical solution has been used to calculate potential groundwater inflow rates to the ARC bunker during the construction phase, using available site data and realistic assumptions. The calculation is a modified version of the Dupuit-Theim solution for unconfined aquifer conditions (see Equation 1).

$$Q = 2\pi K b \frac{s}{\ln(\frac{ro}{rw})}$$

Equation 2 Dupuit-Theim analytical solution

The solution represents the bunker as a large diameter well. The variables and assumptions used in the analytical solution are detailed in Table 7.2. Figure 7.1 provides a graphical representation of the Dupuit-Theim equation, as applied to the ARC bunker excavation. The bunker will be constructed within six months and no groundwater inflows will continue beyond this time as the structure will be fully lined.

Table 7.2 Adopted parameters

Variable ID	Parameter	Unit	Adopted value
K	Hydraulic conductivity	m/day	0.03
s	Height of depressed water level adjacent to the bunker	m	10
r_o	Radius of drawdown (calculated)	m	127
r_w	Radius of the excavation	m	20

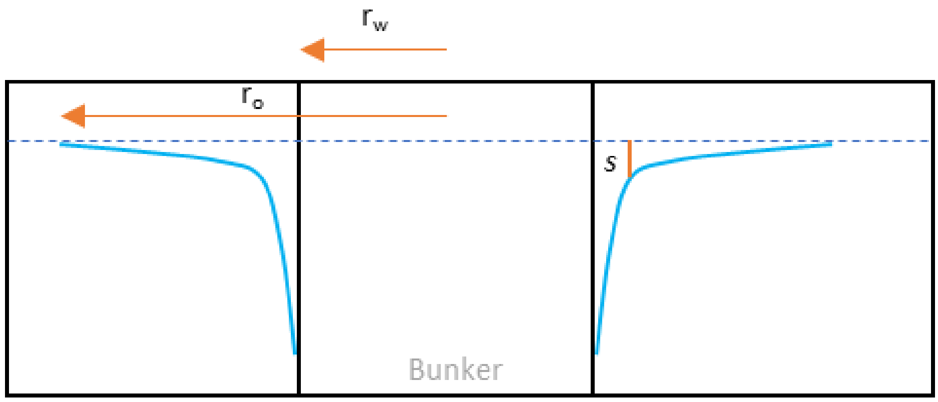


Figure 7.1 Dupuit-Theim analytical solution – illustration of components

Using the bunker design depth, and measured groundwater level and hydraulic conductivity (refer Section 6.2.2), the base case calculated groundwater inflow rate is estimated to be 4 kilolitre per day (kL/day). The total inflows to the bunker are estimated to be 0.7 ML, and assumes the excavation intersects fractures with a similar hydraulic conductivity to those tested at BH3. Should higher conductive fractures/lithology be intersected during excavation, greater volumes of groundwater inflow could be expected. Conversely the fractured rock system is semi-confined and water bearing fractures may not be encountered at all in the uppermost 15 m. If this is the case, then there may be no groundwater inflow or the groundwater inflows will be substantially less than the estimated 0.7 ML.

Table 7.3 details a sensitivity analysis performed on the hydraulic conductivity of the lithology, adjusted both one order of magnitude higher and lower than the value calculated from the hydraulic conductivity test (refer Section 6.2.2). The estimated range in total groundwater inflow during construction of the bunker is between 0.3–1.6 ML.

Table 7.3 Sensitivity analysis

Parameter	Units	Scenario 1	Scenario 2	Scenario 3
Hydraulic conductivity	m/day	0.001	0.03	0.1
Inflow to bunker	L/s	0.02	0.04	0.1
	kL/day	1	4	9
	ML/ 6 months	0.3	0.7	1.6

8 Impact assessment

The potential impacts from the water affecting activities are detailed in this section.

8.1 Hydraulic loading from the encapsulation cell

As part of the project, an encapsulation cell is proposed to be constructed in the south-west corner of the existing evaporation dam, ED1 (refer Figure 2.1). Available information suggests the clayey sediments underlying ED1 are saturated, receiving seepage from ED1 through historical operation of the dam. The applied load from the encapsulation cell on the sediments has the potential to consolidate the clayey sediment, causing the water pressure (groundwater level) to rise and altering the local groundwater flow regime. A qualitative assessment of this effect on groundwater and the potential impacts on receptors during construction and operation is discussed in the following subsections.

8.1.1 Construction

Construction activities for the encapsulation cell would involve (Golder 2022b):

- dewatering of ED1 in the encapsulation cell footprint;
- preparing the encapsulation cell foundation, including excavation and then use of fill to raise and develop the floor of the cell above the highest groundwater level measured to date (786 mAHD); and
- installation of a leachate collection system and double lining the floor of the encapsulation cell.

There is the potential for the shallow watertable in the unconfined colluvial aquifer to be intersected during the construction phase of works, although the base of the encapsulation cell is expected to be just above the watertable. These activities are expected to have minimal effect on the groundwater flow regime and would therefore not impact any receptors.

8.1.2 Operation

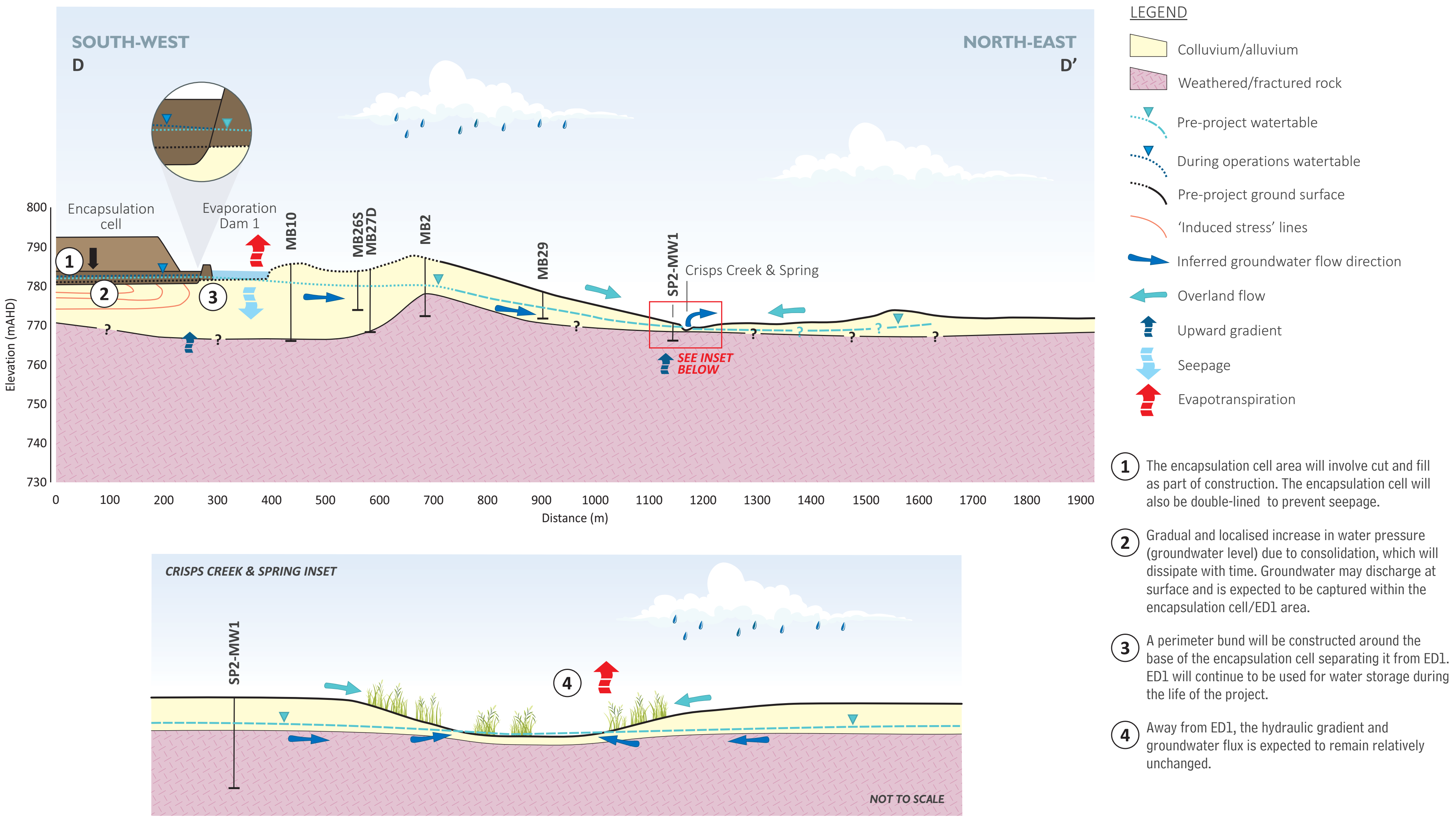
Operation of the encapsulation cell would (Golder 2022b):

- incorporate four placement stages in four main cells;
- placement would commence in the south of the encapsulation cell area and progress north;
- development of each cell would take approximately 6–7 years, with a conceptual design life of 25 years;
- final capping of the encapsulation cell is proposed to occur in year 26, based on the conceptual design life;
- the final height of the encapsulation cell is estimated to be 815 mAHD; and
- operation of the encapsulation cell would include operation of the leachate collection system.

Veolia will continue to operate the remaining portion of ED1 and ED2.

During operation of and filling of the encapsulation cell, the following is expected:

- consolidation of the clayey sediments by up to approximately 0.5 m (total), which would occur gradually and consistent with the placement of the APCr;
- gradual and localised increase in water pressure (groundwater level) in the colluvial/alluvial groundwater system in the immediate vicinity of ED1 due to sediment consolidation, in areas where placement is occurring. The localised increase in water pressure would be temporary and would dissipate with time;
- possible discharge of the existing groundwater stored in the clayey sediments at surface, localised in the ED1 and/or encapsulation area;
- dissipation of the increased water pressure (groundwater level) with time and distance from the encapsulation cell area;
- minimal change to the hydraulic gradient of the watertable away from ED1, towards Crisps Creek;
- under a conservative scenario where the groundwater level at MB10 increases by 0.5 m due to the consolidation effects in the low permeability alluvium/colluvium, the groundwater flux in the MB10 to MB27D area may increase to up to 270 kL/yr (up from 100 kL/yr under the “existing situation” (see Section 6.1.4), however this would reduce with time as the hydraulic gradient reduces;
- there may also be a measurable loading effect on the underlying semi-confined fractured rock groundwater system however the increase in water pressure is expected to be small, and hydraulic gradients are unlikely to substantially change; and
- groundwater flow processes are expected to remain relatively unchanged in the Crisps Creek and Spring 2 dam area, as this area will continue to receive water from rainfall and runoff (overland flow) and shallow groundwater discharge from the north.



1. The encapsulation cell area will involve cut and fill as part of construction. The encapsulation cell will also be double-lined to prevent seepage.
2. Gradual and localised increase in water pressure (groundwater level) due to consolidation, which will dissipate with time. Groundwater may discharge at surface and is expected to be captured within the encapsulation cell/ED1 area.
3. A perimeter bund will be constructed around the base of the encapsulation cell separating it from ED1. ED1 will continue to be used for water storage during the life of the project.
4. Away from ED1, the hydraulic gradient and groundwater flux is expected to remain relatively unchanged.

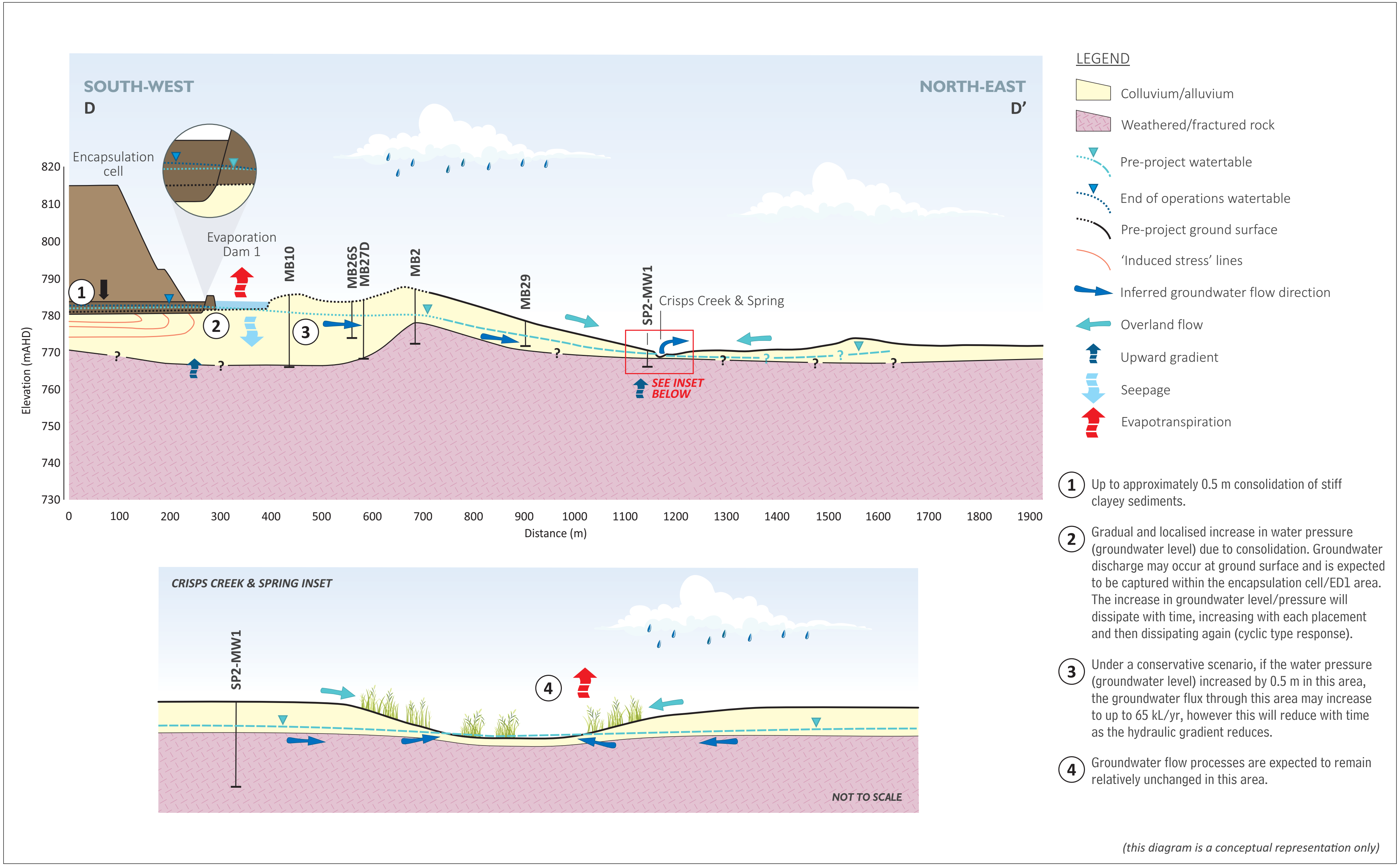
(this diagram is a conceptual representation only)

Encapsulation cell hydraulic loading conceptual diagram – during operations

Woodlawn Advanced Energy Recovery Centre
Groundwater assessment

Figure 8.1

EMM
creating opportunities



Encapsulation cell hydraulic loading conceptual diagram – end of operations

Woodlawn Advanced Energy Recovery Centre
Groundwater assessment
Figure 8.2

EMM creating opportunities

8.2 Groundwater abstraction from Willeroo borefield

The project and existing water demand is a combined total of approximately 140 ML/yr in normal seasons and potentially up to 300 ML/yr in drought seasons. This maximum demand equates to about 0.8 ML/day of groundwater supply from the Willeroo borefield.

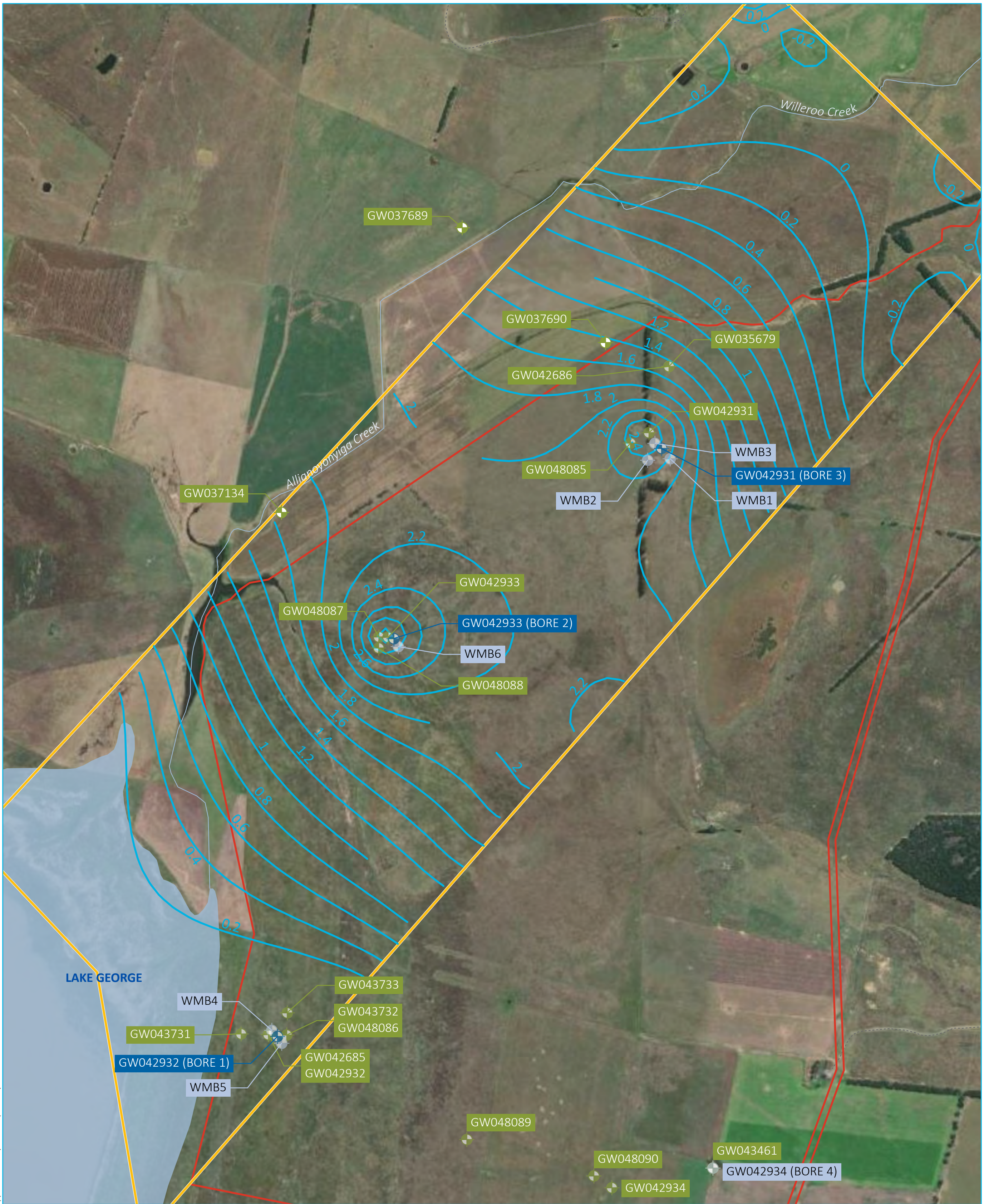
To meet the water demand during non-drought years (~140 ML/yr), one production bore operating at any one time should suffice, however it is important to cycle abstraction between all the operational bores. To meet the greater water demand during drought seasons of up to 300 ML/yr, two production bores will be required to be pumping at the same time. Continued cycling between production bores is recommended.

A preliminary analytical groundwater model was developed to simulate the operation of the bores and estimate the associated drawdown at individual production bores and across the borefield area. The analytical modelling was based on the aquifer parameters derived from the CRT of GW042931 – Bore 3 (see Section 8.2). The same parameters recorded during the CRT were assigned to the deep alluvial aquifer, while the parameters for the shallow alluvium and the bedrock were derived from literature representative values. The detailed modelling report which includes the model conceptualisation, boundaries, assumptions and limitations is provided in Appendix E.

The model assumes that the borefield entitlement of 600 ML/yr is extracted from the deep alluvial aquifer for the duration of the project. This highly conservative approach equates to a continuous abstraction rate of 20 L/s from the borefield. Groundwater abstraction was simulated from 3 production bores (GW042932 – Bore 1, GW042933 – Bore 2 and GW042931 – Bore 3) for a period of 12 months and based on a cyclic pumping schedule with only two bores operating at any one time. The assumed pumping schedule for each production bore was 14 days on and 7 days off.

The preliminary analytical model suggests the Willeroo borefield is capable of continuously supplying 20 L/s with limited drawdown and stress to the shallow and deep alluvial aquifers. The maximum simulated drawdown at each of the production bores after 12 months operation is 6 m or less. The simulated heads in the pumped aquifer show spatially limited drawdown in the vicinity of the production bores compared to the pre-pumping conditions. The simulated groundwater drawdown after 12 months operation is shown in Figure 8.3.

The predicted drawdown following 25 years of cyclic operation of the borefield (at 600 ML/yr) is shown in Figure 8.4. The watertable drawdown is predicted to extend the width of the deep aquifer palaeochannel. Potential drawdown impacts at third party bores, which are a minimum 750 m away, are highly unlikely as pumping is not expected to be continuous for the 25 year period.



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Source: EMM (2022); VEOLIA (2022); DFSI (2017)

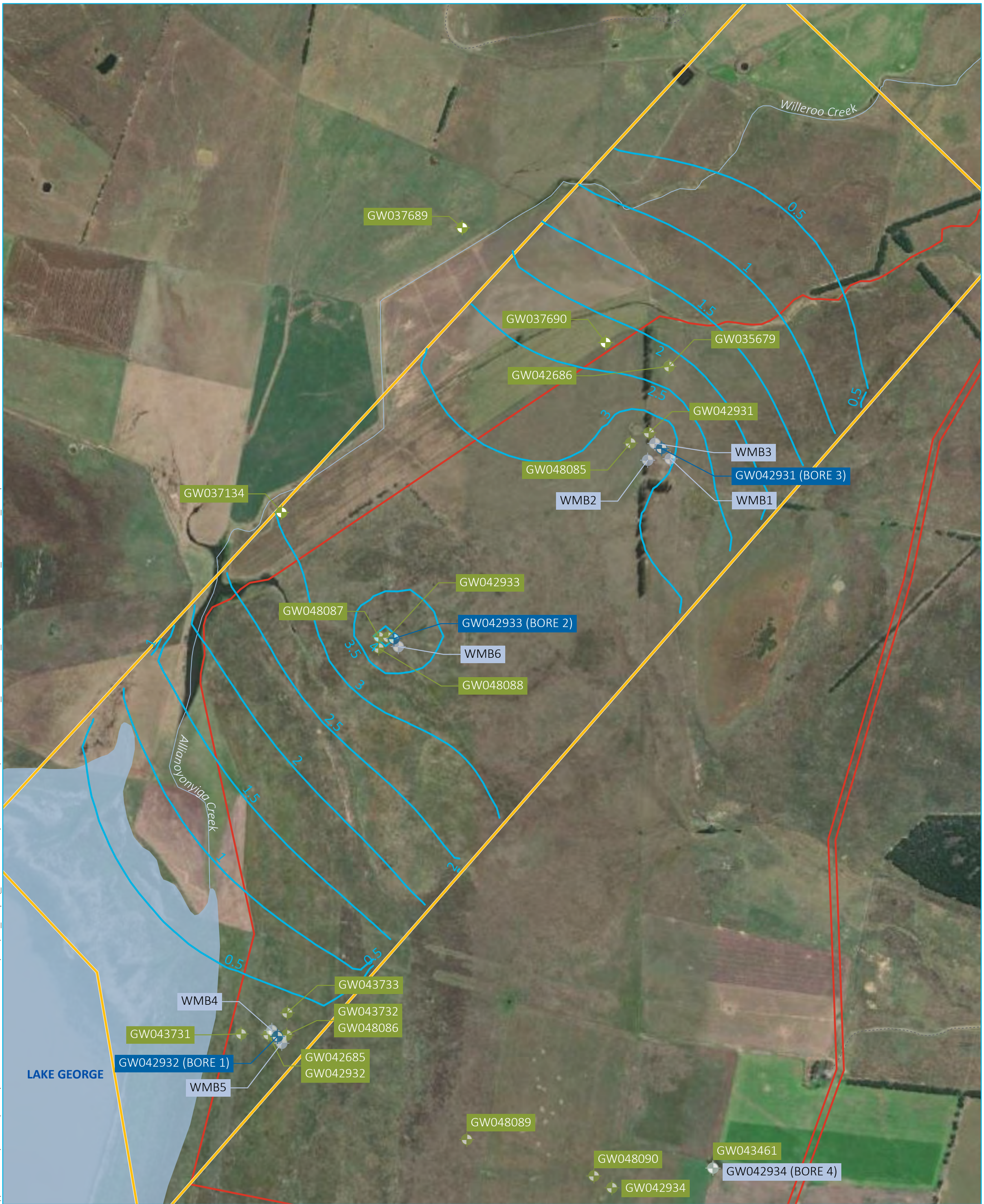
KEY

- Development footprint
- Production bore
- Monitoring bore
- Third-party bore
- Groundwater contour (m)
- Model boundary
- Willeroo borefield lot boundary
- Minor road
- Vehicular track
- Watercourse
- Named waterbody

Simulated groundwater drawdown in aquifer 2, year 1

Woodlawn Advanced Energy Recovery Centre
Groundwater assessment
Figure 8.3

creating opportunities



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Source: EMM (2022); Veolia (2022); DFSI (2017)

KEY

- Development footprint
- Production bore
- Monitoring bore
- Third-party bore
- Groundwater contour (m)
- Model boundary
- Willeroo borefield lot boundary
- Minor road
- Vehicular track
- Watercourse
- Named waterbody

Simulated groundwater drawdown in aquifer 2, year 25

Woodlawn Advanced Energy Recovery Centre
Groundwater assessment
Figure 8.4

EMM
creating opportunities

8.3 Cumulative impacts

The closest water affecting activity that has the potential to contribute to cumulative impacts on groundwater assets is the Woodlawn Mine operation (currently in care and maintenance). As discussed in Section 2.2, the historical mining activity has included open cut mining and underground mining, located below the Eco Precinct. Should mining resume, the planned underground mine workings will be located approximately 150 m laterally offset from the encapsulation cell and approximately 500 mbgl. The mining operation (historical or future) would result in groundwater drawdown within the hard rock /fractured rock groundwater system, which is already depressed due to the open cut mine void. However, due to the low permeability of the geology, the drawdown is localised.

Cumulative impacts are not assessed further, as the potential impacts of the project on the water environment and associated assets are considered negligible to minor and, in the vicinity of former underground workings, are associated with the shallow alluvial/colluvial groundwater system.

9 Risk assessment

9.1 Risk assessment and management framework

An evaluation of the project activities, and the potential impacts to groundwater and groundwater receptors has been completed. The project activities are outlined in Section 2, and the impact assessment approach and impact assessment are outlined in Sections 7 and 8, respectively.

The Veolia risk assessment matrix has been used to quantify the potential risks of the project on groundwater receptors and is outlined in Table 9.1.

Table 9.1 Risk matrix

		Likelihood				
		1. Rare	2. Unlikely	3. Possible	4. Likely	5. Almost certain
Consequence	5. Catastrophic	Medium (5)	High (10)	High (15)	Extreme (20)	Extreme (25)
	4. Major	Medium (4)	Medium (8)	High (12)	Extreme (16)	Extreme (20)
	3. Moderate	Low (3)	Medium (6)	Medium (9)	High (12)	High (15)
	2. Minor	Low (2)	Medium (4)	Medium (6)	Medium (8)	High (10)
	1. Insignificant	Low (1)	Low (2)	Low (3)	Medium (4)	Medium (5)

The classification of likelihood for activities is as follows:

1. rare: may occur in only exceptional circumstances;
2. unlikely: event to occur at least once a year in a two to three year period;
3. possible: event likely to occur at least once a year;
4. likely: event likely to occur at least monthly or quarterly over a year; and
5. almost certain: event likely to occur at least weekly.

The classification of environmental consequence is as follows:

1. Insignificant: no environmental harm or no lasting environmental harm (<1 day).
2. Minor:
   a) release to environment immediately contained within facility limits. Single breach of statutory limits; or
   b) short-term impact (<1 week); or
   c) less than 2 m drawdown at a third-party bore at a distance of 200 m; or
   d) breach of licensing requirements/water entitlement.
3. Moderate:
   a) release to environmental NOT contained within the facility limits. Repeated breach of environmental statutory limits; or
   b) requires moderate remediation; or
   c) greater than 2 m drawdown at a third-party bore at a distance of 200 m.
4. Major:
   a) material environmental harm causing potential severe and extensive loss/damage requiring clean up and rehabilitation;
   b) damage to fauna/flora;
   c) spillage under 155 litres (L) not contained.
5. Catastrophic:
   a) irreversible environmental harm caused to an area of high conservation value;
   b) spillage of toxic, flammable or explosive chemicals;
   c) facility fire requiring emergency services.

9.2 Risk evaluation

The risks of potential impacts caused by the project are summarised in Table 9.2. The risk evaluation assumes no additional controls (beyond those included as part of the project design) are in place. Potential impacts identified as having a medium or greater risk classification may be downgraded if appropriate controls and management measures are implemented and maintained. A revised risk assessment is provided in Table 10.2, and shows the residual risk after mitigation and management measures are implemented.

Table 9.2 Assessment of unmitigated potential impacts or events

Potential impact mechanism	Potential impact or event	Risk analysis (likelihood and consequence)			
		Low	Medium	High	Extreme
Hydraulic loading underlying the encapsulation cell	Increased groundwater levels in the vicinity of the cell and ED1	(3)			
Hydraulic loading underlying the encapsulation cell	Increased groundwater discharge and water quality impacts to Crisps Creek		(6)		
Stockpiling during project construction	Generation of acid mine drainage, altered recharge		(6)		
Release of APCr leakage from either the encapsulation cell and/or leachate pond	Water quality impacts to Crisps Creek		(6)		
Leakage from wastewater ponds and water storages	Local water quality impacts		(8)		
Built infrastructure (roads, buildings, plant)	Local water quality impacts, altered recharge	(3)			
Excavation of the ARC bunker and groundwater interception exceeds predicted volumes	Exceed licence exemption volume (3 ML), Veolia in breach of regulatory requirements		(4)		
Groundwater take at the Willeroo borefield	Greater than expected drawdown at third-party bores		(6)		

10 Monitoring, mitigation and management

10.1 Water management

The water management strategy for the project is based on:

- maintaining zero discharge from the project site;
- retaining water that lies within the existing water storages;
- capturing and re-using rainwater for use within the site;
- maintaining a ‘clean’ and ‘dirty’ water stream, comprising rainwater and process water;
- implementing a leak detection monitoring and management system at the encapsulation cell; and
- managing excavations and stockpiling of excavated material during construction to limit the duration that PAF material is potentially exposed.

10.2 Management and mitigation

Table 10.1 lists the potential impacts to groundwater receptors from water affecting activities and the proposed management measures.

Table 10.1 Management and mitigations summary table

Potential impact	ID	Measure	Timing
Drawdown greater than predicted (ie greater than 2 m) at third-party bores	GW01	Make-good arrangements, such as: • provision of supplementary water to offset loss in water supply; • provision of a new submersible pump to sustain a lost yield; • lowering pumping infrastructure within the bore to increase available drawdown; or • drilling a new bore for the landowner.	Operation
Drawdown greater than predicted (ie greater than 2 m) at third-party bores	GW02	Incorporate groundwater monitoring in the Willeroo borefield area into the overall water monitoring and management program, either through the use of existing monitoring bores and/or installation of additional monitoring bores.	Pre-construction
Hydraulic loading in ED 1 causing seepage at a faster rate	GW03	Conduct hydraulic loading analysis and review of requirements for groundwater seepage interception system, as part of detailed design of the encapsulation cell.	Post-approval, pre-construction

Table 10.1 Management and mitigations summary table

Potential impact	ID	Measure	Timing
Hydraulic loading in ED 1 causing seepage at a faster rate	GW04	Review and update of the water monitoring program ensuring adequate monitoring for potential: • surface expression of seepage; • groundwater discharge and/or increase groundwater pressure/level greater than that inferred in this groundwater assessment; and • in line with the information presented in Section 10.5. Install additional groundwater monitoring bores (nested) down gradient of the ED1 area, towards Crisps Creek. Develop site specific trigger levels, aligned with the environmental and cultural values, including WaterNSW Sydney Drinking Water Catchment requirements.	Post-approval, pre-construction
Hydraulic loading in ED 1 causing seepage at a faster rate	GW05	Develop trigger action response plan that includes contingency measures, if required, such as: • seepage management system, including seepage interception trench, sump and bores.	Consideration post-approval, as part of detailed design. Pre-construction.
Generation of acidic runoff from stockpiles	GW06	The design and management of the stockpiles to ensure PAF materials are exposed for short periods of time before being encapsulated with compacted NAF material. Stockpiles will be covered with uncontaminated topsoil and lime (or other alkaline materials) will be added to prevent the formation of acidic runoff. Stockpiles will be bunded and any captured runoff will be directed to the dirty water stream.	Construction
Seepage of APCr leachate from the leachate evaporation dam, encapsulation cell and/or the IBA maturation pad	GW07	The encapsulation cell and leachate ponds will have a dual lining, with a leachate barrier and detection system. The IBA maturation pad will comprise a hard-stand base, and a leachate collection system. Groundwater monitoring bores will be used as an early indication of seepage. Ongoing site inspection will be undertaken to verify there are no breaches of the leakage management system. Any ongoing risks will be assessed as part of closure planning to determine site closure remediation strategies and (if required) monitoring bores.	Construction and operation
Seepage from water storages (PCD and stormwater pond)	GW08	Water storage areas will be lined to limit loss of water. The dams will be routinely monitored for surface expression of seepage, including existing bores in the PCD area not currently monitored.	Construction and operation
Runoff from areas within the project development (including roads, plant, other buildings and hazard goods storage areas) picking up contaminant solutes and entering the groundwater system	GW09	The project will include runoff containment systems and other features to restrict surface water runoff within the project disturbance area. Where possible runoff from clean water areas will be captured and re-used. There will be dedicated and bunded storage areas for fuel and reagents.	Construction and operation

10.3 Residual risk

Application of the management measures outlined in Table 10.1 reduce the potential impact risk. The residual risks are summarised in Table 10.2.

Table 10.2 Assessment of mitigated potential impacts or events

Potential impact mechanism	Potential impact \event	Risk analysis (likelihood and consequence)			
		Low	Medium	High	Extreme
Hydraulic loading underlying the encapsulation cell	Increased groundwater levels in the vicinity of the cell and ED1	(3)			
Hydraulic loading underlying the encapsulation cell	Increased groundwater discharge and water quality impacts to Crisps Creek		(6)		
Stockpiling during project construction	Generation of acid mine drainage	(2)			
Release of APCr leakage from either the encapsulation cell and/or leachate pond	Water quality impacts to Crisps Creek	(3)			
Leakage from wastewater ponds and water storages	Local water quality impacts		(4)		
Built infrastructure (roads, buildings, plant)	Local water quality impacts	(3)			
Excavation of the ARC bunker and groundwater interception exceeds predicted volumes	Exceed licence exemption volume (3 ML), Veolia in breach of regulatory requirements	(2)			
Groundwater take at Willeroo borefield	Greater than expected drawdown at third-party bores	(3)			

10.4 Water management plan

The water management plan (WMP) will be updated for the project, encompassing both the construction phase and the operational phase of the project. The WMP will document the proposed mitigation and management measures for the approved project, and will include the surface and groundwater monitoring program, reporting requirements, spill management and response, site specific trigger levels, trigger action response plan (corrective actions), contingencies, and responsibilities for all management measures.

The WMP will be prepared in consultation with DIPE Water, the Natural Resources Access Regulator (NRAR) and EPA and will consider concerns raised during the exhibition and approvals process for the project.

The WMP will include details of the surface water and groundwater monitoring program, which will incorporate the existing monitoring network and any identified updates (see Section 10.5), monitoring frequencies and water quality constituents.

Reporting frameworks for the above will be prepared in accordance with licensing and agency requirements. Trigger levels for water quality parameters at key monitoring sites will be developed as part of the WMP to assist in early identification of adverse water quality trends due to potential increased seepage migration. The monitoring program will be prepared in accordance with the development consent conditions and environment protection licence(s) (EPL) for the project, once enacted.

Groundwater quality performance triggers around the encapsulation cell will be based on statistical analysis of the reported ranges in baseline concentrations of identified analytes of concern. This analytical suite will likely include pH, salinity concentrations, and concentrations of other analytes such as arsenic, aluminium, cadmium, copper, sulfate, iron, zinc, as well as any additional analytes specific to the ash leachate composition from the APCr. The Ash Management Study (WSP 2021) analysed ash compositions from existing global energy from waste processes and recorded the following metals at high levels: antimony, arsenic, cadmium, chromium, lead, mercury and nickel.

Groundwater level performance triggers will be based on a comparison of observed groundwater levels. Key monitoring bores will be selected for the installation of continuous groundwater level loggers.

The hazardous goods management plan will identify requirements for storing fuels and other potential contaminants on site to minimise the risk of spill.

10.5 Water monitoring

10.5.1 Eco Precinct

The Eco Precinct baseline monitoring network is discussed in Section 5.1. The groundwater monitoring network currently includes 36 project specific monitoring bores. Groundwater monitoring (levels and quality) has been conducted since 1997. The Veolia environmental monitoring network also includes surface water quality monitoring and a weather station.

The monitoring network will provide an early indication of potential impact to sensitive receptors, including Crisps Creek.

As part of the update the WMP, Veolia will review and update of the water monitoring program:

- ensuring adequate monitoring for potential:
  - surface expression of seepage from the encapsulation cell; and
  - groundwater discharge and/or increase groundwater pressure/level in the encapsulation cell area greater than that inferred in this groundwater assessment;
- identifying additional monitoring bore locations (with consideration of logistics, safety and access constraints):
  - down gradient of the ED1 area towards Crisps Creek, installing nested monitoring bores to allow monitoring of the alluvium/colluvium and fractured rock groundwater systems;
  - around the perimeter of the encapsulation cell;
  - near MB2 and MB10, turning these sites into nested sites to monitor for increased groundwater levels arising from hydraulic loading; and
- identifying additional surface water monitoring locations closer to the Eco Precinct (for quality and flow, if practical).

Key monitoring bores will be selected for the installation of continuous groundwater level loggers.

All water quality monitoring will be undertaken in accordance with the *Approved Methods for the Sampling and Analysis of Water Pollutant in NSW* (EPA 2004).

The need for, and methodology of, ongoing water monitoring after completion of the project will be confirmed during development of the detailed rehabilitation and closure plan.

10.5.2 Willeroo borefield

Veolia propose the following additional works at the Willeroo borefield to ensure long-term supply reliability and operating efficiency:

- production bore re-development works to improve bore efficiency – due to the age of the bores, this has been identified as an activity that will improve operating efficiency and long-term supply reliability;
- contemporising the flow monitoring system to ensure conformance with the NSW non-urban water metering framework;
- confirmation of the integrity of the existing monitoring bores in the Willeroo borefield;
- incorporating groundwater level and quality monitoring at the Willeroo borefield into the water monitoring program (refer Figure 2.2), including:
  - consideration of the existing monitoring bores (dependent on bore integrity);
  - consideration of installing additional monitoring bores to replace decommissioned monitoring bores adjacent to production bores; and
  - consideration of installing additional monitoring bores further afield for impact assessment monitoring purposes.

11 Groundwater licensing

11.1 Groundwater take requirements

Veolia is required to licence water that is taken in accordance with the WM Act 2000 or where incidental water is intercepted as described under the AIP. Veolia are required to hold WALs in each affected water source to account all water extracted and intercepted. The volume of water to be licensed for the project is defined as:

- groundwater inflow to the ARC bunker during construction, should this exceed 3 ML/yr; and
- groundwater take from the Willeroo borefield.

The results of the groundwater analytical models have been used to estimate the required groundwater licence entitlements for the project, based on the predicted total groundwater inflow rates to the bunker during construction and operation of the Willeroo borefield.

11.2 Entitlement

Veolia has a WAL for 600 ML (WAL: 28983) linked to four production bores (GW042931, GW042932, GW042933 and GW042934). Water is licensed under the NSW Murray Darling Basin Fractured Rock Groundwater Sources Water Sharing Plan (WSP) (2020), specifically the Lachlan Fold Belt Murray Darling Basin Groundwater Source.

Veolia requires 90 ML/yr for the proposed ARC project, and EMM (2021) predict the annual groundwater demand will be between 53-90 ML/yr, (ie 60−100% of demand), depending on climate conditions. Rainfall capture and re-use will supplement the water demand when available. Combined with the additional demand for the existing operations at the Eco Precinct the total water demand is 146 ML in average years, and up to 300 ML in severe drought conditions.

Veolia holds sufficient groundwater licence volume to cater for site demands, even during severe drought periods. Veolia is the sole owners of the water licence allocation and have an agreement with the mine operator to provide them with water, if required.

11.3 Exemptions

In December 2019, the NSW Government introduced an exemption in the Water Management (General) Regulation 2018 that allows up to 3 ML of groundwater to be taken through aquifer interference activities, including excavations. This exemption is applicable to the proposed construction works to be undertaken at the ARC waste bunker, where the predicted total inflow range is between 0.3-1.6 ML. This take is from the Lachlan Fold Belt Murray Darling Basin Groundwater Source, managed by the NSW Murray Darling Basin Fractured Rock Groundwater Sources WSP (2020).

Therefore, Veolia is exempt from requiring to hold entitlement for the groundwater that may be intercepted during excavation and construction of the ARC bunker.

12 Conclusions

The potential impacts of the project have been assessed with consideration of the SEARs and relevant regulations, policy and guidelines.

The following is a summary of the key conclusions of the groundwater assessment:

- the existing groundwater supply to the Eco Precinct from the Willeroo borefield is adequate to meet the project water requirements;
- Veolia holds sufficient entitlement for the take associated with operation of the Willeroo borefield;
- excavation of the ARC bunker is expected to intercept groundwater for a short duration during construction and would not impact groundwater assets;
- water take associated with intercepting groundwater during construction of the ARC bunker is expected to be less than 3 ML/yr and Veolia is therefore exempt from licensing this take (in accordance with the Water Management (General) Regulation 2018);
- development of the encapsulation cell is expected to consolidate the underlying clayey sediments of the alluvium/colluvium, causing the water pressure (groundwater level) to rise gradually and locally, which would dissipate with distance and time;
- groundwater flow processes are expected to remain relatively unchanged in the Crisps Creek and Spring 2 dam area, as this area will continue to receive water from rainfall and runoff (overland flow) and shallow groundwater discharge from the north;
- the potential effects of hydraulic loading on the groundwater system or excavation for the ARC bunker (the main water affecting activities in the Goulburn Fractured Rock Groundwater Source[2]) is not expected to have an adverse impact on the water quality of groundwater discharging to Crisps Creek or the greater Sydney drinking water catchment;
- Veolia has adopted several leading practices to produce a project design that avoids and minimises impacts to water assets; and
- the water management strategy for the project is based on a number of water efficiency measures and a commitment to maintain zero discharge from the Eco Precinct.

Monitoring of the groundwater monitoring network will continue, and the network will be expanded to target the identification of potential impacts from project activities. Triggers and thresholds will be developed to provide context on if, how and when management measures are required as part of the WMP for the project.

[2] Managed by the *Water Sharing Plan for the Greater Metropolitan Region Groundwater Sources (2011)*

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Abbreviations

AEMR	Annual Environmental Management Report
AIP	Aquifer Interference Policy
ANZG	Australian and New Zealand Guidelines for Fresh and Marine Water Quality
AHD	Australian Height Datum
ALS	Australian Laboratory Services
AMD	acid mine drainage
APC	air pollution control
APCr	air pollution control residues
ARC	Woodlawn Advanced Energy Recovery Centre
BAT	best available techniques
BDAR	Biodiversity Development Assessment Report
Bioreactor	Woodlawn Bioreactor
BoM	Bureau of Meteorology
C&I	Commercial and industrial
CRT	Constant rate test
DEC	Department of Environment and Conservation
DECC	Department of Environment Climate Change
DECCW	Department of Environment Climate Change and Water
DWLC	Department of Land and Water Conservation
DPI	Department of Primary Industries
DPIE	Department of Planning, Industry and Environment
DPIW	Department of Primary Industries, Water
Eco Precinct	Woodlawn Eco Precinct
ED	Evaporation Dam
EIS	Environmental Impact Statement
EfW	Energy from Waste
EMM	EMM Consulting Pty Limited
EP&A Act	*Environmental Planning and Assessment Act 1979*
EPA	Environment Protection Authority
EPBC Act	*Environment Protection and Biodiversity Conservation Act 1999*
EPL	Environment protection licence
ERF	energy recovery facility
GDE	Groundwater dependent ecosystem
GDR	Great Dividing Range
IBA	incinerator bottom ash
IMF	Crisps Creek Intermodal Facility
K	Hydraulic conductivity
LFG	landfill gas

LTP	leachate treatment plant
mAHD	meters Australian Height Datum
mbgl	meters below ground level
MBT	Woodlawn Mechanical Biological Treatment Facility
MSW	municipal solid waste
Mtpa	Million tonnes per annum
MW	Mega watt
NEPC	National Environment Protection Council
NorBE	Neutral or Beneficial Effect
NRAR	Natural Resources Access Regulator
OEH	Office of Environment and Heritage
POEO Act	*Protection of the Environment Operations Act 1997*
S	Storativity
SEARs	Secretary's Environmental Assessment Requirements
SEPP	State Environmental Planning Policy
SSD	State significant development
T	Transmissivity
tpa	tonnes per annum
Veolia	Veolia Environmental Services (Australia) Pty Ltd
WAL	Water Allocation Licence
WM Act	Water Management Act
WMP	Water management plan
WSP	Water sharing plan

Glossary

Term	Definition
Allocation	The specific volume of water allocated to water access entitlements in a given water year or allocated as specified within a water resource plan.
Alluvium	Loose, unconsolidated (not cemented together into a solid rock), soil or sediments (including clay, silt, sand, gravel, cobbles and boulders), eroded, deposited and reshaped by water in some form in a non-marine setting.
Aquifer	A geological formation or group of formations; able to receive, store and transmit significant quantities of water. Means a geological structure or formation, or an artificial landfill, that is permeated with water or is capable of being permeated with water (NSW Water Management Act 2000 definition).
Aquifer, confined	An aquifer overlain by a confining bed. The confining bed has a significantly lower hydraulic conductivity than the aquifer. Typically, groundwater in a confined aquifer is under pressure significantly greater than atmospheric pressure.
Aquifer, fractured rock	An aquifer that occurs in sedimentary, igneous and metamorphosed rocks which have been subjected to disturbance, deformation, or weathering, and which allow water to move through joints, bedding planes, fractures and faults.
Aquifer interference activity	Means an activity involving any of the following: (a) the penetration of an aquifer, (b) the interference with water in an aquifer, (c) the obstruction of the flow of water in an aquifer, (d) the taking of water from an aquifer in the course of carrying out mining, or any other activity prescribed by the regulations, (e) the disposal of water taken from an aquifer as referred to in paragraph (d). (*NSW Water Management Act 2000* definition).
Aquifer, unconfined	An aquifer in which there is no confining bed between the zone of saturation and the surface. The water table is the upper boundary of an unconfined aquifer and is at atmospheric pressure.
Aquitard	A geological formation that may contain groundwater but is not capable of transmitting significant quantities of it under normal hydraulic gradients. May function as a confining bed.
Baseflow	The component of streamflow supplied by groundwater discharge. Baseflow is characterised by an exponential decay curve following the cessation of surface runoff.
Beneficial use	Referenced in the NSW Aquifer Interference Policy relating to assessment of water quality impacts. The term “beneficial use” is interchangeable with the term “environmental value” (NWQMS 2013) (see below for definition).
Bore	A hole drilled in the ground, a well or any other excavation used to access groundwater. May be used for observation of groundwater (including water level, pressure or quality).
Calibration	Process of adjusting the values of model parameters within physically defensible ranges until the model performance adequately matches observed historical data from one or more locations represented by the model (ie a match is obtained that is robust and fit for purpose).
Catchment	The land area draining to a point of interest, such as a water storage or monitoring site on a watercourse.
Colluvium	Unconsolidated sediments that have been deposited at the base of hillslopes or depressions in the landscape by either runoff, sheet wash, slow continuous downslope creep, or a variable combination of these processes.

Term	Definition
Conceptual model	Documentation or schematic of the conceptual understanding of groundwater recharge and discharge processes, flow within a groundwater system, and the interaction of groundwater with surface water and GDEs.
Drawdown	The lowering of water levels in a surface water or groundwater storage resulting from the loss or take of water from the storage.
Ecological water requirement	Description of the water regimes needed to sustain the ecological values of water-dependent ecosystems at a low level of risk.
Ecosystem	A dynamic complex of plant, animal and micro-organism communities and their non-living environment interacting as a functional unit.
Electrical conductivity (EC)	Electrical conductivity (EC) measures dissolved salt in water. The standard EC unit is microSiemens per centimetre (µS/cm) at 25 °C.
Environmental value	Environmental values are particular values, or uses, of the water resource that are important for a healthy ecosystem or for public benefit, welfare, safety or health, and which require protection from the effects of contamination, waste discharges and deposits (NWQMS 2013). They reflect the ecological, social and economic values and uses of a water resource. The term "environmental value" replaces the term "beneficial use", which was used in previous guidelines (NWQMS 2013) and also in the NSW Aquifer Interference Policy.
Ephemeral	Something which only lasts for a short time. Typically used to describe rivers, lakes and wetlands that are intermittently dry.
Evaporation	A process that occurs at a liquid surface, resulting in a change of state from liquid to vapour. In relation to water resource assessment and water accounting, evaporation refers to the movement of water from the land surface (predominantly liquid) to the atmosphere (water vapour). The liquid water at the land surface that may be available for evaporation includes surface water, soil water, shallow groundwater, water within vegetation, and water on vegetation and paved surfaces.
Evapotranspiration	The combined loss of water from a given area during a specified period of time by evaporation from the soil or water surface and by transpiration from plants.
Extraction	Synonymous with abstraction in the case where water is removed from a groundwater store.
Gaining stream	A stream where groundwater discharge contributes to streamflow.
Groundwater	Water contained within rocks and sediments below the ground surface in the saturated zone, including perched systems above the regional watertable.
Groundwater access entitlement	Water access entitlement granted on the groundwater resource. In NSW, equivalent to an aquifer access licence.
Groundwater allocation	Volume of water resulting from an allocation announcement made on a groundwater access entitlement.
Groundwater, artesian	Groundwater that is under pressure when tapped by a bore and rises above the level at which it is first encountered. It may or may not flow out at ground level.
Groundwater Dependent Ecosystem (GDE)	Natural ecosystems that require access to groundwater to meet all or some of their water requirements on a permanent or intermittent basis, so as to maintain their communities of plants and animals, ecosystem processes and ecosystem services.
Groundwater, deep	Groundwater below the regional water table in the fractured rock groundwater system that has a long circulation flowpath and discharges to regional features (generally low in the landscape) such as incised gorges, and permanent creeks and rivers.
Groundwater discharge	The process by which groundwater is released into the environment usually either via baseflow or evapotranspiration.
Groundwater flow	Water that flows in aquifers and aquitards.

Term	Definition
Groundwater level	The level of groundwater in an aquifer, typically measured in a groundwater bore. In the case of an unconfined aquifer, the groundwater level is equal to the water table level.
Groundwater, perched	A region in the unsaturated zone where the soil or rock may be locally saturated because it overlies a low-permeability unit. In the KNP, perched groundwater is very shallow groundwater above the regional water table that is derived from rainfall and is retained in the elevated wetlands and some mid-slope bogs/fens, and potentially some basalt caps.
Groundwater, regional	A collective term for shallow and deep groundwater.
Groundwater recharge	The process which replenishes groundwater, usually by rainfall infiltrating from the ground surface to the water table and/or by surface water infiltrating to the water table from a stream. Other forms of recharge include flooding and irrigation, and artificial recharge can also occur through various means, including bore injection.
Groundwater, shallow	Groundwater below the regional water table in the weathered fractured rock groundwater system that has a short circulation flowpath and discharges to local features (generally in upper and mid catchment landscape areas) such as springs and permanent creeks.
Groundwater system	Multiple aquifers that are overlying or adjacent but not necessarily connected, and are hydrogeologically similar regarding geological province, hydraulic characteristics and water quality. A system may consist of groundwater in one or more geological formations.
Hydraulic conductivity	A property of soil or rock, which describes the ease with which water can move through pore spaces or fractures. It depends on the intrinsic permeability of the material and on the degree of saturation. Saturated hydraulic conductivity describes water movement through saturated media.
Hydraulic gradient	Calculated as the difference between two hydraulic head measurements divided by the distance between the two measurements. Hydraulic gradient is used in the calculation of water flow.
Hydrogeologic unit	One or more geologic units which have similar hydrogeological characteristics and behaviour.
Hydrograph	A graph showing the surface level, discharge, velocity, or some other feature of water, with respect to time.
Hydrostratigraphic unit	The subsurface is divided into hydrostratigraphic units that have similar properties from the point of view of storage and transmission of groundwater. Units that store significant amounts of water and transmit this water relatively easily are called aquifers. Units that offer a high resistance to flow are called aquitards, or confining layers. See also Hydrogeologic unit.
Incidental water	Water that is taken by an aquifer interference activity that is incidental to the activity; including water that is encountered within and extracted from mine workings, tunnels, basements or other aquifer interference structures that must be dewatered to maintain access, serviceability and/or safe operating conditions. (NSW AIP).
Infiltration	The process by which water on the ground surface enters the soil profile.
Losing stream	A stream from which water is lost to the surrounding and underlying substrate via infiltration through the streambed and banks.
Monitoring site	A place where observations of the environment are made; typically a physical location where sensors are used to measure the properties of one or more features of the environment (eg depth of a river, water level in a bore, surface or groundwater quality).
Nested bore	A bore with more than one pipe or a group of nearby bores, open at different levels in aquifers/aquitards, used to evaluate the vertical variation in groundwater pressure head or chemistry.
Overland flow	Surface runoff, which is caused when either, the ground surface is impervious, the underlying soil is saturated and cannot accommodate any more water, or because the intensity of rainfall is greater than the soil's capacity to infiltrate it.

Term	Definition
Parameter	A measurable characteristic of a physical entity (feature); for example, the temperature of water in a river.
Permeability	The measure of the ability of a rock, soil or sediment to transmit a fluid. The magnitude of the permeability depends largely on the porosity and the connectedness of pores spaces. Synonymous with hydraulic conductivity when water is the fluid involved.
pH	Value that represents the acidity or alkalinity of an aqueous solution. It is defined as the negative logarithm of the hydrogen ion concentration of the solution.
Potentiometric surface	A surface representing the hydraulic head of groundwater; represented by the water table altitude in an unconfined aquifer or by the altitude to which water will rise in a properly constructed bore in a confined aquifer.
Precipitation	All forms in which water falls on the land surface and open water bodies as rain, sleet, snow, hail, or drizzle.
Regulated river	River on which a licensed entitlement regime exists with centralised allocation, and from which orders may be placed for upstream release of a licensed allocation. A necessary, but not sufficient condition for a river to be regulated is that it is located downstream of a surface water storage.
Riparian	An area or zone within or along the banks of a stream or adjacent to a watercourse or wetland; relating to a riverbank and its environment, particularly to the vegetation.
Saturated zone	The soil and geological layers below the land surface where all spaces between soil/sediment/rock particles are filled with water. It encompasses all the soil and geological layers below the water table.
Seepage	The infiltration of water from streams, irrigation channels, water storages, farm dams, natural surface water features and septic tanks into the groundwater system. It is a form of surface water–groundwater interaction and groundwater recharge. The term can also apply to low volumes of groundwater discharge.
Sensitivity	The degree to which numerical model outputs are affected by changes in selected input parameters.
Specific yield	The storage property for an unconfined aquifer that defines the quantity of water that can be drained from an aquifer under the influence of gravity or extracted by pumping.
Standing water level	Depth to groundwater below a datum point or reference point, usually from the top of casing or natural surface.
Storativity	The volume of water a confined aquifer will release when the water-level is lowered due to pumping or natural discharge. Upon the lowering of potentiometric water levels in such aquifers, they remain fully saturated so that no dewatering occurs (ie the potentiometric surface remains above the top of the confined aquifer formation). The water released is volumetrically equivalent to the volumetric expansion of the water and contraction of the pore space.
Stream	A watercourse and its tributaries. A stream can be permanent or ephemeral.
Streamflow	The flow of water in streams, rivers and other channels.
Surface runoff	Water from precipitation or other sources that flows over the land surface.
Surface water	Water that flows over or is stored on the surface of the earth that includes: (a) water in a watercourse, lake or wetland and (b) any water flowing over or lying on land: (i) after having precipitated naturally or (ii) after having risen to the surface naturally from underground.

Term	Definition
Take	Take water from a water resource means to remove water from, or to reduce the flow of water in or into, the water resource including by any of the following means: (a) pumping or siphoning water from the water resource; (b) stopping, impeding or diverting the flow of water in or into the water resource; (c) releasing water from the water resource if the water resource is a wetland or lake; (d) permitting water to flow from the water resource if the water resource is a well or watercourse; and includes storing water as part of, or in a way that is ancillary to, any of the processes or activities referred to in paragraphs (a) to (d). (Commonwealth Water Act 2007 definition).
Total dissolved solids (TDS)	The sum of all particulate material dissolved in water. Usually expressed in terms of milligrams per litre (mg/L).
Uncertainty	A state of lack of confidence to exactly describe the current or future condition of a system when limited knowledge of that system is available. Uncertainty is often categorised into two main types (Barnett et al. 2012): • deficiency in our knowledge of the natural world (including the effects of error in measurements); • failure to capture the complexity of the natural world (or what we know about it) in a model. Formal definition from AS/NZS ISO 310000:2009: Uncertainty is the state, even partial, of deficiency of information related to the understanding or knowledge of an event, its consequence, or its likelihood.
Unregulated river	A river where there is no entitlement system at all or where there is an entitlement system that does not allow orders to be placed for upstream release of a licensed allocation.
Unsaturated zone	The soil between the land surface and the regional water table in which the pore space contains both air and water.
Validation	Where observations and model simulations are compared using data that were not part of the model calibration.
Verification	Verification involves comparing the predictions of the calibrated model to a set of measurements that were not used to calibrate the model, in order to confirm that the model is suitable for use as a predictive tool.
Water access entitlement	A perpetual or ongoing entitlement to exclusive access to a share of water from a specified consumptive pool as defined in the relevant water plan. In NSW, equivalent to a water access licence (ie an access licence referred to in section 56 of the Water Management Act 2000).
Water balance	The flow of water into and out of, and changes in the storage volume of, a surface water system, groundwater system, catchment or specified area over a defined period of time.
Water quality	The physical, chemical and biological characteristics of water. Water-quality compliance is usually assessed by comparing these characteristics with a set of reference standards. Common standards used are those for drinking water, safety of human contact and the health of ecosystems.
Water resource	All natural water (surface water or groundwater) and alternative water sources, such as recycled or desalinated water, that has not yet been abstracted or used.
Water sharing plan	A legislated plan that establishes rules for managing and sharing water between ecological processes and environmental needs of the respective water source (river/aquifer). It manages water access licences, water allocation and trading, water extraction, operation of dams, management of water flows, and use and rights of different water users.

Term	Definition
Water source	In NSW, water source means the whole or any part of: (a) one or more rivers, lakes or estuaries, or (b) one or more places where water occurs on or below the surface of the ground (including overland flow water flowing over or lying there for the time being), and includes the coastal waters of the State. (NSW Water Management Act 2000 definition).
Water table	The top of an unconfined aquifer which can be either perched or regional. It is at atmospheric pressure and, in a regional context, indicates the level below which soil and rock are saturated with water.
Water year	A continuous twelve-month period starting from a specified month for water accounting purposes. In NSW this is 1 July to 30 June each year.
Wetland	An area of land whose soil is saturated with moisture either permanently or intermittently. Wetlands are typically highly productive ecosystems. They include areas of marsh, fen, parkland and open water. Open water can be natural or artificial; permanent or temporary; static or flowing; and fresh, brackish or salty.

Appendix A
Aquifer Interference Assessment Framework

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AQUIFER INTERFERENCE ASSESSMENT FRAMEWORK

Assessing a proposal against the NSW Aquifer Interference Policy – step by step guide

Note for proponents

This is the basic framework which the NSW Office of Water uses to assess project proposals against the **NSW Aquifer Interference Policy (AIP).**

The NSW Aquifer Interference Policy can be downloaded from the NSW Office of Water website (www.water.nsw.gov.au under Water management > Law and policy > Key policies > Aquifer interference).

While you are not required to use this framework, you may find it a useful tool to aid the development of a proposal or an **Environmental Impact Statement (EIS)***.*

We suggest that you summarise your response to each AIP requirement in the tables following and provide a reference to the section of your EIS that addresses that particular requirement. Using this tool can help to ensure that all necessary factors are considered, and will help you understand the requirements of the AIP.

Table 1. Does the activity require detailed assessment under the AIP?

	Consideration	Response
1	Is the activity defined as an aquifer interference activity?	If **NO,** then no assessment is required under the AIP. If **YES,** continue to Question 2.
2	Is the activity a defined minimal impact aquifer interference activity according to section 3.3 of the AIP?	If **YES**, then no further assessment against this policy is required. Volumetric licensing still required for any water taken, unless exempt. If **NO**, then continue on for a full assessment of the activity.

Note for proponents

Section 3.2 of the AIP defines the framework for assessing impacts. These are addressed here under the following headings:

1. Accounting for or preventing the take of water
2. Addressing the minimal impact considerations
3. Proposed remedial actions where impacts are greater than predicted.

1. Accounting for, or preventing the take of water

Where a proposed activity will take water, adequate arrangements must be in place to account for this water. It is the proponent's responsibility to ensure that the necessary licences are held. These requirements are detailed in Section 2 of the AIP, with the specific considerations in Section 2.1 addressed systematically below.

Where a proponent is unable to demonstrate that they will be able to meet the requirements for the licensing of the take of water, consideration should be given to modification of the proposal to prevent the take of water.

Table 2. Has the proponent:

	AIP requirement	Proponent response	NSW Office of Water comment
1	Described the water source(s) the activity will take water from?	WSP for the Greater Metropolitan Region Groundwater Sources (2011): Goulburn Fractured Rock Groundwater Source; and WSP for the NSW Murray Darling Basin Fractured Rock Groundwater Sources Order (2020), Lachlan Fold Belt MDB Groundwater Source	
2	Predicted the total amount of water that will be taken from each connected groundwater or surface water source on an annual basis as a result of the activity?	Goulburn Fractured Rock: take < 3ML during construction phase only for the ARC bunker	
3	Predicted the total amount of water that will be taken from each connected groundwater or surface water source after the closure of the activity?	Zero for both units	
4	Made these predictions in accordance with Section 3.2.3 of the AIP? (refer to Table 3, below)	Yes	
5	Described how and in what proportions this take will be assigned to the affected aquifers and connected surface water sources?	All take will be wholly from the Goulburn Fractured Rock Groundwater Source	
6	Described how any licence exemptions might apply?	Take from the fractured rock will be exempt from licencing in accordance with the Water Management (General) Regulation 2018 that allows up to 3 ML of groundwater to be taken through aquifer interference activities, including excavations	
7	Described the characteristics of the water requirements?	Take from the fractured rock is incidential take expected during the construction of an excavation.	

	AIP requirement	Proponent response	NSW Office of Water comment
8	Determined if there are sufficient water entitlements and water allocations that are able to be obtained for the activity?	NA - no entitlement required	
9	Considered the rules of the relevant water sharing plan and if it can meet these rules?	NA	
10	Determined how it will obtain the required water?	NA	
11	Considered the effect that activation of existing entitlement may have on future available water determinations?	Yes	
12	Considered actions required both during and post-closure to minimize the risk of inflows to a mine void as a result of flooding?	NA - lined bunker - there will be no void	
13	Developed a strategy to account for any water taken beyond the life of the operation of the project?	NA - will not occur	
Will uncertainty in the predicted inflows have a significant impact on the environment or other authorised water users? If **YES,** items 14-16 must be addressed.			
14	Considered any potential for causing or enhancing hydraulic connections, and quantified the risk?		
15	Quantified any other uncertainties in the groundwater or surface water impact modelling conducted for the activity?		
16	Considered strategies for monitoring actual and reassessing any predicted take of water throughout the life of the project, and how these requirements will be accounted for?		

Table 3. Determining water predictions in accordance with Section 3.2.3
(complete one row only – consider both during and following completion of activity)

	AIP requirement	Proponent response	NSW Office of Water comment
1	**For the Gateway process**, is the estimate based on a simple modelling platform, using suitable baseline data, that is, fit-for-purpose?		
2	**For State Significant Development or mining or coal seam gas production**, is the estimate based on a complex modelling platform that is: • Calibrated against suitable baseline data, and in the case of a **reliable water source,** over at least two years? • Consistent with the Australian Modelling Guidelines? • Independently reviewed, robust and reliable, and deemed fit-for-purpose?		
3	In all other processes, estimate based on a desk-top analysis that is: • Developed using the available baseline data that has been collected at an appropriate frequency and scale; and • Fit-for-purpose?	Fit for purpose	

Other requirements to be reported on under Section 3.2.3

Table 4. Has the proponent provided details on:

	AIP requirement	Proponent response	NSW Office of Water comment
1	Establishment of baseline groundwater conditions?	Yes, data set spans 14 years	
2	A strategy for complying with any water access rules?	Yes	
3	Potential water level, quality or pressure drawdown impacts on nearby basic landholder rights water users?	No nearby BLR water users	
4	Potential water level, quality or pressure drawdown impacts on nearby licensed water users in connected groundwater and surface water sources?	Drawdown has been predicted, with no impacts to landholders in connected groundwater and surface water sources. No groundwater quality impacts are predicted.	
5	Potential water level, quality or pressure drawdown impacts on groundwater dependent ecosystems?	Drawdown has been predicted, with no impacts to GDEs. No groundwater quality impacts are predicted.	
6	Potential for increased saline or contaminated water inflows to aquifers and highly connected river systems?	Fractured rock water table may be depressed for a short period during construction with any encountered groundwater taken to onsite evaporation dams. No potential for increased inflows to aquifers or hihghly connected rivers	
7	Potential to cause or enhance hydraulic connection between aquifers?	No	
8	Potential for river bank instability, or high wall instability or failure to occur?	No	
9	Details of the method for disposing of extracted activities (for coal seam gas activities)?	No	

2. Addressing the minimal impact considerations

Note for proponents

Section 3.2.1 of the AIP describes how aquifer impact assessment should be undertaken.

1. Identify all water sources that will be impacted, referring to the water sources defined in the relevant water sharing plan(s). Assessment against the minimal impact considerations of the AIP should be undertaken for each ground water source.
2. Determine if each water source is defined as 'highly productive' or 'less productive'. If the water source is named in then it is defined as highly productive, all other water sources are defined as less productive.
3. With reference to pages 13-14 of the Aquifer Interference Policy, determine the sub-grouping of each water source (eg alluvial, porous rock, fractured rock, coastal sands).
4. Determine whether the predicted impacts fall within Level 1 or Level 2 of the minimal impact considerations defined in Table 1 of the AIP, for each water source, for each of water table, water pressure, and water quality attributes. The tables below may assist with the assessment. There is a separate table for each sub-grouping of water source – only use the tables that apply to the water source(s) you are assessing, and delete the others.
5. If unable to determine any of these impacts, identify what further information will be required to make this assessment.
6. Where the assessment determines that the impacts fall within the Level 1 impacts, the assessment should be 'Level 1 – Acceptable'
7. Where the assessment falls outside the Level 1 impacts, the assessment should be 'Level 2'. The assessment should further note the reasons the assessment is Level 2, and any additional requirements that are triggered by falling into Level 2.
8. If water table or water pressure assessment is not applicable due to the nature of the water source, the assessment should be recorded as 'N/A – reason for N/A'.

Table 5. Minimal impact considerations – *example tables*

<table>
<tr><th>Aquifer</th><th colspan="2">Alluvial aquifer</th></tr>
<tr><th>Category</th><th colspan="2">Highly Productive</th></tr>
<tr><th colspan="2">Level 1 Minimal Impact Consideration</th><th>Assessment</th></tr>
<tr><td colspan="2">Water table
Less than or equal to a 10% cumulative variation in the water table, allowing for typical climatic post-water sharing plan variations, 40 metres from any:
• high priority groundwater dependent ecosystem or
• high priority culturally significant site
listed in the schedule of the relevant water sharing plan.
OR
A maximum of a 2 metre water table decline cumulatively at any water supply work.</td><td></td></tr>
<tr><td colspan="2">Water pressure
A cumulative pressure head decline of not more than 40% of the post-water sharing plan pressure head above the base of the water source to a maximum of a 2 metre decline, at any water supply work.
OR, for the Lower Murrumbidgee Deep Groundwater Source:
A cumulative pressure head decline of not more than 40% of the post-water sharing plan pressure head above the top of the relevant aquifer to a maximum of a 3 metre decline, at any water supply work.</td><td></td></tr>
<tr><td colspan="2">Water quality
Any change in the groundwater quality should not lower the beneficial use category of the groundwater source beyond 40 metres from the activity.
No increase of more than 1% per activity in long-term average salinity in a highly connected surface water source at the nearest point to the activity.
No mining activity to be below the natural ground surface within 200 metres laterally from the top of high bank or 100 metres vertically beneath (or the three dimensional extent of the alluvial water source - whichever is the lesser distance) of a highly connected surface water source that is defined as a reliable water supply.
Not more than 10% cumulatively of the three dimensional extent of the alluvial material in this water source to be excavated by mining activities beyond 200 metres laterally from the top of high bank and 100 metres vertically beneath a highly connected surface water source that is defined as a reliable water supply.</td><td></td></tr>
</table>

Aquifer	Alluvial aquifer
Category	Highly Productive
Level 1 Minimal Impact Consideration	Assessment

Aquifer	Coastal sands
Category	Highly Productive

Level 1 Minimal Impact Consideration	Assessment
Water table Less than or equal to a 10% cumulative variation in the water table, allowing for typical climatic 'post-water sharing plan' variations, 40 metres from any: • high priority groundwater dependent ecosystem or • high priority culturally significant site listed in the schedule of the relevant water sharing plan. **OR** A maximum of a 2 metre water table decline cumulatively at any water supply work.	
Water pressure A cumulative pressure head decline of not more than a 2 metre decline, at any water supply work.	
Water quality Any change in the groundwater quality should not lower the beneficial use category of the groundwater source beyond 40 metres from the activity.	

Aquifer	Porous Rock – except Great Artesian Basin
Category	Highly Productive

Level 1 Minimal Impact Consideration	Assessment
Water table Less than or equal to a 10% cumulative variation in the water table, allowing for typical climatic 'post-water sharing plan' variations, 40 metres from any: • high priority groundwater dependent ecosystem or • high priority culturally significant site listed in the schedule of the relevant water sharing plan. **OR** A maximum of a 2 metre water table decline cumulatively at any water supply work.	
Water pressure A cumulative pressure head decline of not more than a 2 metre decline, at any water supply work.	
Water quality Any change in the groundwater quality should not lower the beneficial use category of the groundwater source beyond 40 metres from the activity.	

<table>
<tr><th>Aquifer</th><th colspan="2">Porous Rock – Great Artesian Basin – Eastern Recharge and Southern Recharge</th></tr>
<tr><th>Category</th><th colspan="2">Highly Productive</th></tr>
<tr><th colspan="2">Level 1 Minimal Impact Consideration</th><th>Assessment</th></tr>
<tr><td colspan="2">Water table
Less than or equal to a 10% cumulative variation in the water table, allowing for typical climatic ‘post-water sharing plan’ variations, 40 metres from any:
• high priority groundwater dependent ecosystem or
• high priority culturally significant site
listed in the schedule of the relevant water sharing plan.
OR
A maximum of a 2 metre water table decline cumulatively at any water supply work.</td><td></td></tr>
<tr><td colspan="2">Water pressure
Less than 0.2 metre cumulative variation in the groundwater pressure, allowing for typical climatic ‘post-water sharing plan’ variations, 40 metres from any:
• high priority groundwater dependent ecosystem or
• high priority culturally significant site
listed in the schedule of the relevant water sharing plan.
A cumulative pressure level decline of not more than 15 metres, allowing for typical climatic ‘post-water sharing plan’ variations.
The cumulative pressure level decline of no more than 10% of the 2008 pressure level above ground surface at the NSW State border, as agreed between NSW and Queensland.</td><td></td></tr>
<tr><td colspan="2">Water quality
Any change in the groundwater quality should not lower the beneficial use category of the groundwater source beyond 40 metres from the activity.</td><td></td></tr>
</table>

Aquifer	Porous Rock – Great Artesian Basin – Surat, Warrego and Central
Category	**Highly Productive**
Level 1 Minimal Impact Consideration	**Assessment**
Water table NOT APPLICABLE	
Water pressure Less than 0.2 metre cumulative variation in the groundwater pressure, allowing for typical climatic 'post-water sharing plan' variations, 40 metres from any: • high priority groundwater dependent ecosystem or • high priority culturally significant site listed in the schedule of the relevant water sharing plan. A cumulative pressure level decline of not more than 30 metres, allowing for typical climatic 'post-water sharing plan' variations. The cumulative pressure level decline of no more than 10% of the 2008 pressure level above ground surface at the NSW State border, as agreed between NSW and Queensland.	
Water quality Any change in the groundwater quality should not lower the beneficial use category of the groundwater source beyond 40 metres from the activity.	

Aquifer	Fractured Rock
Category	Highly Productive

Level 1 Minimal Impact Consideration	Assessment
Water table Less than or equal to a 10% cumulative variation in the water table, allowing for typical climatic 'post-water sharing plan' variations, 40 metres from any: • high priority groundwater dependent ecosystem; or • high priority culturally significant site; listed in the schedule of the relevant water sharing plan. **OR** A maximum of a 2 metre water table decline cumulatively at any water supply work.	
Water pressure A cumulative pressure head decline of not more than a 2 metre decline, at any water supply work.	
Water quality Any change in the groundwater quality should not lower the beneficial use category of the groundwater source beyond 40 metres from the activity.	

Aquifer	Alluvial
Category	Less productive

Level 1 Minimal Impact Consideration	Assessment
Water table Less than or equal to a 10% cumulative variation in the water table, allowing for typical climatic ‘post-water sharing plan’ variations, 40 metres from any: • high priority groundwater dependent ecosystem or • high priority culturally significant site listed in the schedule of the relevant water sharing plan. **OR** A maximum of a 2 metre water table decline cumulatively at any water supply work unless make good provisions apply	No impacts predicted
Water pressure A cumulative pressure head decline of not more than 40% of the ‘post-water sharing plan’ pressure head above the base of the water source to a maximum of a 2 metre decline, at any water supply work.	No impacts predicted
Water quality Any change in the groundwater quality should not lower the beneficial use category of the groundwater source beyond 40 metres from the activity. No increase of more than 1% per activity in long-term average salinity in a highly connected surface water source at the nearest point to the activity. No mining activity to be below the natural ground surface within 200 metres laterally from the top of high bank or 100 metres vertically beneath (or the three dimensional extent of the alluvial water source - whichever is the lesser distance) of a highly connected surface water source that is defined as a ‘reliable water supply’.	No impacts predicted

Aquifer	**Porous rock or fractured rock**
Category	**Less productive**
Level 1 Minimal Impact Consideration	**Assessment**
Water table Less than or equal to a 10% cumulative variation in the water table, allowing for typical climatic 'post-water sharing plan' variations, 40 metres from any: • high priority groundwater dependent ecosystem or • high priority culturally significant site listed in the schedule of the relevant water sharing plan. **OR** A maximum of a 2 metre water table decline cumulatively at any water supply work.	Slight water table decine in the vicinity of the ARC bunker - No impacts at distance predicted
Water pressure A cumulative pressure head decline of not more than a 2 metre decline, at any water supply work.	No impacts predicted
Water quality Any change in the groundwater quality should not lower the beneficial use category of the groundwater source beyond 40 metres from the activity.	No impacts predicted

3. Proposed remedial actions where impacts are greater than predicted.

Note for proponents

Point 3 of section 3.2 of the AIP provides a basic framework for considerations to consider when assessing a proponent's proposed remedial actions.

Table 6. Has the proponent:

	AIP requirement	Proponent response	NSW Office of Water comment
1	Considered types, scale, and likelihood of unforeseen impacts *during operation*?	Yes - bunker is lined - no impacts during operation	
2	Considered types, scale, and likelihood of unforeseen impacts *post closure*?	yes - no impacts post closure	
3	Proposed mitigation, prevention or avoidance strategies for each of these potential impacts?	NA	
4	Proposed remedial actions should the risk minimization strategies fail?	NA	
5	Considered what further mitigation, prevention, avoidance or remedial actions might be required?	NA	
6	Considered what conditions might be appropriate?	NA	

4. Other considerations

Note for proponents

These considerations are not included in the assessment framework outlined within the AIP, however are discussed elsewhere in the document and are useful considerations when assessing a proposal.

Table 7: Has the proponent:

	AIP requirement	Proponent response	NSW Office of Water comment
1	Addressed how it will measure and monitor volumetric take? (page 4 of the AIP)	yes - recording pump rate and hours of operation to remove any water from excavation / sump area	
2	Outlined a reporting framework for volumetric take? (page 4 of the AIP)	yes - water management plan	

More information

www.water.nsw.gov.au

Disclaimer:

This is a draft document produced as a guide for discussion, and to aid interpretation and application of the NSW Aquifer Interference Policy (2012). All information in this document is drawn from that policy, and where there is any inconsistency, the policy prevails over anything contained in this document.
Any omissions from this framework do not remove the need to meet any other requirements listed under the Policy.

The information contained in this publication is based on knowledge and understanding at the time of writing (November 2021). However, because of advances in knowledge, users are reminded of the need to ensure that information upon which they rely is up to date and to check currency of the information with the appropriate officer of the Department of Primary Industries or the users independent adviser.

Published by the NSW Department of Primary Industries.

Reference 12279

Appendix B

Monitoring network and sampling span

creating opportunities

B.1 Overview of groundwater monitoring

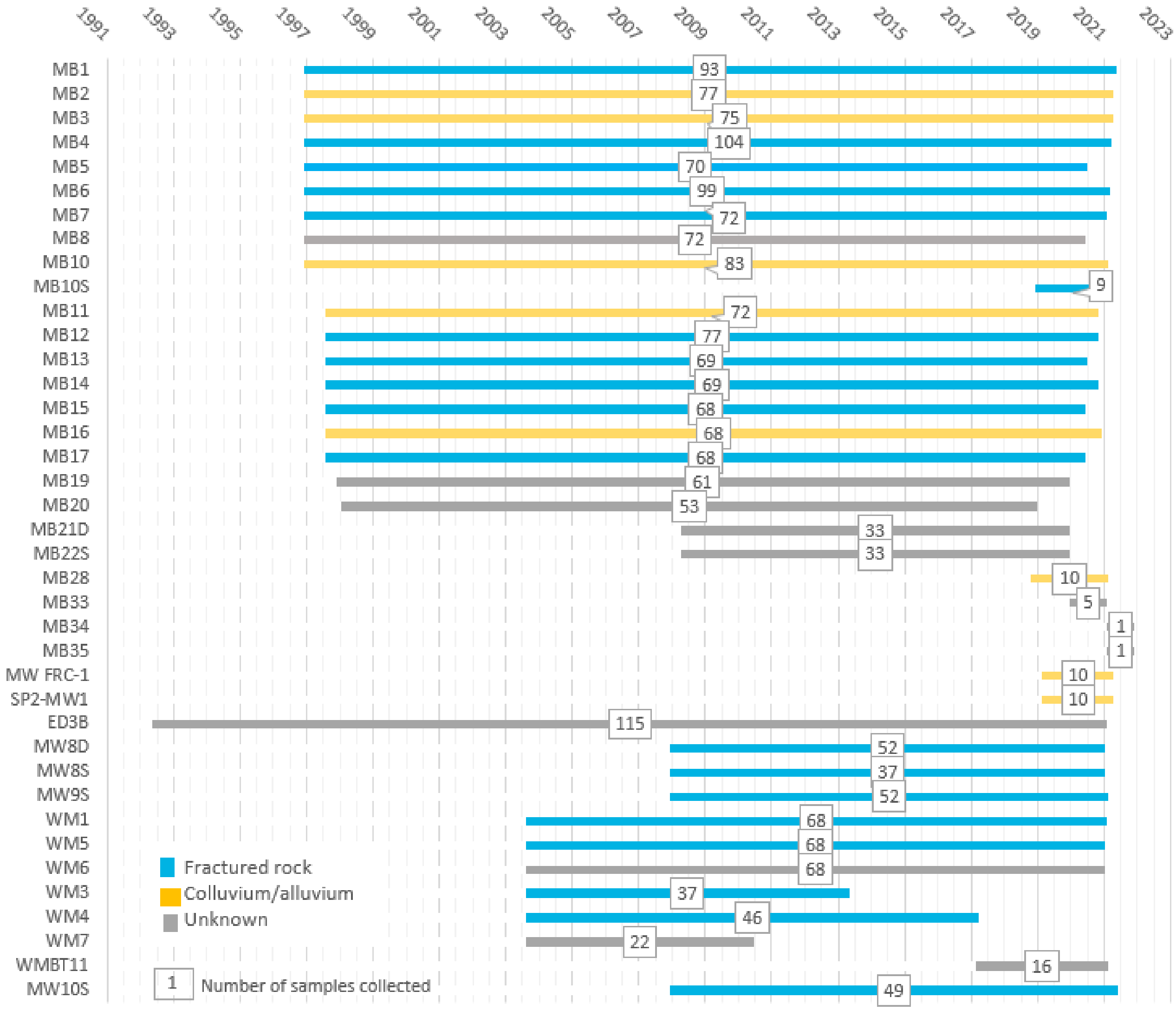

Table B.1 Overview of groundwater monitoring network

Monitoring Point	Depth (mbgl)	Screen (mbgl)	Target unit	Target formation	Location
ARC-BH3	19.15	16.15–19.15	Siltstone	Fractured rock	ARC
MB1	32.2	26–32.2	Dolerite	Fractured rock	Evaporation dam
MB2	13.2	7–13.2	Clay/dolerite (weathered)	Colluvium	Evaporation dam
MB3	25.8	20.8–25.8	Clay/gravel	Colluvium/alluvium	North of Crisps Creek
MB4	25.8	20.8–25.8	Shale	Fractured rock	Bioreactor
MB5	25.8	20.8–25.8	Tuff	Fractured rock	Waste rock dam
MB6	25.8	20.8–25.8	Shale	Fractured rock	Evaporation dam
MB7	29	26–29	Shale/tuff	Fractured rock	Evaporation dam
MB8	25.9	Unknown	Unknown	Unknown	Collector Road
MB10	20.8	19.8–20.8	Gravel/dolerite (weathered)	Colluvium	Evaporation dam
MB10S	9.1	Unknown	Tuff	Fractured rock	Evaporation dam
MB11	5.3	2.3–5.3	Dolerite/shale (weathered)	Colluvium	Evaporation dam
MB12	13.2	10.2–13.2	Dolerite	Fractured rock	Evaporation dam
MB13	13.2	10.2–13.2	Dolerite	Fractured rock	Allianoyonyiga Creek
MB14	12.5	9.5–12.5	Dolerite	Fractured rock	Evaporation dam
MB15	23.7	17–23.7	Rhyolite	Fractured rock	Waste rock dam
MB16	7.3	3–6	Clay, gravel, dolerite	Colluvium	Waste rock dam
MB17	15.4	9.4–15.4	Volcanics, tuff	Fractured rock	Waste rock dam
MB19	Unknown	Unknown	Unknown	Unknown	Evaporation dam
MB20	Unknown	Unknown	Unknown	Unknown	Evaporation dam
MB21D	Unknown	Unknown	Unknown	Unknown	Southern tailings dam
MB22S	Unknown	Unknown	Unknown	Unknown	Southern tailings dam
MB23	10	7–10	Gravely clay	Colluvium/alluvium	Evaporation dam
MB24	6.3	3.3–6.3	Rhyolite (weathered)	Colluvium	Evaporation dam
MB25	9	6–9	Clay and sand	Colluvium/alluvium	Evaporation dam
MB26S	6	3–6	Clay and sand	Colluvium/alluvium	Evaporation dam
MB27D	17.7	14.7–15.7	Clay and sand	Colluvium/alluvium	Evaporation dam
MB28	9	6–9	Gravely clay	Colluvium/alluvium	Evaporation dam
MB29	6	2–6	Gravely clay	Colluvium/alluvium	Evaporation dam

Table B.1 Overview of groundwater monitoring network

Monitoring Point	Depth (mbgl)	Screen (mbgl)	Target unit	Target formation	Location
MB30	12	6–12	Clay and sand	Colluvium/alluvium	Evaporation dam
MB31	9	6–9	Sandy clay	Colluvium/alluvium	Evaporation dam
MB32	Unknown	Unknown	Unknown	Unknown	Evaporation dam
MB33	Unknown	Unknown	Unknown	Unknown	Bioreactor
MB34	Unknown	Unknown	Unknown	Unknown	Bioreactor
MB35	Unknown	Unknown	Unknown	Unknown	Bioreactor
MW-FRC1	5.2	2.2–5.2	Siltstone (weathered), clay	Colluvium	Evaporation dam
SP2-MW1	4.5	1.5–4.5	Clay	Colluvium/alluvium	Spring 2
ED3B	5.9	Unknown	Unknown	Unknown	Evaporation dam
MW8D	10.4	7.4–10.4	Tuff/Siltstone	Fractured rock	Evaporation dam
MW8S	6.5	7.4–10.4	Tuff/Siltstone	Fractured rock	Evaporation dam
MW9S	7	4–7	Siltstone	Fractured rock	Evaporation dam
MW10S	9.1	6–9	Siltstone	Fractured rock	Evaporation dam
WM1	115	Unknown	Dolerite	Fractured rock	Bioreactor
WM3	85	Unknown	Tuff	Fractured rock	
WM4	108	Unknown	Dolerite	Fractured rock	
WM5	6	Unknown	Clay/tuff	Unknown	Evaporation dam
WM6	6	Unknown	Tuff/volcanics	Unknown	Evaporation dam
WM7	Unknown	Unknown	Unknown	Unknown	
SP2C	Unknown	Unknown	Unknown	Unknown	Tailings dam
SP3C	Unknown	Unknown	Unknown	Unknown	Tailings dam
NTP1	Unknown	Unknown	Unknown	Unknown	Tailings dam
NTP2	Unknown	Unknown	Unknown	Unknown	Tailings dam
WWTD001	Unknown	Unknown	Unknown	Unknown	Bioreactor
ETP8	Unknown	Unknown	Unknown	Unknown	Tailings dam
SP11B	Unknown	Unknown	Unknown	Unknown	Tailings dam
WMBT11	Unknown	Unknown	Unknown	Unknown	

Appendix C

Hydraulic conductivity testing

EMM
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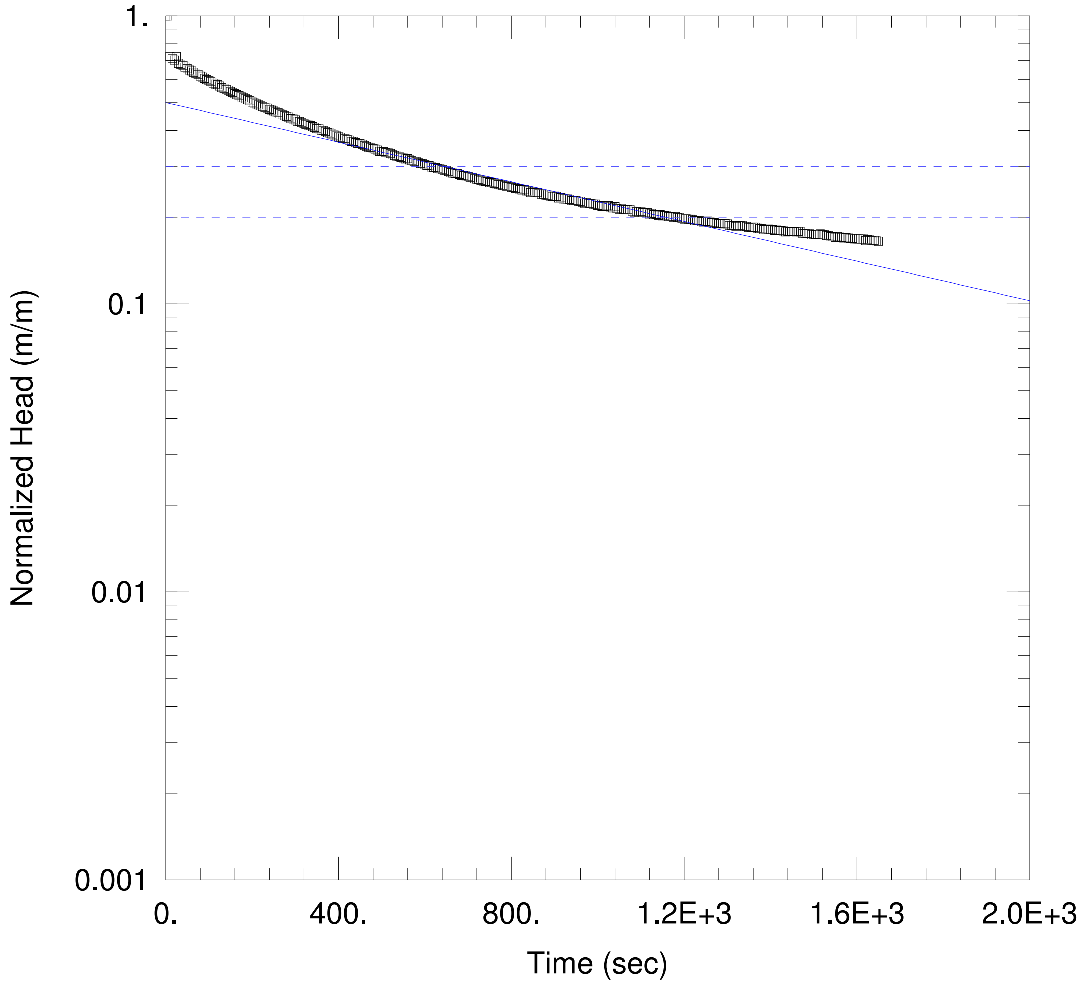


WELL TEST ANALYSIS

Data Set: \...\BH3.aqt
Date: 08/30/21 Time: 09:10:44

PROJECT INFORMATION

Company: EMM Consulting
Client: Veolia
Project: J200931
Location: Woodlawn, NSW
Test Well: BH3
Test Date: 20/08/21

AQUIFER DATA

Saturated Thickness: 17.28 m Anisotropy Ratio (Kz/Kr): 1.

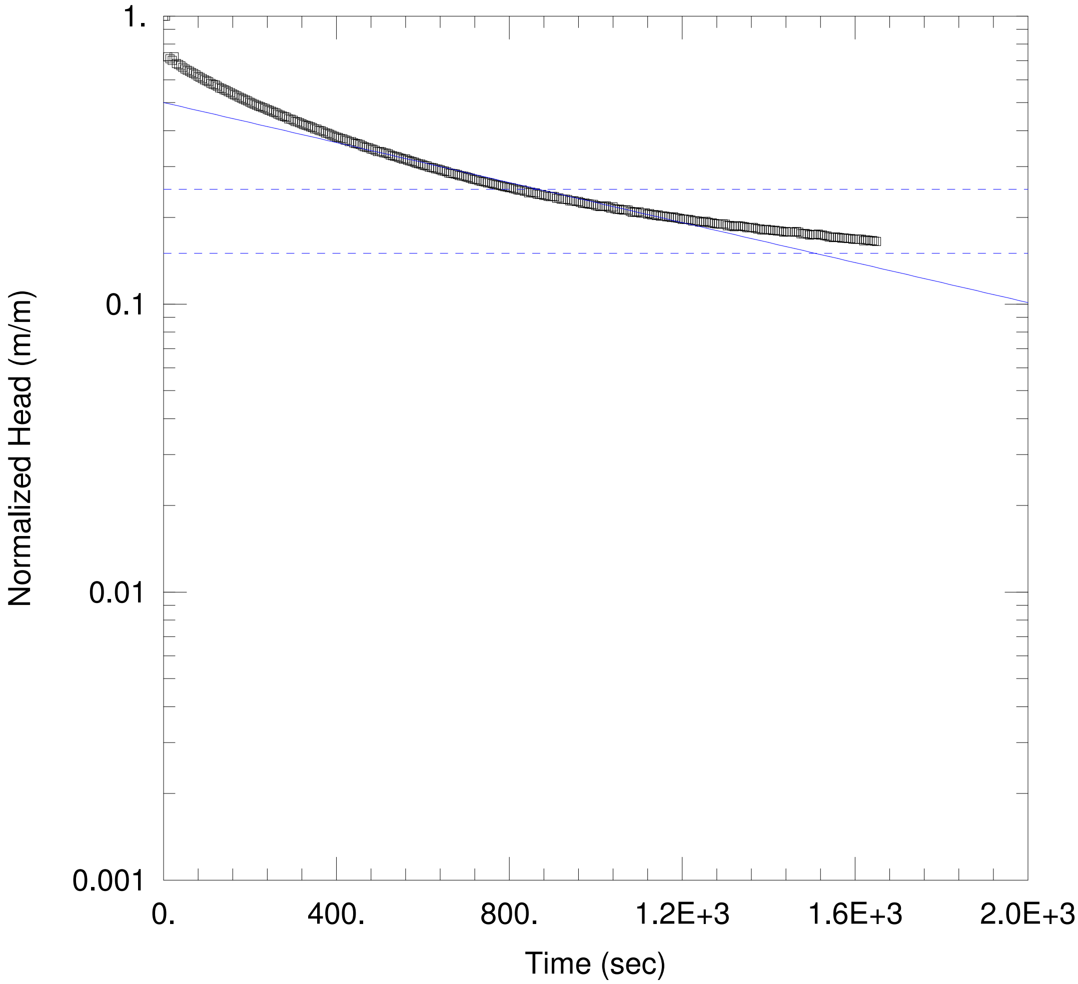
WELL DATA (New Well)

Initial Displacement: 0.9424 m
Total Well Penetration Depth: 19.65 m
Casing Radius: 0.025 m
Static Water Column Height: 17.28 m
Screen Length: 3. m
Well Radius: 0.075 m

SOLUTION

Aquifer Model: Confined Solution Method: Bouwer-Rice

K = 0.02797 m/day y0 = 0.4709 m



WELL TEST ANALYSIS

Data Set: \...\BH3.aqt
Date: 08/30/21 Time: 09:11:19

PROJECT INFORMATION

Company: EMM Consulting
Client: Veolia
Project: J200931
Location: Woodlawn, NSW
Test Well: BH3
Test Date: 20/08/21

AQUIFER DATA

Saturated Thickness: 17.28 m Anisotropy Ratio (Kz/Kr): 1.

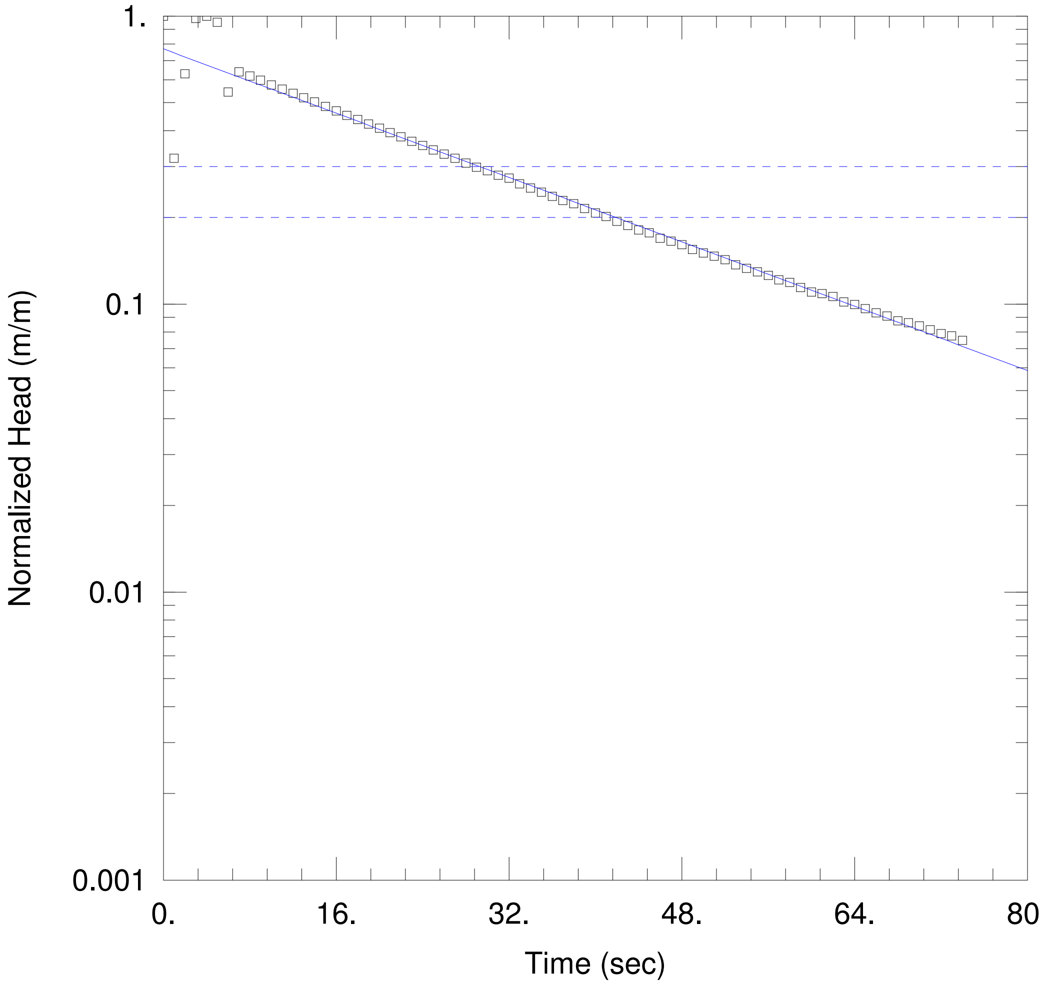
WELL DATA (New Well)

Initial Displacement: 0.9424 m
Total Well Penetration Depth: 19.65 m
Casing Radius: 0.025 m
Static Water Column Height: 17.28 m
Screen Length: 3. m
Well Radius: 0.075 m

SOLUTION

Aquifer Model: Confined Solution Method: Hvorslev

K = 0.03153 m/day y0 = 0.4717 m



WELL TEST ANALYSIS

Data Set: \...\MB10.aqt
Date: 08/30/21 Time: 09:24:22

PROJECT INFORMATION

Company: EMM Consulting
Client: Veolia
Project: J200931
Location: Woodlawn, NSW
Test Well: MB10
Test Date: 26/08/21

AQUIFER DATA

Saturated Thickness: 18.18 m Anisotropy Ratio (Kz/Kr): 1.

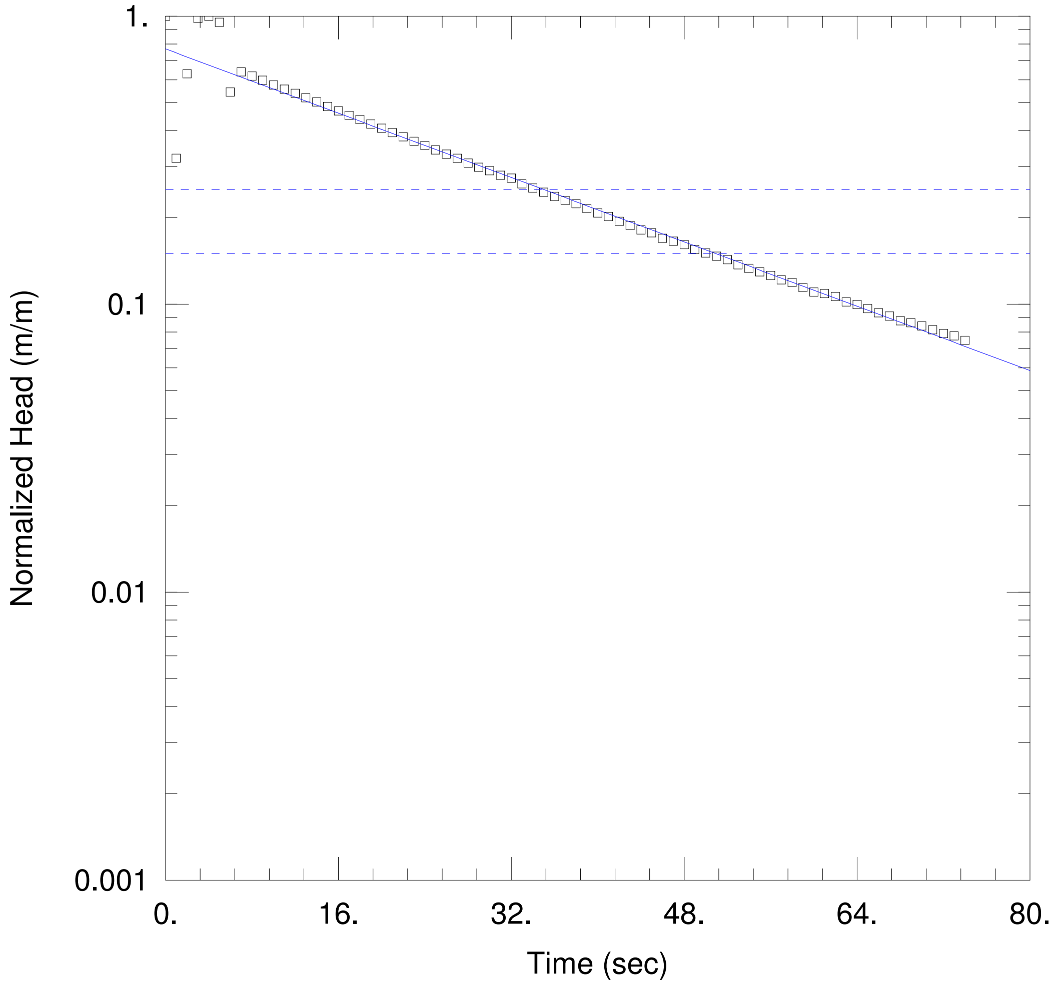
WELL DATA (New Well)

Initial Displacement: 0.8531 m Static Water Column Height: 18.18 m
Total Well Penetration Depth: 18.18 m Screen Length: 3. m
Casing Radius: 0.025 m Well Radius: 0.062 m

SOLUTION

Aquifer Model: Unconfined Solution Method: Bouwer-Rice

K = 1.17 m/day y0 = 0.6556 m



WELL TEST ANALYSIS

Data Set: \...\MB10.aqt
Date: 08/30/21 Time: 09:33:36

PROJECT INFORMATION

Company: EMM Consulting
Client: Veolia
Project: J200931
Location: Woodlawn, NSW
Test Well: MB10
Test Date: 26/08/21

AQUIFER DATA

Saturated Thickness: 18.18 m Anisotropy Ratio (Kz/Kr): 1.

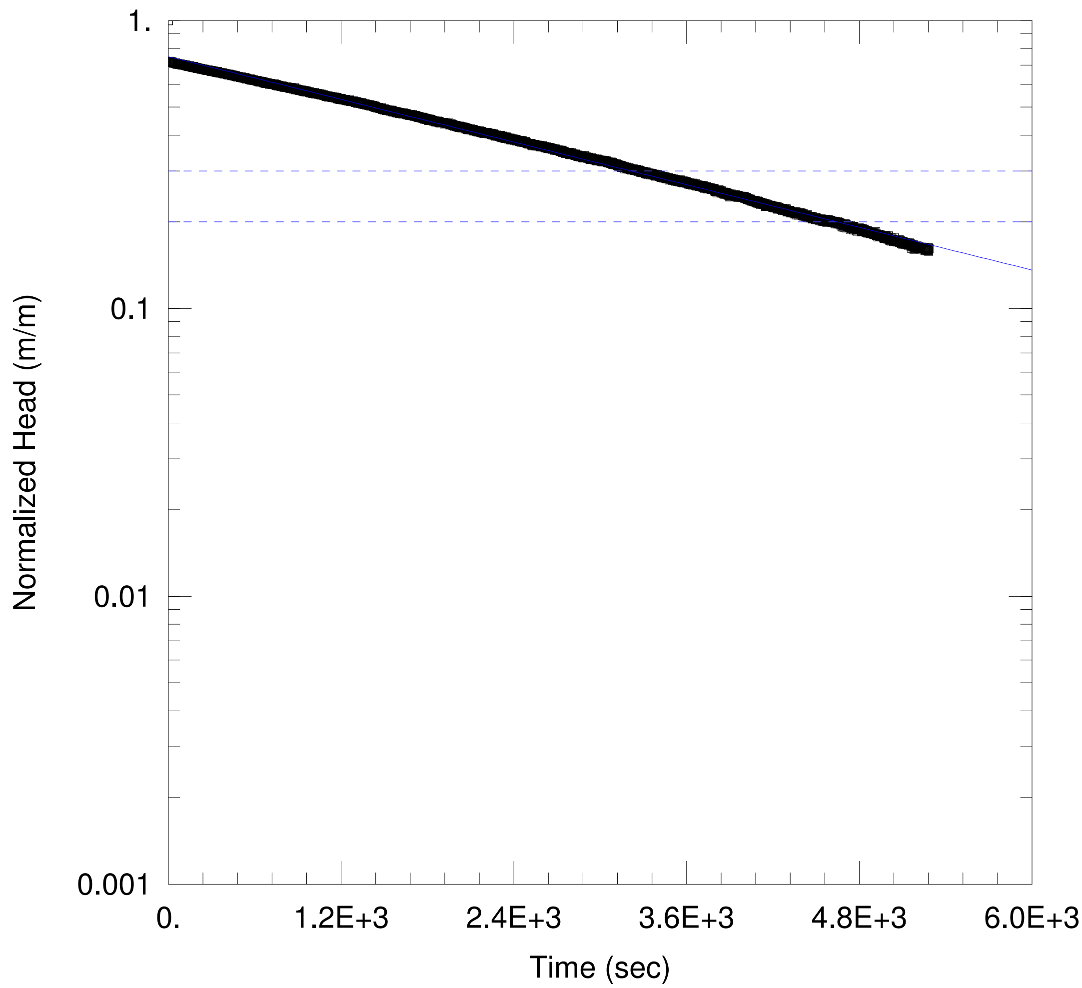
WELL DATA (New Well)

Initial Displacement: 0.8531 m Static Water Column Height: 18.18 m
Total Well Penetration Depth: 18.18 m Screen Length: 3. m
Casing Radius: 0.025 m Well Radius: 0.062 m

SOLUTION

Aquifer Model: Unconfined Solution Method: Hvorslev

K = 1.322 m/day y0 = 0.6556 m



WELL TEST ANALYSIS

Data Set: \...\MB26s.aqt
Date: 08/31/21 Time: 12:34:24

PROJECT INFORMATION

Company: EMM Consulting
Client: Veolia
Project: J200931
Location: Woodlawn, NSW
Test Well: MB26s
Test Date: 31/08/21

AQUIFER DATA

Saturated Thickness: 10. m Anisotropy Ratio (Kz/Kr): 1.

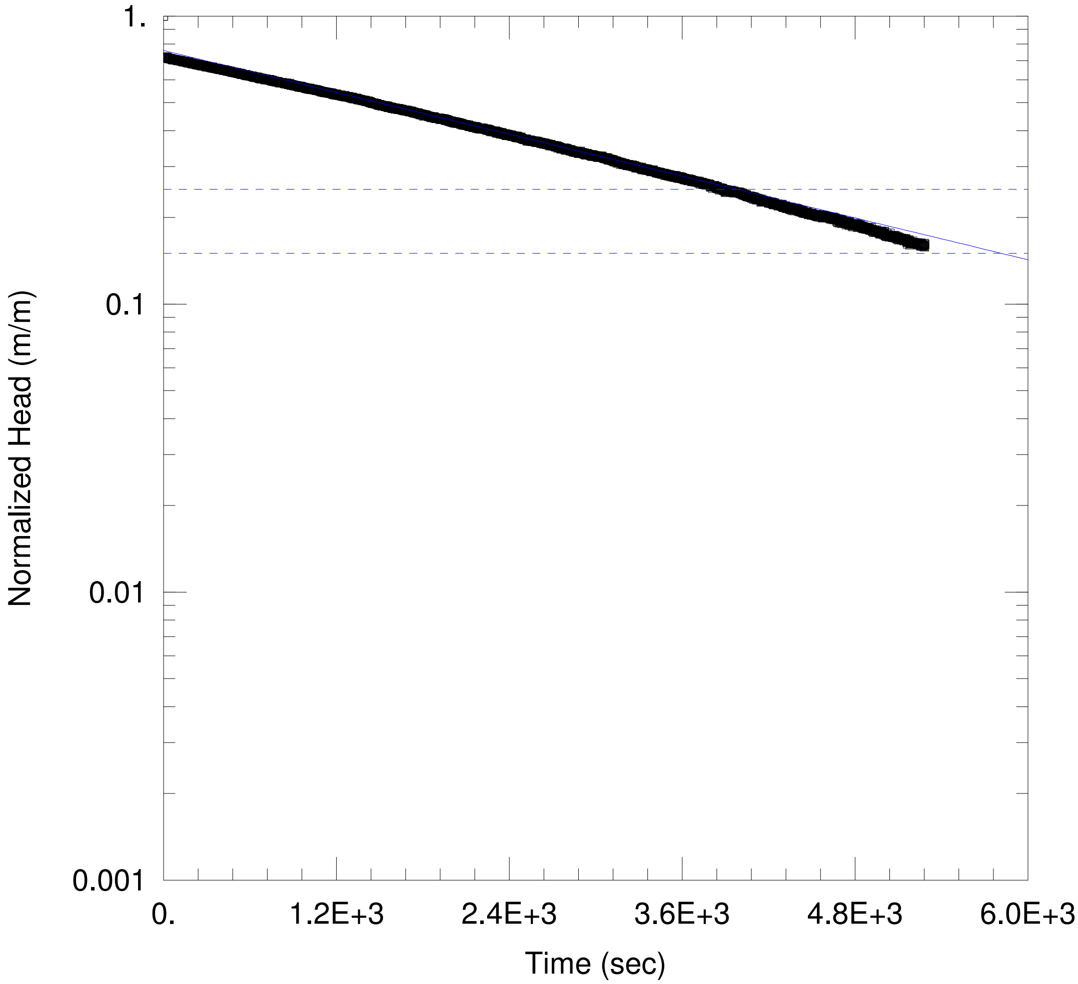
WELL DATA (New Well)

Initial Displacement: 0.4541 m Static Water Column Height: 5.426 m
Total Well Penetration Depth: 5.426 m Screen Length: 3. m
Casing Radius: 0.025 m Well Radius: 0.075 m

SOLUTION

Aquifer Model: Unconfined Solution Method: Bouwer-Rice

K = 0.006881 m/day y0 = 0.3398 m



WELL TEST ANALYSIS

Data Set: \...\MB26s.aqt
Date: 08/31/21 Time: 12:35:11

PROJECT INFORMATION

Company: EMM Consulting
Client: Veolia
Project: J200931
Location: Woodlawn, NSW
Test Well: MB26s
Test Date: 31/08/21

AQUIFER DATA

Saturated Thickness: 10. m Anisotropy Ratio (Kz/Kr): 1.

WELL DATA (New Well)

Initial Displacement: 0.4541 m
Total Well Penetration Depth: 5.426 m
Casing Radius: 0.025 m
Static Water Column Height: 5.426 m
Screen Length: 3. m
Well Radius: 0.075 m

SOLUTION

Aquifer Model: Unconfined
Solution Method: Hvorslev

K = 0.009259 m/day
y0 = 0.3447 m

Appendix D

Pumping test analysis

creating opportunities

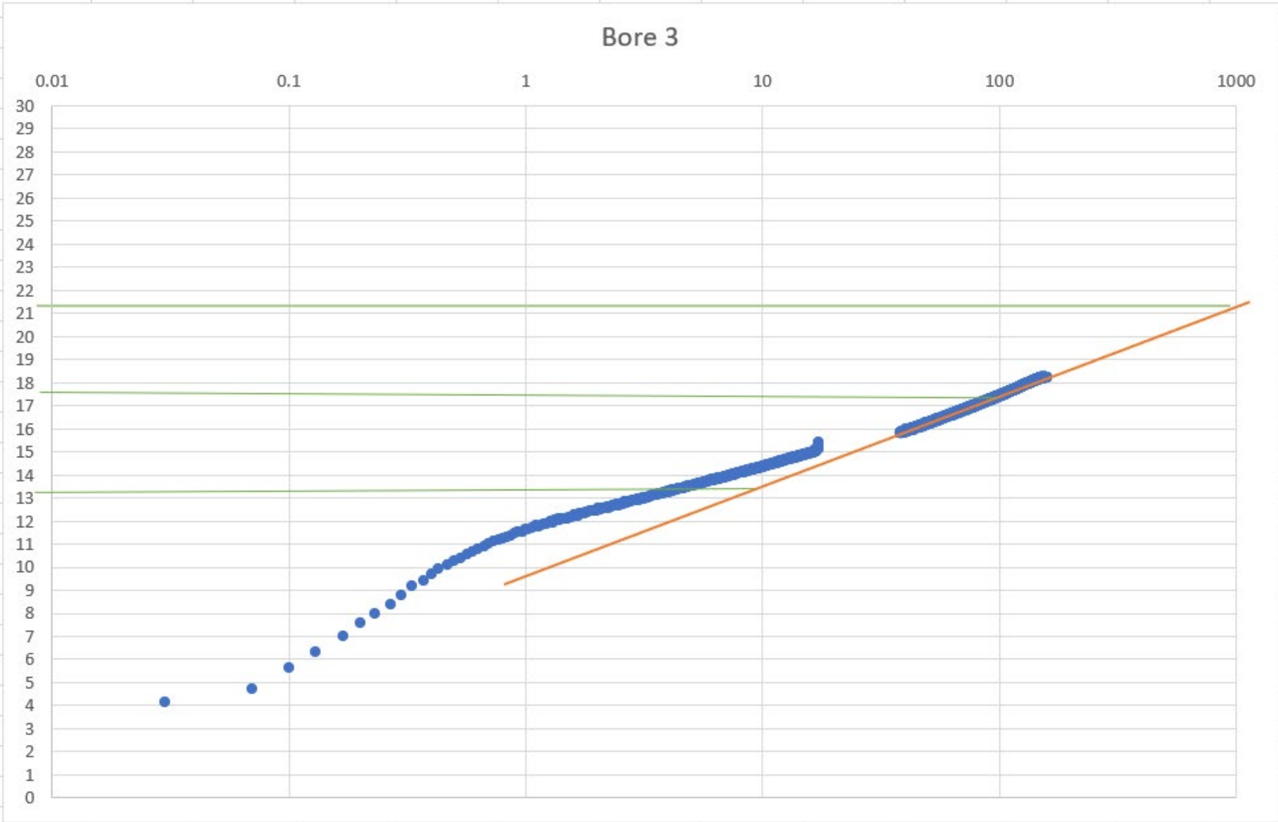
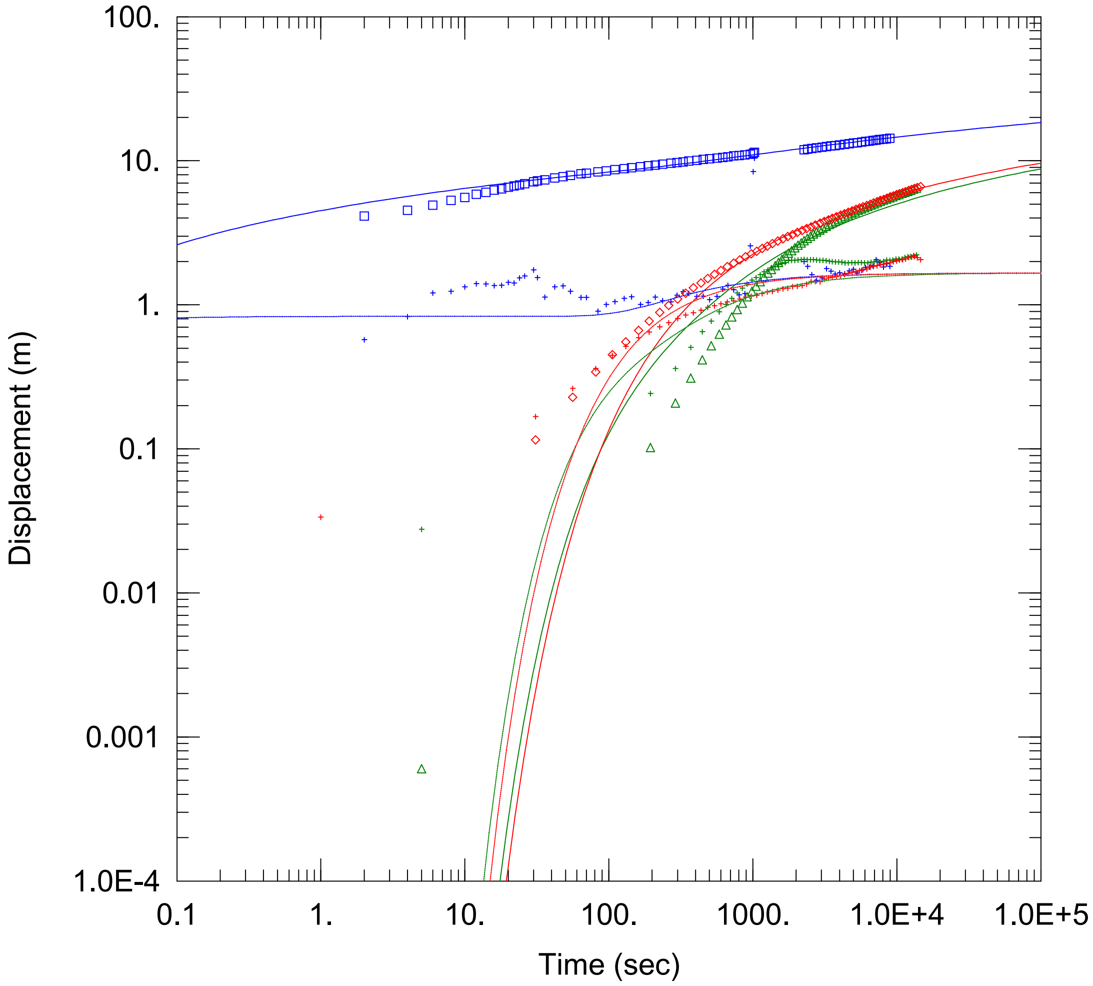


Figure D.1 Bore 3, semi log pumping test results and drawdown per log cycle



WELL TEST ANALYSIS

Data Set: \...\pumping test_CC_Hantush leaky_v3.aqt
Date: 09/16/21 Time: 08:42:35

PROJECT INFORMATION

Company: EMM Consulting
Client: Veolia
Project: J200931
Location: Woodlawn, NSW
Test Well: Bore 3
Test Date: 20/08/21

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
Bore 3	0	0

Observation Wells

Well Name	X (m)	Y (m)
□ Bore 3	0	0
△ WMB01	24	-29
◇ WMB02	-38	-33

SOLUTION

Aquifer Model: Leaky

Solution Method: Hantush-Jacob

T = 128.1 m^2/day
1/B = 5.882E-5 m^{-1}
b = 16. m

S = 0.0005115
Kz/Kr = 1.

Appendix E
Groundwater quality laboratory reports

creating opportunities

CERTIFICATE OF ANALYSIS

Work Order	: **ES2131566**	Page	: 1 of 6
Amendment	: **1**		
Client	: **EMM CONSULTING PTY LTD**	Laboratory	: Environmental Division Sydney
Contact	: MS NINA BAULCH	Contact	: Sepan Mahamad
Address	: Ground Floor Suite 1 20 Chandos Street St Leonards NSW NSW 2065	Address	: 277-289 Woodpark Road Smithfield NSW Australia 2164
Telephone	: +61 02 9493 9500	Telephone	: +61 2 8784 8555
Project	: J200931	Date Samples Received	: 31-Aug-2021 15:00
Order number	: ----	Date Analysis Commenced	: 31-Aug-2021
C-O-C number	: ----	Issue Date	: 07-Sep-2021 09:53
Sampler	: ANDREW TREASURE		
Site	: ----		
Quote number	: EN/112/20 Primary work		
No. of samples received	: 8		
No. of samples analysed	: 8		

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, unless the sampling was conducted by ALS. This document shall not be reproduced, except in full.

This Certificate of Analysis contains the following information:

- General Comments
- Analytical Results

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

Signatories

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

Signatories	*Position*	*Accreditation Category*
Ankit Joshi	Inorganic Chemist	Sydney Inorganics, Smithfield, NSW
Ivan Taylor	Analyst	Sydney Inorganics, Smithfield, NSW

General Comments

The analytical procedures used by ALS have been developed from established internationally recognised procedures such as those published by the USEPA, APHA, AS and NEPM. In house developed procedures are fully validated and are often at the 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.

- ED045G: The presence of Thiocyanate, Thiosulfate and Sulfite can positively contribute to the Chloride result, thereby may bias results higher than expected. Results should be scrutinised accordingly.
- EG020: It is recognised that total concentration is less than dissolved for some metal analytes. However, the difference is within experimental variation of the methods.
- Amendment (07/09/2021): This report has been amended and re-released to allow the reporting of additional analytical data, specifically Al, Fe, and Mn.
- 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)			Sample ID	MB3_210826	CULVERT1_210826	SPRING_DS_210826	ARC-BH3_210826	PROD1_GW_210826
			Sampling date / time	26-Aug-2021 00:00	26-Aug-2021 00:00	26-Aug-2021 00:00	26-Aug-2021 00:00	26-Aug-2021 00:00
Compound	CAS Number	LOR	Unit	ES2131566-001	ES2131566-002	ES2131566-003	ES2131566-004	ES2131566-005
				Result	Result	Result	Result	Result
ED037P: Alkalinity by PC Titrator								
Hydroxide Alkalinity as CaCO3	DMO-210-001	1	mg/L	<1	<1	<1	<1	<1
Carbonate Alkalinity as CaCO3	3812-32-6	1	mg/L	<1	<1	<1	<1	<1
Bicarbonate Alkalinity as CaCO3	71-52-3	1	mg/L	248	21	16	452	310
Total Alkalinity as CaCO3	----	1	mg/L	248	21	16	452	310
ED041G: Sulfate (Turbidimetric) as SO4 2- by DA								
Sulfate as SO4 - Turbidimetric	14808-79-8	1	mg/L	37	312	220	394	42
ED045G: Chloride by Discrete Analyser								
Chloride	16887-00-6	1	mg/L	454	27	91	1280	455
ED093F: Dissolved Major Cations								
Calcium	7440-70-2	1	mg/L	120	71	38	122	81
Magnesium	7439-95-4	1	mg/L	98	28	40	273	82
Sodium	7440-23-5	1	mg/L	70	30	43	581	162
Potassium	7440-09-7	1	mg/L	2	1	<1	2	1
EG020F: Dissolved Metals by ICP-MS								
Aluminium	7429-90-5	0.01	mg/L	----	----	----	----	<0.01
Arsenic	7440-38-2	0.001	mg/L	----	----	----	----	<0.001
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	----	----	----	----	0.002
Nickel	7440-02-0	0.001	mg/L	----	----	----	----	0.005
Lead	7439-92-1	0.001	mg/L	----	----	----	----	<0.001
Zinc	7440-66-6	0.005	mg/L	----	----	----	----	0.010
Manganese	7439-96-5	0.001	mg/L	----	----	----	----	0.004
Iron	7439-89-6	0.05	mg/L	----	----	----	----	<0.05
EG020T: Total Metals by ICP-MS								
Aluminium	7429-90-5	0.01	mg/L	0.02	0.28	0.53	4.04	0.04
Arsenic	7440-38-2	0.001	mg/L	<0.001	<0.001	<0.001	0.002	<0.001
Cadmium	7440-43-9	0.0001	mg/L	0.0014	0.0478	0.0058	0.0150	<0.0001
Chromium	7440-47-3	0.001	mg/L	<0.001	<0.001	0.001	0.010	<0.001
Copper	7440-50-8	0.001	mg/L	0.005	0.385	0.069	0.053	0.002
Nickel	7440-02-0	0.001	mg/L	0.005	0.035	0.008	0.028	0.004
Lead	7439-92-1	0.001	mg/L	0.001	0.010	0.003	0.038	<0.001
Zinc	7440-66-6	0.005	mg/L	0.260	10.0	1.44	1.31	0.010
Manganese	7439-96-5	0.001	mg/L	0.015	0.425	0.394	0.593	0.005

Analytical Results

Sub-Matrix: WATER (Matrix: WATER)			Sample ID	MB3_210826	CULVERT1_210826	SPRING_DS_210826	ARC-BH3_210826	PROD1_GW_210826
			Sampling date / time	26-Aug-2021 00:00	26-Aug-2021 00:00	26-Aug-2021 00:00	26-Aug-2021 00:00	26-Aug-2021 00:00
Compound	CAS Number	LOR	Unit	ES2131566-001	ES2131566-002	ES2131566-003	ES2131566-004	ES2131566-005
				Result	Result	Result	Result	Result
EG020T: Total Metals by ICP-MS - Continued								
Iron	7439-89-6	0.05	mg/L	<0.05	**0.20**	**0.87**	**5.76**	<0.05
EK055G: Ammonia as N by Discrete Analyser								
Ammonia as N	7664-41-7	0.01	mg/L	**0.01**	----	<0.01	**0.15**	<0.01
EK057G: Nitrite as N by Discrete Analyser								
Nitrite as N	14797-65-0	0.01	mg/L	<0.01	----	<0.01	**0.02**	<0.01
EK058G: Nitrate as N by Discrete Analyser								
Nitrate as N	14797-55-8	0.01	mg/L	**0.50**	----	<0.01	**0.26**	**1.16**
EK059G: Nitrite plus Nitrate as N (NOx) by Discrete Analyser								
Nitrite + Nitrate as N	----	0.01	mg/L	**0.50**	----	<0.01	**0.28**	**1.16**
EK061G: Total Kjeldahl Nitrogen By Discrete Analyser								
Total Kjeldahl Nitrogen as N	----	0.1	mg/L	<0.1	----	**1.8**	**0.4**	<0.1
EK062G: Total Nitrogen as N (TKN + NOx) by Discrete Analyser								
^ Total Nitrogen as N	----	0.1	mg/L	**0.5**	----	**1.8**	**0.7**	**1.2**
EK067G: Total Phosphorus as P by Discrete Analyser								
Total Phosphorus as P	----	0.01	mg/L	**0.06**	----	**0.17**	**0.01**	**0.01**
EN055: Ionic Balance								
ø Total Anions	----	0.01	meq/L	**18.5**	**7.68**	**7.47**	**53.3**	**19.9**
ø Total Cations	----	0.01	meq/L	**17.1**	**7.18**	**7.06**	**53.9**	**17.9**
ø Ionic Balance	----	0.01	%	**3.87**	**3.36**	**2.81**	**0.50**	**5.40**

Analytical Results

Sub-Matrix: WATER
(Matrix: WATER)

			Sample ID	SPRING_DAM_210826	SP2_MW1_210826	MB29_210826	----	----
			Sampling date / time	26-Aug-2021 00:00	26-Aug-2021 00:00	26-Aug-2021 00:00	----	----
Compound	CAS Number	LOR	Unit	ES2131566-006	ES2131566-007	ES2131566-008	--------	--------
				Result	Result	Result	----	----
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	**16**	**256**	**213**	----	----
Total Alkalinity as CaCO3	----	1	mg/L	**16**	**256**	**213**	----	----
ED041G: Sulfate (Turbidimetric) as SO4 2- by DA								
Sulfate as SO4 - Turbidimetric	14808-79-8	1	mg/L	**225**	**154**	**197**	----	----
ED045G: Chloride by Discrete Analyser								
Chloride	16887-00-6	1	mg/L	**90**	**503**	**3020**	----	----
ED093F: Dissolved Major Cations								
Calcium	7440-70-2	1	mg/L	**39**	**91**	**303**	----	----
Magnesium	7439-95-4	1	mg/L	**41**	**114**	**351**	----	----
Sodium	7440-23-5	1	mg/L	**42**	**121**	**748**	----	----
Potassium	7440-09-7	1	mg/L	<1	<1	<1	----	----
EG020F: Dissolved Metals by ICP-MS								
Aluminium	7429-90-5	0.01	mg/L	**0.32**	<0.01	**0.04**	----	----
Arsenic	7440-38-2	0.001	mg/L	<0.001	<0.001	<0.001	----	----
Cadmium	7440-43-9	0.0001	mg/L	**0.0058**	**0.0006**	**0.0046**	----	----
Chromium	7440-47-3	0.001	mg/L	<0.001	<0.001	<0.001	----	----
Copper	7440-50-8	0.001	mg/L	**0.044**	**0.002**	**0.003**	----	----
Nickel	7440-02-0	0.001	mg/L	**0.008**	**0.009**	**0.027**	----	----
Lead	7439-92-1	0.001	mg/L	**0.002**	<0.001	<0.001	----	----
Zinc	7440-66-6	0.005	mg/L	**1.42**	**0.054**	**0.190**	----	----
Manganese	7439-96-5	0.001	mg/L	**0.641**	**0.108**	**0.058**	----	----
Iron	7439-89-6	0.05	mg/L	**0.56**	<0.05	**0.12**	----	----
EG020T: Total Metals by ICP-MS								
Aluminium	7429-90-5	0.01	mg/L	**0.61**	**1.83**	**0.39**	----	----
Arsenic	7440-38-2	0.001	mg/L	<0.001	**0.008**	<0.001	----	----
Cadmium	7440-43-9	0.0001	mg/L	**0.0058**	**0.0015**	**0.0052**	----	----
Chromium	7440-47-3	0.001	mg/L	**0.001**	**0.078**	**0.005**	----	----
Copper	7440-50-8	0.001	mg/L	**0.050**	**0.058**	**0.006**	----	----
Nickel	7440-02-0	0.001	mg/L	**0.009**	**0.042**	**0.030**	----	----
Lead	7439-92-1	0.001	mg/L	**0.004**	**0.202**	**0.002**	----	----
Zinc	7440-66-6	0.005	mg/L	**1.43**	**0.474**	**0.219**	----	----
Manganese	7439-96-5	0.001	mg/L	**0.507**	**0.688**	**0.087**	----	----

Analytical Results

Sub-Matrix: WATER (Matrix: WATER)			Sample ID	SPRING_DAM_210826	SP2_MW1_210826	MB29_210826	----	----
			Sampling date / time	26-Aug-2021 00:00	26-Aug-2021 00:00	26-Aug-2021 00:00	----	----
Compound	CAS Number	LOR	Unit	ES2131566-006	ES2131566-007	ES2131566-008	--------	--------
				Result	Result	Result	----	----
EG020T: Total Metals by ICP-MS - Continued								
Iron	7439-89-6	0.05	mg/L	**0.94**	**1.37**	**0.81**	----	----
EK055G: Ammonia as N by Discrete Analyser								
Ammonia as N	7664-41-7	0.01	mg/L	**0.04**	**0.02**	**0.02**	----	----
EK057G: Nitrite as N by Discrete Analyser								
Nitrite as N	14797-65-0	0.01	mg/L	<0.01	<0.01	<0.01	----	----
EK058G: Nitrate as N by Discrete Analyser								
Nitrate as N	14797-55-8	0.01	mg/L	**0.04**	**0.42**	**7.89**	----	----
EK059G: Nitrite plus Nitrate as N (NOx) by Discrete Analyser								
Nitrite + Nitrate as N	----	0.01	mg/L	**0.04**	**0.42**	**7.89**	----	----
EK061G: Total Kjeldahl Nitrogen By Discrete Analyser								
Total Kjeldahl Nitrogen as N	----	0.1	mg/L	**1.7**	**0.4**	**0.7**	----	----
EK062G: Total Nitrogen as N (TKN + NOx) by Discrete Analyser								
^ Total Nitrogen as N	----	0.1	mg/L	**1.7**	**0.8**	**8.6**	----	----
EK067G: Total Phosphorus as P by Discrete Analyser								
Total Phosphorus as P	----	0.01	mg/L	**0.11**	**0.16**	**0.02**	----	----
EN055: Ionic Balance								
ø Total Anions	----	0.01	meq/L	**7.54**	**22.5**	**93.5**	----	----
ø Total Cations	----	0.01	meq/L	----	----	**77.2**	----	----
ø Total Cations	----	0.01	meq/L	**7.15**	**19.2**	----	----	----
ø Ionic Balance	----	0.01	%	----	----	**9.61**	----	----
ø Ionic Balance	----	0.01	%	**2.69**	**7.97**	----	----	----

Appendix F
Willeroo borefield analytical model

creating opportunities

F.1 Analytical model – Willeroo borefield

A preliminary analytical model was developed to assess the potential drawdown effects of operation of the Willeroo borefield over a 12-month period. It is assumed that borefield comprises the three existing production bores (Bore1, Bore 2, and Bore 3 but not Bore 4 which is abandoned), and pumping reaches the maximum authorised volume under licence (that is 600 ML/yr). Pumping lesser volumes or having longer recovery periods between pumping cycles would reduce the predicted drawdowns across the borefield area.

This appendix report describes the model conceptualisation, set-up, assumptions and results.

F.2 Model development

The analytical model was developed using AnAqSim (analytic aquifer simulator), a multi-layer analytic element method software.

F.2.1 Conceptual model

The borefield targets deep alluvium in a paleochannel, that is river deposited alluvium in a buried paleochannel cut into the bedrock that drains into Lake George. The alluvium comprises sand, gravel and clay in various thicknesses depending on the location within the paleochannel. There are two sand and gravel aquifers within the alluvial sequence at this borefield location:

- a shallow aquifer that typically occurs in the uppermost 15–20 m of the alluvial sequence; and
- a deeper aquifer that typically occurs between 25 and 50 m and is located on bedrock.

A low permeability clay layer separates the shallow aquifer from the deep aquifer. Production bores are typically only screened in the more permeable deep aquifer. The shallow aquifer is conceptualised as unconfined, while the deeper aquifer is considered semi-confined. Leakage occurs from the shallow aquifer to the deeper aquifer. Recharge is from rainfall in the upper catchment area while discharge is conceptualised to be to Lake George.

F.2.2 Paleochannel aquifer extent

The extent of the paleochannel aquifer used in this model report was derived from available borelogs of groundwater bores in the area and geophysical data from a national database.

The airborne geophysical data (available on the Geoscience Australia's website) shows a low magnetic signal with a north-eastern direction where the Willeroo borefield is located. This low magnetic area may be consistent with the paleochannel lithology, with sediments usually having low magnetic susceptibility compared to adjacent igneous and other fractured rocks (surrounding lithology). Therefore, the low magnetic area was used to delineate the extent and direction of the paleochannel (Figure F.1).

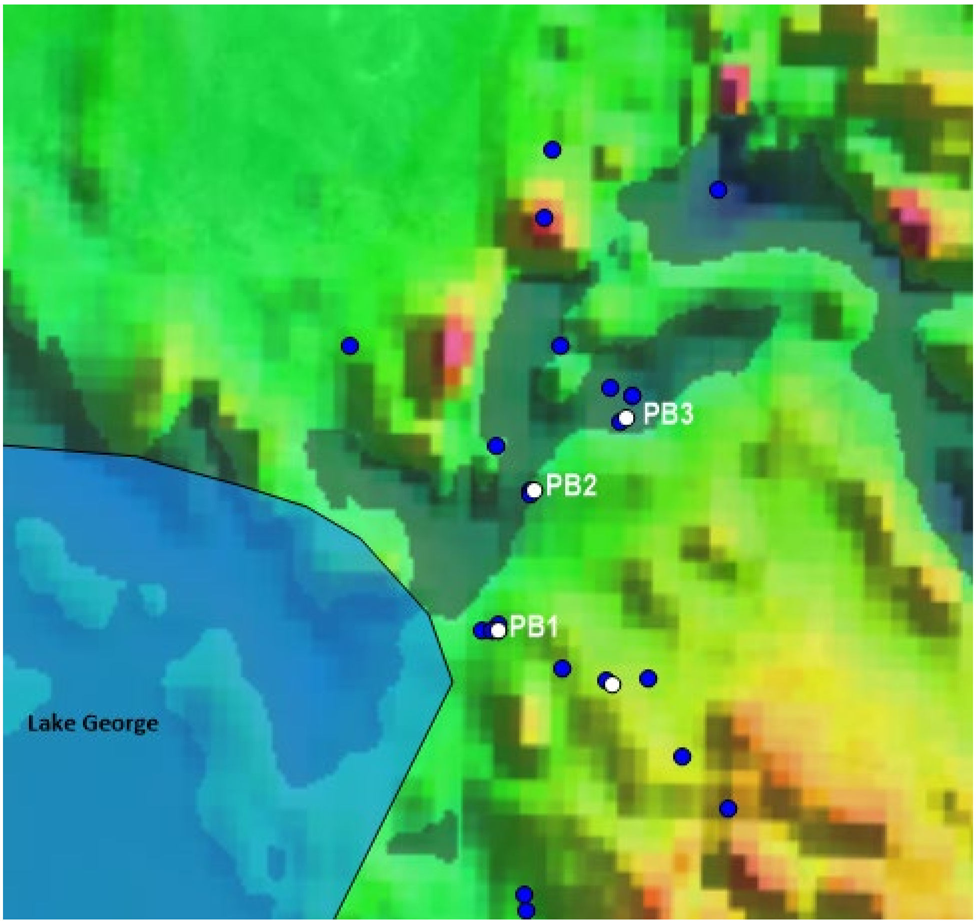


Figure F.1 Airborne magnetic geophysical data

F.2.3 Model design

The model was designed based on the review of the available information. Figure F.2 presents the model set up. Figure F.3 and Figure F.4 provide cross-sections through the model (cross-sections A-A' and B-B' in Figure F.2).

The model components and key assumptions are as follows:

- The paleochannel is comprised of two layers: an unconfined layer (L1_p) underlain by a semi-confined layer (L2_p). L2_p is the aquifer targeted by the production bores within the Willeroo borefield. The north-east – south-west sloping bedrock underlying the paleochannel is represented as a sloping no-flow boundary (Figure F.2).
- The surrounding rock/bedrock was represented as a single layer (L1_b).
- Lake George is represented by a head-specified head boundary, with a constant head of 675 mAHD.
- The model is bounded to the north-west and south-east by no-flow boundaries, and to the north-east by a head-specified boundary. The head-specified boundary is based on groundwater elevation contours derived from available groundwater level data at surrounding bores.
- The Willeroo borefield comprises three production bores (Bore 1, Bore 2 and Bore 3). The production bores are assumed to be fully penetrating in layer 2 (the semi-confined paleochannel aquifer L2_p), that is screened and only taking water from L2_p.

- No transient conditions such as rainfall recharge, evapotranspiration or groundwater pumping by others in the borefield model area are simulated in this simple model, and the model does not take into account the efficiency of individual bores.

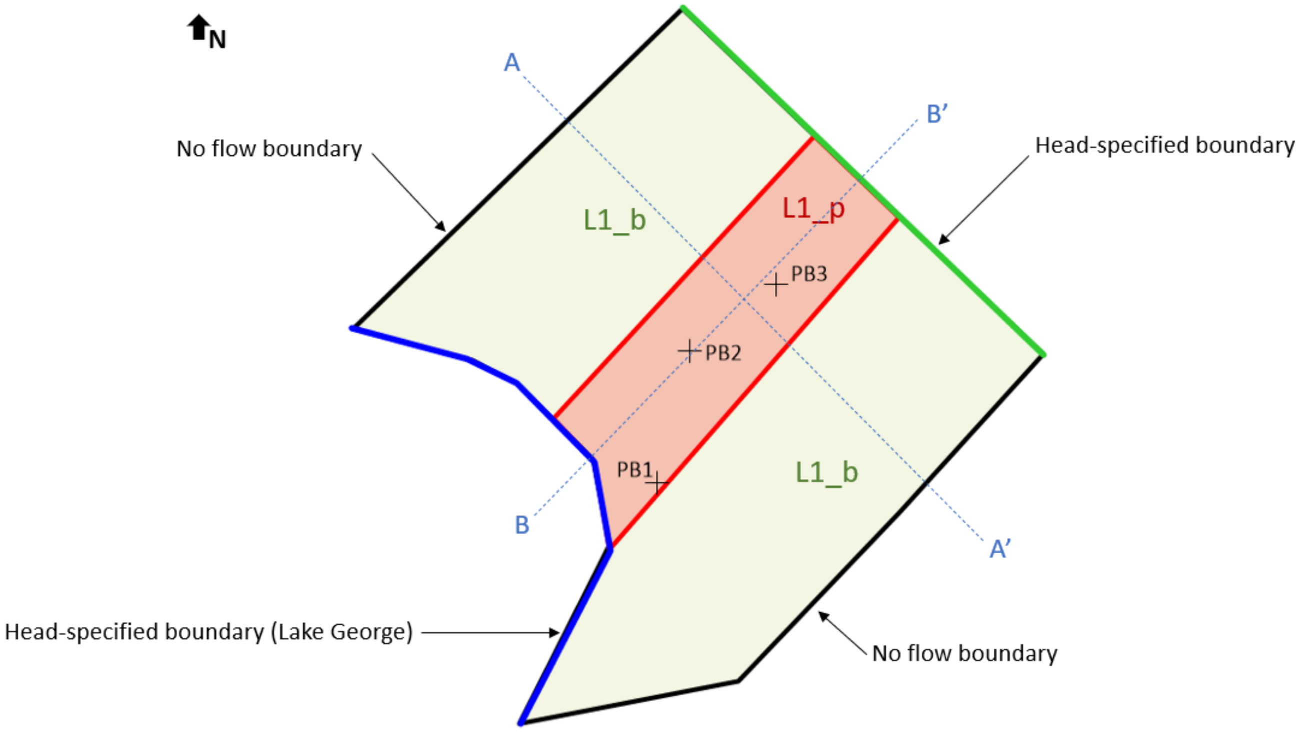


Figure F.2 Model design (top view)

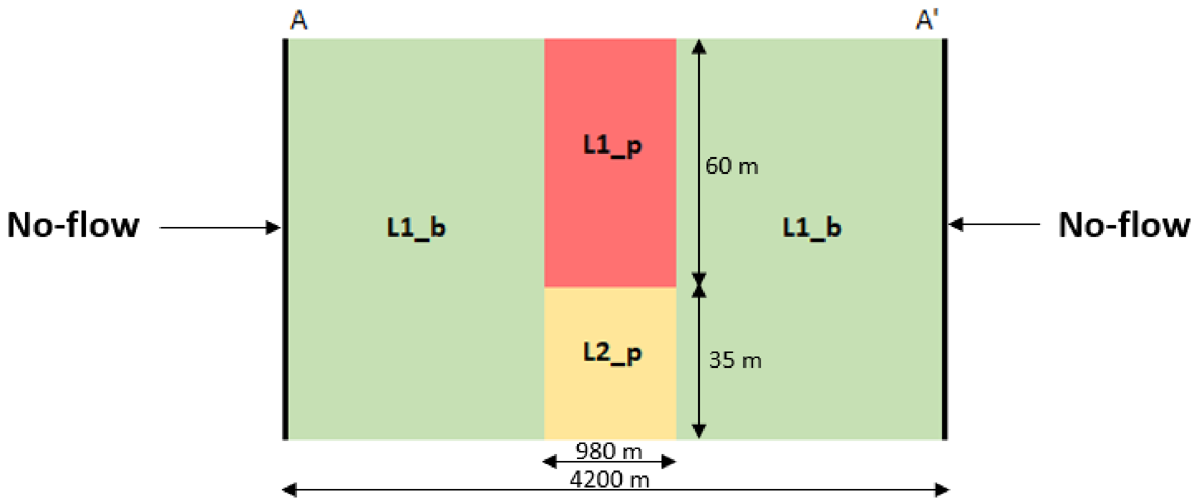


Figure F.3 Cross-section A-A' (north-west – south-east)

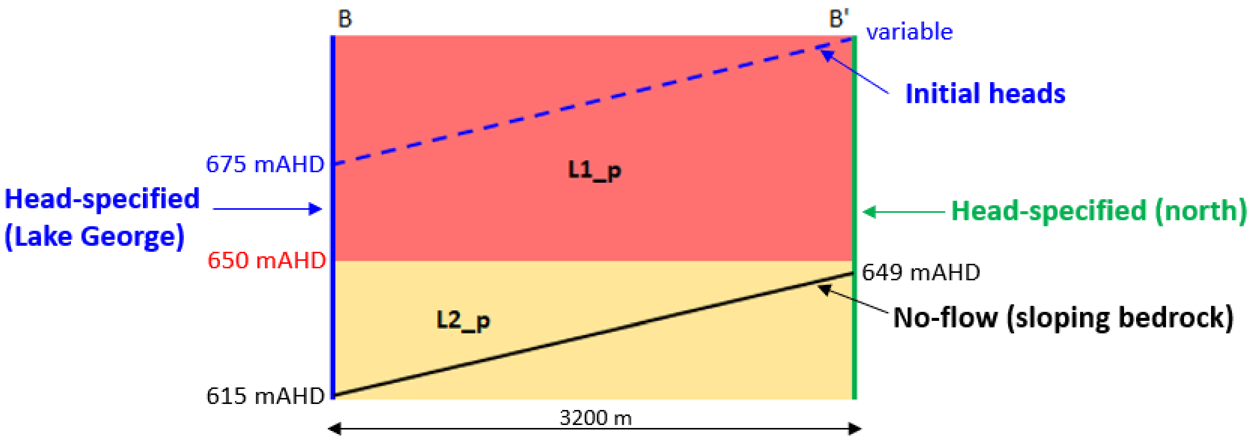


Figure F.4 Cross-section B-B' (south-west – north-east)

F.2.4 Hydraulic properties

Table F.1 outlines the hydraulic properties of the three model domains. All domains are assumed to be isotropic and uniform.

The hydraulic parameters of domain L2_p (the paleochannel aquifer targeted by the Willeroo borefield) were estimated from the constant rate pumping test conducted at Bore 3.

The hydraulic properties of domains L1_b and L1_p (representing basement geology) have not been tested, and therefore were derived from literature representative values for similar lithologies.

Table F.1 Domain hydraulic properties

Label	Lithology	Type	K_x=K_y (m/day)	S	S_y	Porosity	K_3 top (m/day) [1]	K_3 bottom (m/day) [1]
Layer 1 bedrock (**L1_b**)	igneous and fractured rock rock	confined	$1x10^{-5}$	$1x10^{-4}$		0.1	$1x10^{-3}$	$1x 10^{-5}$
Layer 1 paleochannel (**L1_p**)	sediments (sand and gravel)	unconfined	1	$2x10^{-1}$	$2x10^{-1}$	0.3	$1x 10^{-1}$	$1x 10^{-4}$
Layer 2 paleochannel (**L2_p**)	sediments (sand and gravel, overlain by aquitard)	semi-confined	8	$5x10^{-4}$		0.3	$1x 10^{-4}$	$1x 10^{-5}$

1. K_3 top and bottom represent the vertical hydraulic conductivities at the top and bottom of the domain. For example, the K_3 top of L2_p is 10^{-4} m/day to simulate the aquitard between L1_p and L2_p.
2. K = hydraulic conductivity; S = storativity; Sy = specific yield

F.3 Model results

F.3.1 Initial heads (steady state, pre-pumping)

The model was first run in steady state assuming no pumping from the Willeroo borefield to estimate the initial heads for the transient modelling. The initial heads in layers 1 and 2 are provided in Figure F.5 and Figure F.6.

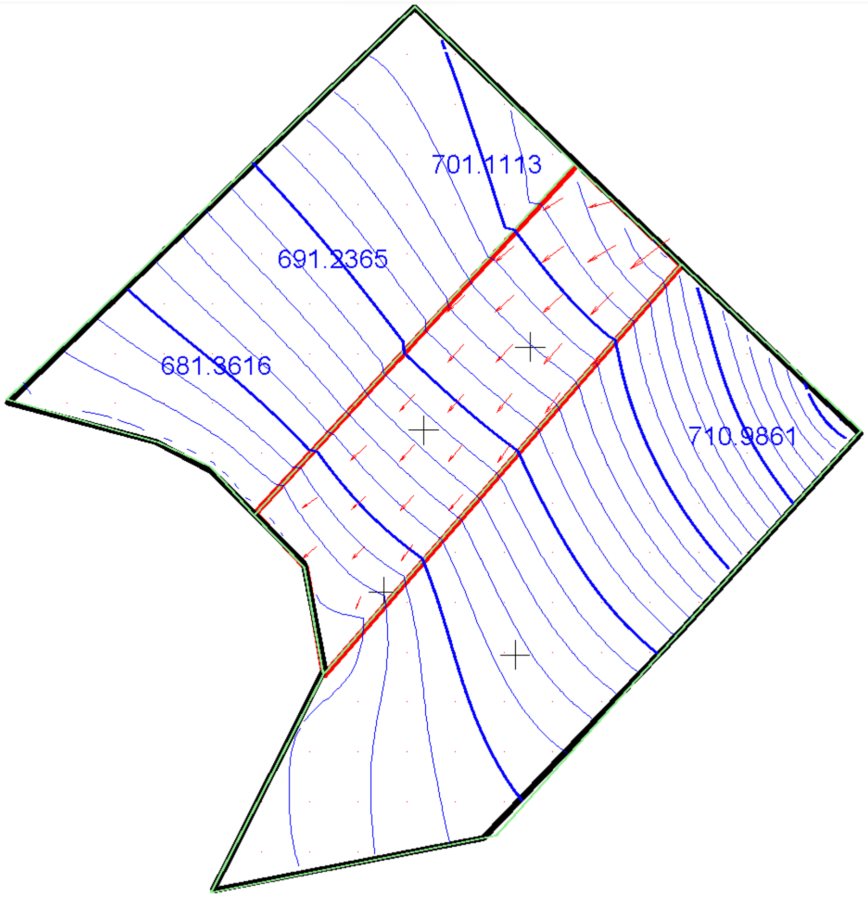


Figure F.5 Initial heads and flow direction vectors in layer 1 (L1_b and L1_p)

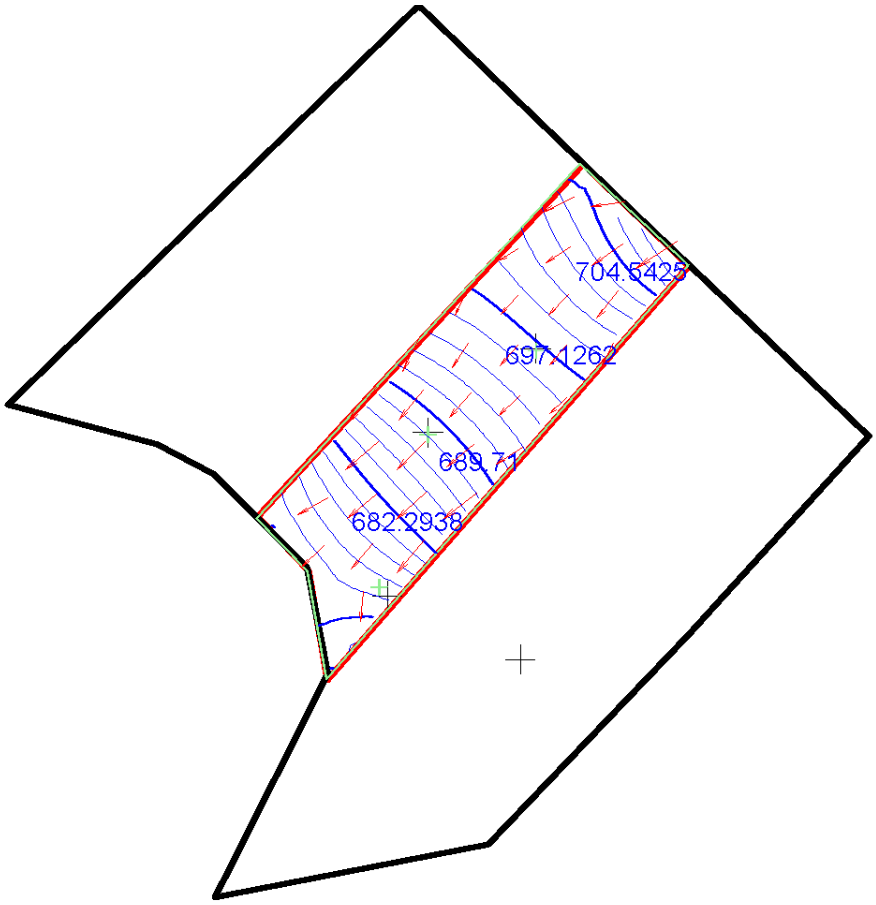


Figure F.6 Initial heads and flow direction vectors in layer 2 (L2_p)

F.3.2 Pumping water levels (transient model)

i Pumping schedule

Table F.2 presents the first three-week cycle of the pumping schedule set up in AnAqSim. The individual bore pumping rates are the maximum safe yield estimated from the pumping test conducted at Bore 3, that is 10 L/s over a 14-day period.

With higher pumping rates, dewatering of the shallow and deep aquifers is unlikely, however drawdown to below the pump intake may occur, as observed during the Bore3 pumping test.

The following pumping schedule has been simulated as an example of a drought operational cycle.

A typically drought pumping cycle with two bores operational at any one time would be as follows:

- week 1 (time step 1) – PB2 and PB3 operating, PB1 off;
- week 2 (time step 2) – PB1 and PB3 operating, PB2 off; and
- week 3 (time step 3) – PB1 and PB2 operating, PB3 off; and then the cycle repeats.

Table F.2 Typical pumping schedule for borefield operation (first three-week cycle)

Time step	Duration	PB1 (L/s)	PB2 (L/s)	PB3 (L/s)	Total (L/s)
1	7 days	0	10	10	20
2	7 days	10	0	10	20
3	7 days	10	10	0	20

ii Hydrographs

Figure F.7 shows the simulated heads at each of the production bores in Layer 2 after a 52-week (one-year) pumping period (ie 17.3 three-week cycles).

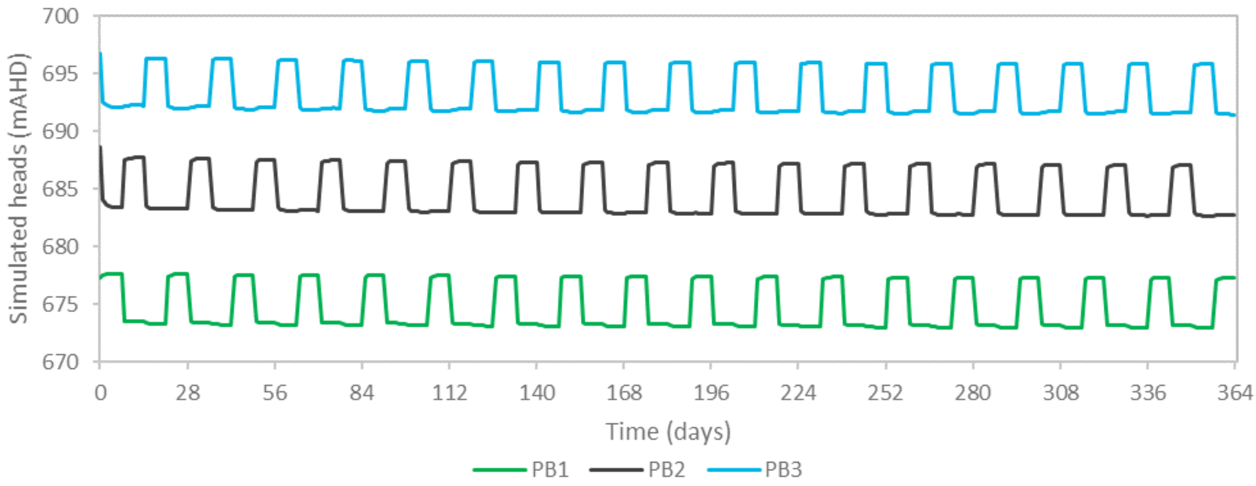


Figure F.7 Hydrographs – simulated heads at Bore 1, Bore 2 and Bore 3

The maximum simulated drawdowns at each of the production bore are:

- 4.7 m at Bore1;
- 6.0 m at Bore 2; and
- 5.3 m at Bore3.

iii Heads at end of the one-year simulation

The simulated heads in layers 1 (basement) and 2 (paleochannel) at the end of the one-year simulation are presented in Figure F.8 and Figure F.9.

The key findings are as follows:

- The simulated heads in the bedrock (L1_b) are similar to the pre-pumping heads (Figure F.8), suggesting pumping operations have negligible impact on the bedrock groundwater system.

- The simulated heads in layer 1 of the paleochannel (L1_p) are similar to the pre-pumping heads (Figure F.9) although slightly lower near the production bores (up to 0.9 m lower).

- The simulated heads in the pumped aquifer (L2_p) show spatially limited drawdown in the vicinity of the production bores compared to the pre-pumping conditions (Figure E2.2).

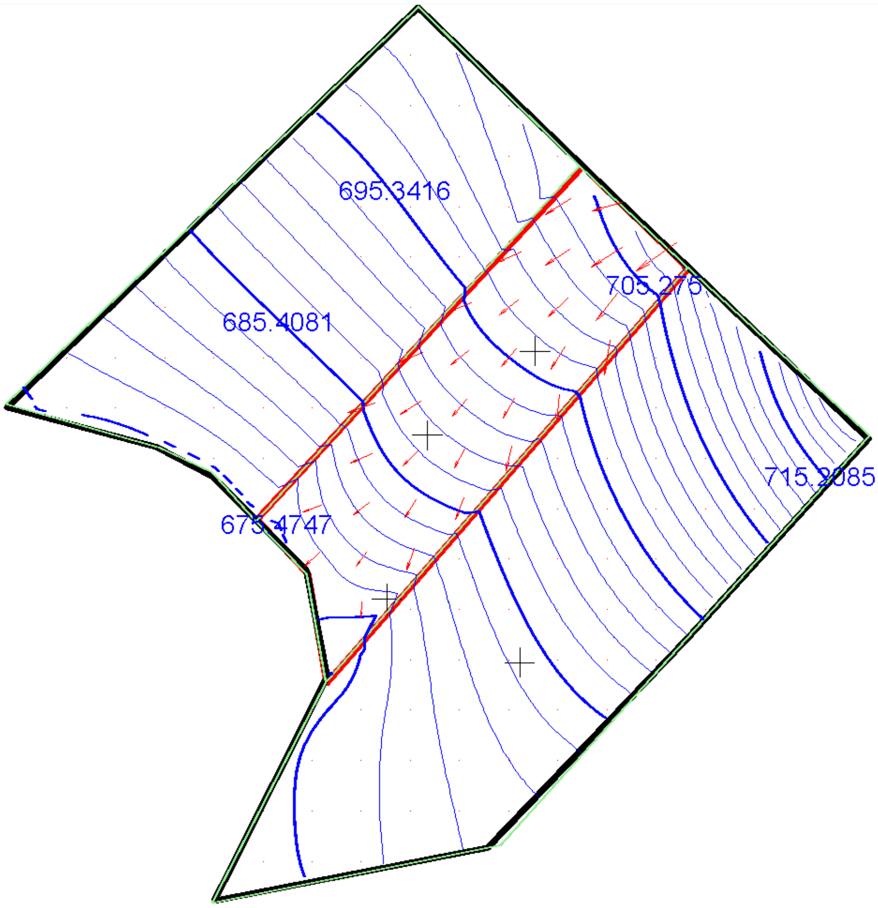


Figure F.8 Pumping heads and flow direction vectors in layer 1 (L1_b and L1_p) at end of one-year simulation

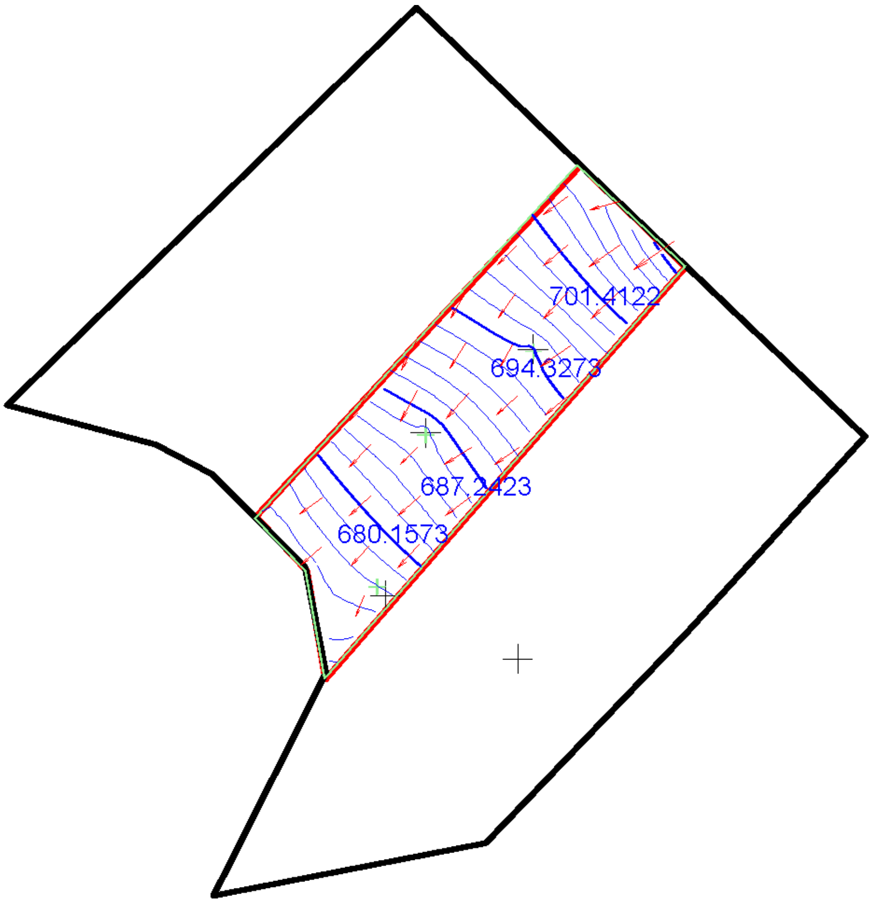


Figure F.9 Pumping heads and flow direction vectors in layer 2 (L2_p) at end of one-year simulation

F.4 Summary and limitations

The analytical model suggests the Willeroo borefield is capable of continuously supplying 20 L/s (as per pumping schedule in Table F.2) with limited drawdown and stress to the aquifer. The maximum simulated drawdown at each of the production bores is 6 m or less. This is equivalent to pumping 630 ML/yr from the borefield. This is a highly conservative approach as this volume is effectively the licensed volume for the borefield even though the typical (future) annual requirement is only 140 ML/yr and the drought water supply requirement is probably only 300 ML/yr.

However, the model was based on several assumptions and unknowns. The model limitations are as follows:

- The paleochannel extent was delineated based in national geophysical data and available borelogs. No site-specific investigations were undertaken to map the full extent of deep alluvial aquifer. The aquifer in the paleochannel was assumed to be 980 m in width, however the actual paleochannel could be narrower.
- There are no apparent boundaries or interference effects between the production bores given the spacing of these bores and the assumed width of the paleochannel. If the paleochannel is narrower than 980 m, boundary effects or greater drawdowns within the deep aquifer associated with long term pumping may be observed.
- The model assumes uniform hydraulic parameters for each model domain. However, heterogeneities are common in alluvial aquifers and different aquifer parameters may influence the actual aquifer response at different locations.

- The hydraulic properties of the pumped aquifer (L2_p) and safe pumping yields were derived from a short pumping test conducted at Bore 3, assuming uniform parameters within the aquifer. However, Bore 1 and Bore 2 were not tested.

  The hydraulic properties and safe yields may be different for those bores and should be confirmed by short-term pumping tests (up to 72 hours). Also, long-term pumping (or close monitoring of early operational cycles) plus monitoring of responses in the monitoring bore network are recommended to confirm the safe yields of the three production bores when operating in combination.

- The model predicts full recovery at individual bores between pumping cycles due to the steep hydraulic gradient created by the fixed head boundaries at Lake George and the upstream recharge area. This may not be the case during drought periods when there is lesser rainfall recharge and lake levels are significantly lower.

- Production bore efficiencies are not factored in the model. Therefore, actual drawdowns in each of the operational bores will be lower than those simulated by this simple model.

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