7. Assessment of key issues

7.10 Groundwater quality and hydrology

This section describes the potential groundwater quality and hydrology impacts that may be generated by construction and operation of the project and presents a proposed approach to the management of these impacts. **Table 7-144** outlines the SEARs that relate to groundwater quality and hydrology and identifies where they are addressed in this EIS. The full assessment of groundwater quality and hydrology impacts is provided in **Appendix N**.

Table 7-144 SEARs (groundwater quality and hydrology)

Secretary's requirement	Where addressed in this EIS
14. Water - Hydrology	
1. The Proponent must describe (and map) the existing hydrological regime for any surface and groundwater resource (including reliance by users and for ecological purposes) likely to be impacted by the project, including stream orders, as per the FBA.	The existing groundwater hydrological regime is presented in **Section 7.10.3** The existing surface water hydrological regime is presented in **Section 7.9.3**
2. The Proponent must prepare a detailed water balance for ground and surface water including the proposed intake and discharge locations, volume, frequency and duration.	A groundwater balance is presented in **Section 7.10.4** A surface water balance is presented in **Section 7.9.4**
3. The Proponent must assess (and model if appropriate) the impact of the construction and operation of the project and any ancillary facilities (both built elements and discharges) on surface and groundwater hydrology in accordance with the current guidelines, including: a. natural processes within rivers, wetlands, estuaries, marine waters and floodplains that affect the health of the fluvial, riparian, estuarine or marine system and landscape health (such as modified discharge volumes, durations and velocities), aquatic connectivity and access to habitat for spawning and refuge;	Impacts on groundwater natural processes and access to habitat are assessed in **Section 7.10.4** Impacts on surface water natural processes and access to habitat are assessed in **Section 7.9.4**
b. impacts from any permanent and temporary interruption of groundwater flow, including the extent of drawdown, barriers to flows, implications for groundwater dependent surface flows, ecosystems and species, groundwater users and the potential for settlement;	Impacts on groundwater flows are assessed in **Section 7.10.4** and **Appendix N**
c. changes to environmental water availability and flows, both regulated/licensed and unregulated/rules-based sources;	Changes to environmental groundwater availability and flows are assessed in **Section 7.10.4** Changes to environmental surface water availability and flows are discussed in **Section 7.9.4**
f. water take (direct or passive) from all surface and groundwater sources with estimates of annual volumes during construction and operation.	Water take from groundwater sources is assessed in **Section 7.10.4** Water take relating to surface water is assessed in **Section 7.9.4**

Secretary's requirement	Where addressed in this EIS
4. The Proponent must identify any requirements for baseline monitoring of hydrological attributes.	Requirements for baseline groundwater monitoring are discussed in **Section 7.10.6** Requirements for surface water baseline monitoring are discussed in **Section 7.9.6** and **Appendix M**
15. Water - quality	
1. The Proponent must: a. state the ambient NSW Water Quality Objectives (NSW WQO) and environmental values for the receiving waters relevant to the project, including the indicators and associated trigger values or criteria for the identified environmental values;	Criteria relating to groundwater are discussed in **Sections 7.10.2** and **7.10.4** Criteria relating to surface water are discussed in **Section 7.9.1**
b. identify and estimate the quality and quantity of all pollutants that may be introduced into the water cycle by source and discharge point and describe the nature and degree of impact that any discharge(s) may have on the receiving environment, including consideration of all pollutants that pose a risk of non-trivial harm to human health and the environment;	The potential introduction of pollutants relating to groundwater are discussed in **Sections 7.10.2** to **7.10.4** The potential introduction of pollutants relating to surface water are discussed in **Section 7.9.4**
d. assess the significance of any identified impacts including consideration of the relevant ambient water quality outcomes;	The significance of identified impacts relating to groundwater is discussed in **Section 7.10.4** The significance of identified impacts relating to surface water are discussed in **Section 7.9.4**
e. demonstrate how construction and operation of the project will, to the extent that the project can influence, ensure that: – where the NSW WQOs for receiving waters are currently being met, they will continue to be protected; – where the NSW WQOs are not currently being met, activities will work toward their achievement over time;	The protection of receiving waters relating to groundwater is discussed in **Section 7.10.4** The protection of receiving waters relating to surface water is discussed in **Section 7.9.4**
g. demonstrate that all practical measures to avoid or minimise water pollution and protect human health and the environment from harm are investigated and implemented;	Measures to avoid or minimise groundwater pollution and protect health and the environment are discussed in **Section 7.10.6** Measures to avoid or minimise surface water pollution and protect health and the environment are discussed in **Sections 7.9.4** and **7.9.6**
h. identify sensitive receiving environments (which may include estuarine and marine waters downstream) and develop a strategy to avoid or minimise impacts on these environments; and	Sensitive receiving environment relating to groundwater are discussed in **Section 7.10.3** and **Section 7.10.6** Sensitive receiving environment relating to surface water are discussed in **Section 7.9.3** and **Section 7.9.6**
i. identify proposed monitoring locations, monitoring frequency and indicators of surface and groundwater quality.	Groundwater monitoring is discussed in **Section 7.10.6** Surface water monitoring is discussed in **Section 7.9.6**

Secretary's requirement	Where addressed in this EIS
17. Soils	
4. The Proponent must assess whether salinity is likely to be an issue and if so, determine the presence, extent and severity of soil salinity within the project area.	The presence, extent and severity of soil salinity is described in **Section 8.1.3**
5. The Proponent must assess the impact of the project on soil salinity and how it may affect groundwater resources and hydrology	Potential impacts of soil salinity on hydrology is described in **Section 7.9.4**, groundwater in **Section 7.10.4** and within **Section 8.1.4**.

7.10.1 Policy and planning setting

The groundwater quality and hydrology assessment was prepared with consideration of the following relevant legislation, policies, guidelines and water sharing plans:

- *Water Act 1912* (NSW), Water Management Act 2000 (NSW) and *Water Management Regulation 2018*
- Water Sharing Plan for the Greater Metropolitan Regional Groundwater Sources 2011 (NSW DPI Office of Water, 2011)
- NSW Aquifer Interference Policy (NSW DPI Office of Water, 2012a)
- Groundwater Dependent Ecosystem Policy (Department of Land and Water Conservation [DLWC], 2002a)
- National Water Quality Management Strategy (DAWR, 2018)
- Guidelines for Groundwater Quality Protection in Australia (DAWR, 2013)
- NSW Water Quality Objectives (DECCW, 2006)
- Australian and New Zealand Guidelines for Fresh and Marine Water Quality ANZECC/ARMCANZ, 2000.

The project is compliant (or where relevant consistent) with the legislation and guidelines outlined above**.** This compliance and consistency is demonstrated in detail in **Appendix N**.

The following additional policy and guidelines documents have also been reviewed and informed the groundwater quality and hydrology assessment, including:

- Australian Drinking Water Guidelines (ADWG) (National Health and Medical Research Council [NHMRC], 2011)
- NSW State Groundwater Policy Framework Document (NSW Department of Land and Water Conservation [DLWC], 1998a)
- NSW Groundwater Quality Protection Policy (DLWC, 1998b)
- NSW Groundwater Quantity Management Policy (DLWC, undated)
- Risk Assessment Guidelines for Groundwater Dependent Ecosystems (NSW DPI Office of Water, 2012b)
- Using the ANZECC Guidelines and Water Quality Objectives in NSW (Department of Environment and Conservation [DEC], 2006a).

Further detail on the relevant legislation, policies, guidelines and water sharing plans and how they apply to project is provided in Chapter 2 of **Appendix N**.

7.10.2 Assessment methodology

The assessment of potential groundwater quality and hydrology related impacts arising from the project was carried out in accordance with the following tasks:

- Desktop assessment, involving characterisation of the existing environment, including:
  - Rainfall data from gauging stations in/around the study area from the Bureau of Meteorology (BOM, 2018a)
  - BOM's GDE Atlas to investigate the potential for GDEs (BOM, 2018c)
  - The Water Register (WaterNSW) for data on existing groundwater users, including WAL holders and stock and domestic users
  - BOM's Australian Groundwater Explorer (BOM, 2018d) to investigate registered groundwater bores and associated groundwater level records in the region of the project
  - Greater Metropolitan Region WSP (Schedule 4 identifies high priority GDEs and Appendix 2 lists GDEs)
  - Review of geological, topography, drainage and soil maps and data
- Field investigations, including:
  - Installation of 31 project groundwater monitoring bores
  - Hydraulic conductivity testing using slug tests at five project monitoring bores
  - Groundwater level monitoring at 28 project monitoring bores
  - Groundwater quality monitoring at 10 project monitoring bores
- Groundwater model:
  - Creation of a conceptual groundwater model
- Impact assessment, involving:
  - Assessment of potential groundwater-related impacts on satisfy the minimal impact considerations of the AIP and to address groundwater related issues raised in the SEARs
  - Assessment of the project's potential to interfere with the water table and underlying groundwater systems
  - Estimation of groundwater inflows into project cuts
- Monitoring and management of identified impacts, including:
  - Recommended mitigation measures as appropriate.

The methodology is described in the following sections. Further detail is provided in Chapter 3 of **Appendix N**.

Groundwater quality and hydrology study area

The study area used to inform the groundwater quality and hydrology impact assessment comprises the construction footprint and a two kilometre buffer. In a discrete location to the west of the construction footprint, the buffer is extended to about three kilometres to capture an existing bore in Luddenham (GW108933.1.1). The groundwater quality and hydrology study area is shown in **Figure 7-131**.

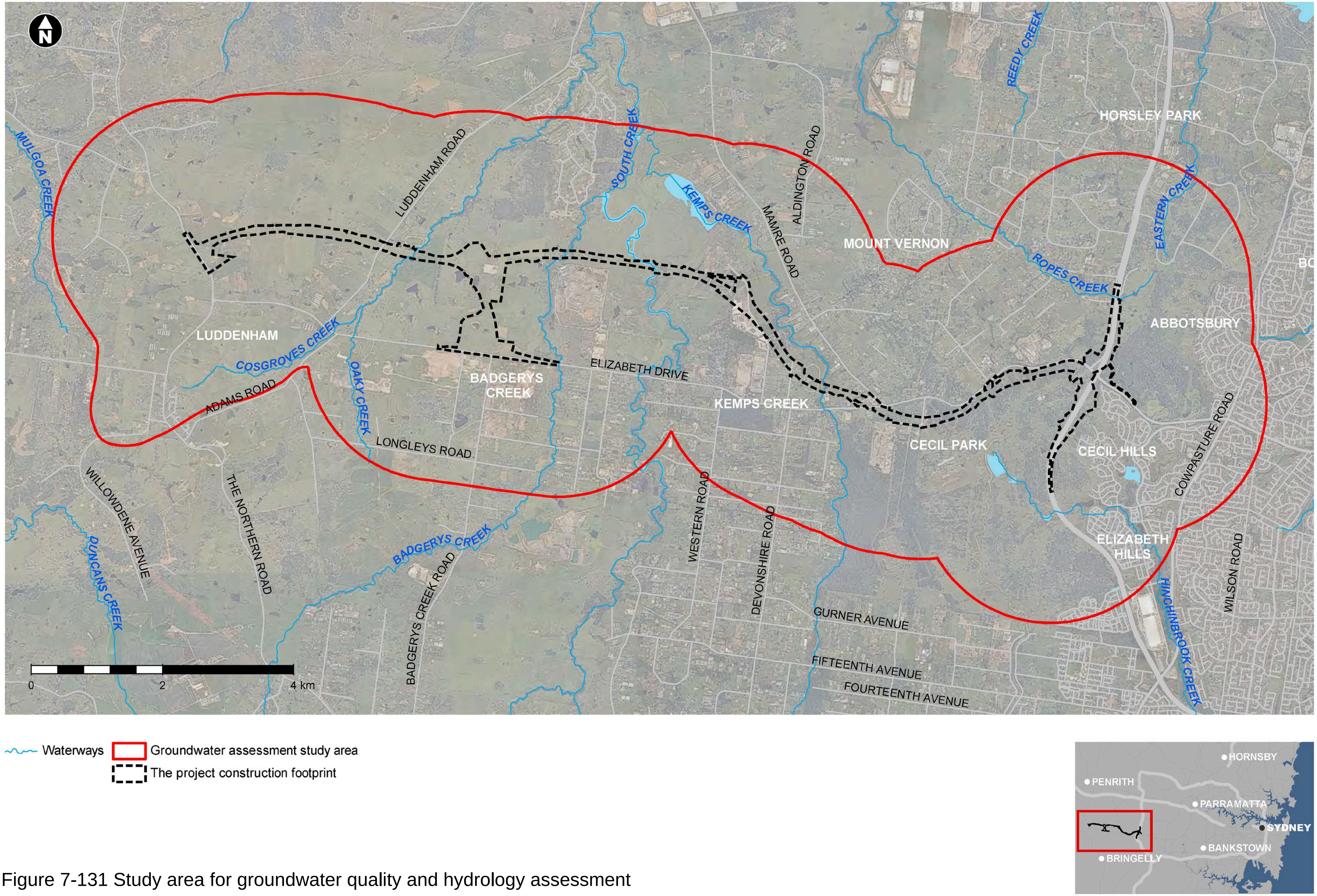

Figure 7-131 Study area for groundwater quality and hydrology assessment

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Field investigations

Groundwater field investigations, including drilling boreholes, monitoring well installation, groundwater level gauging, groundwater sampling and hydrogeochemical analysis, were carried out across the study area between February 2018 and January 2019.

Installation of project groundwater bores

Thirty-one groundwater monitoring bores were installed between November 2017 and August 2018 for the purpose of informing geotechnical design and a range of environmental assessments. Project groundwater monitoring bore locations are shown in **Figure 7-132**.

Hydraulic conductivity testing

Hydraulic conductivity is measured in metres per day and is a calculation of how easily groundwater flows through a porous medium (soil matrix or rock mass). The higher the value of hydraulic conductivity, the greater the movement of groundwater expected (including into unsealed excavations below the water table). Hydraulic conductivity assists in the understanding of potential groundwater inflows into excavations below the water table and the local drawdown (ie the reduction in the water level) that may be imposed on the local hydrogeological regime.

Hydraulic testing through slug tests was carried out at five of the project monitoring bores. Slug tests involve displacing or removing (or adding) water from the bore and measuring the water level response in the bore. The five bores comprised three bores located in the areas of the deepest cuts and two bores located in areas of alluvium, as follows:

- Deepest cuts:
  - BH 104
  - BH 112
  - BH 145
- Alluvium:
  - BH 202
  - BH 217.

The location of the five project monitoring bores where hydraulic conductivity was carried out are shown in **Figure 7-133**.

Groundwater level monitoring

Of the 31 groundwater monitoring bores that were installed for the project, groundwater level data was obtained from 28, which included one location (BH139) that remained dry due to being located above the water table and three locations where manual dip meter readings were collected (BH162, BH170 and BH175).

Three groundwater monitoring bores were not used for groundwater level monitoring, due to either restricted land access (BH129), or where bores were primarily installed to monitor gas and therefore not equipped with water level data loggers (BH301 and BH302).

The locations of the groundwater monitoring bores are shown in **Figure 7-132**.

A summary of monitoring and testing completed at project groundwater monitoring bores is provided in **Figure 7-134**. The overall groundwater level monitoring period was variable at the bores and ranged from 67 to 334 days, with an average duration of 130 days.

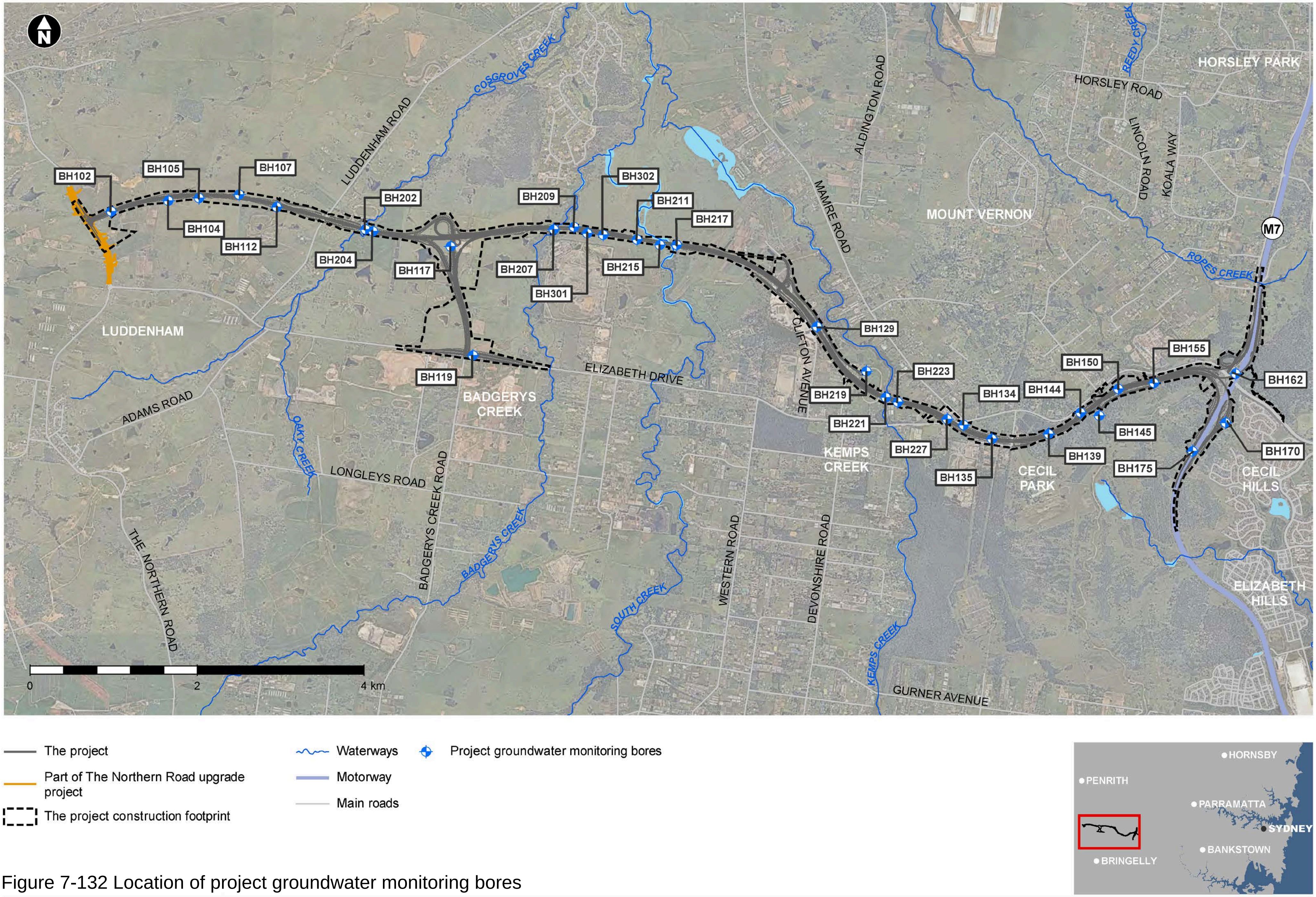

Figure 7-132 Location of project groundwater monitoring bores

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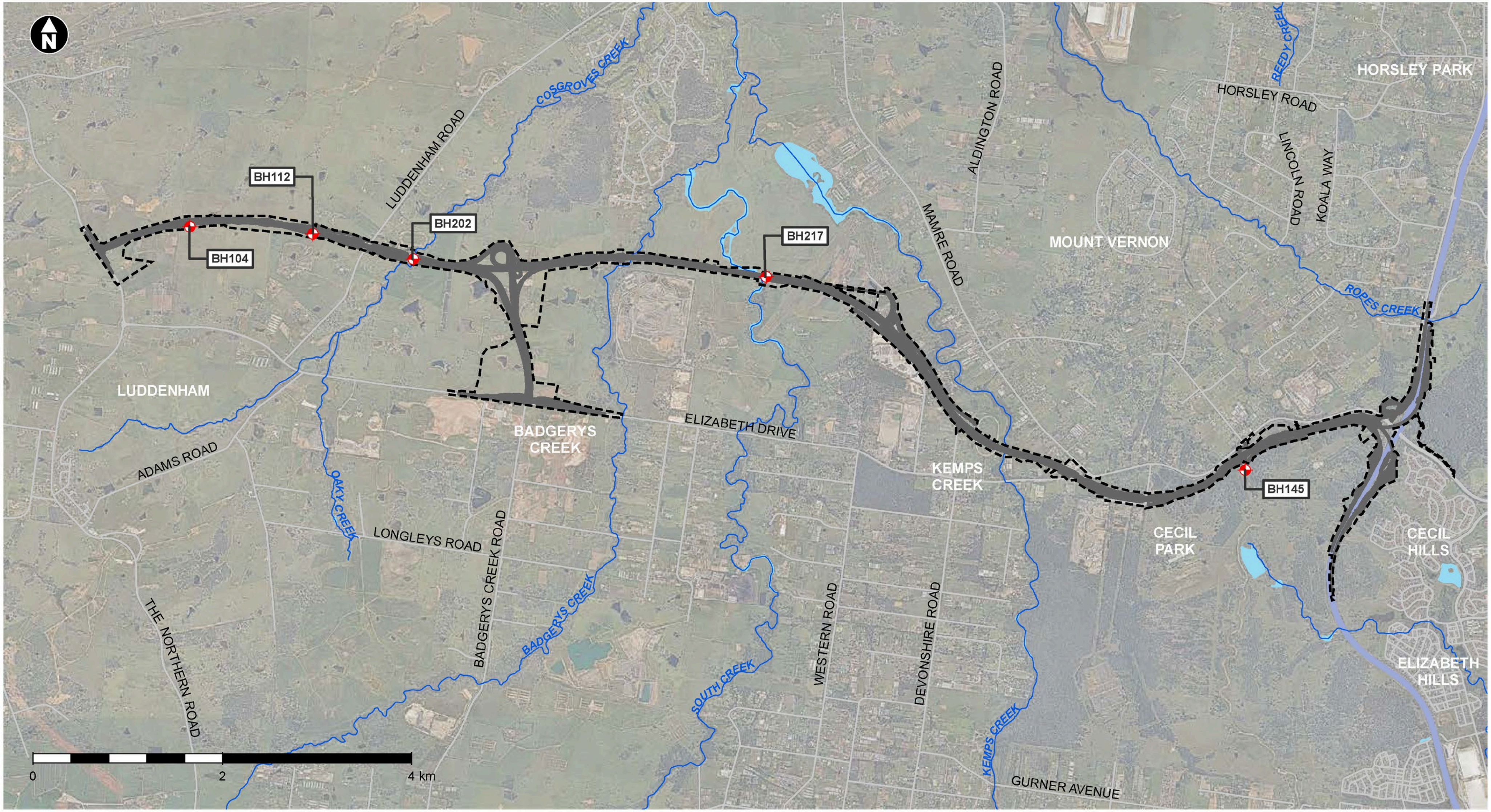

Figure 7-133 Location of project groundwater bores tested for hydraulic conductivity

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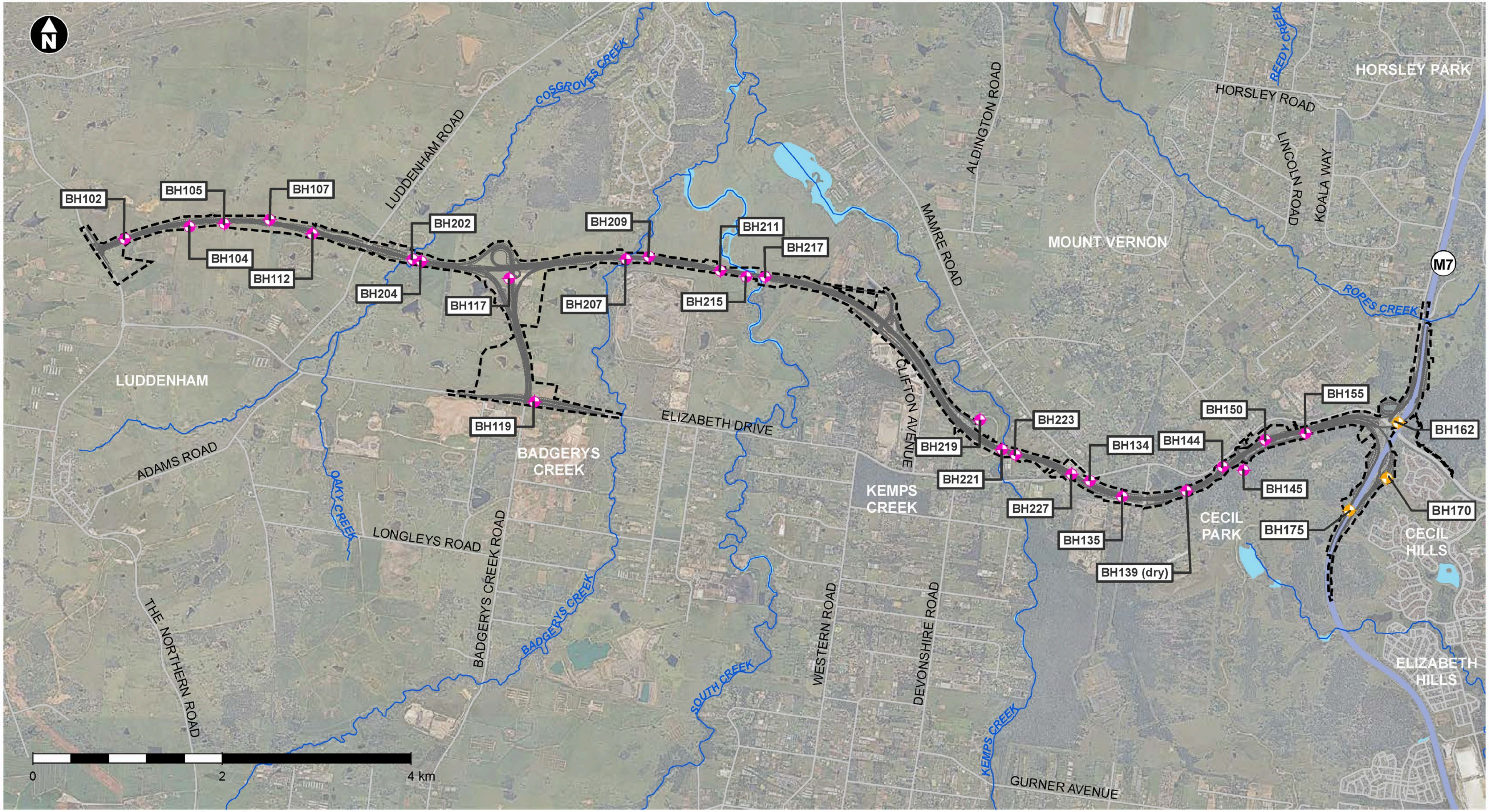

The project
The project construction footprint
Groundwater level monitoring (dip meter)
Waterways
Groundwater level monitoring (data logger)
Motorway
Main roads

Figure 7-134 Location of project groundwater bores used for groundwater level monitoring

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Groundwater quality testing

Groundwater samples were collected once from the following bores in August 2018 to characterise the local groundwater quality of each of the main hydrogeological units applicable to the project:

- BH104
- BH112
- BH145
- BH202
- BH207
- BH209
- BH217
- BH223
- BH3012
- BH3022.

The purpose of the sampling was to determine:

- Groundwater quality changes across the study area
- Potential areas of groundwater contamination.

These 10 bores were considered adequate to characterise groundwater systems applicable to the project given the project's anticipated minimal interaction with groundwater. Groundwater quality samples tested the following components:

- Heavy metals (including arsenic, cadmium, chromium, copper, lead, magnesium, mercury, nickel and zinc)
- Total recoverable hydrocarbons
- Benzene, toluene, ethylbenzene, xylene and naphthalene (BTEXN)
- Ammonia
- Nutrients
- Electrical conductivity (EC)
- pH
- Total dissolved solids (TDS)
- Total suspended solids (TSS)
- Turbidity
- Major anions and cations.

The locations of the 10 project groundwater monitoring bores that were selected for groundwater quality sampling are shown in **Figure 7-135**.

Groundwater modelling

A conceptual hydrogeological model was developed to characterise existing groundwater quality and hydrology conditions and determine the potential construction and operational groundwater quality and hydrology impacts associated with the project. Given the variable hydrogeological conditions across the study area, the conceptual hydrogeological model incorporated alluvial groundwater systems and the Bringelly Shale groundwater system. A cross-section of the conceptual groundwater model is provided in **Figure 7-136**.

Further information regarding the conceptual groundwater model, including model assumptions, is provided in **Appendix N**.

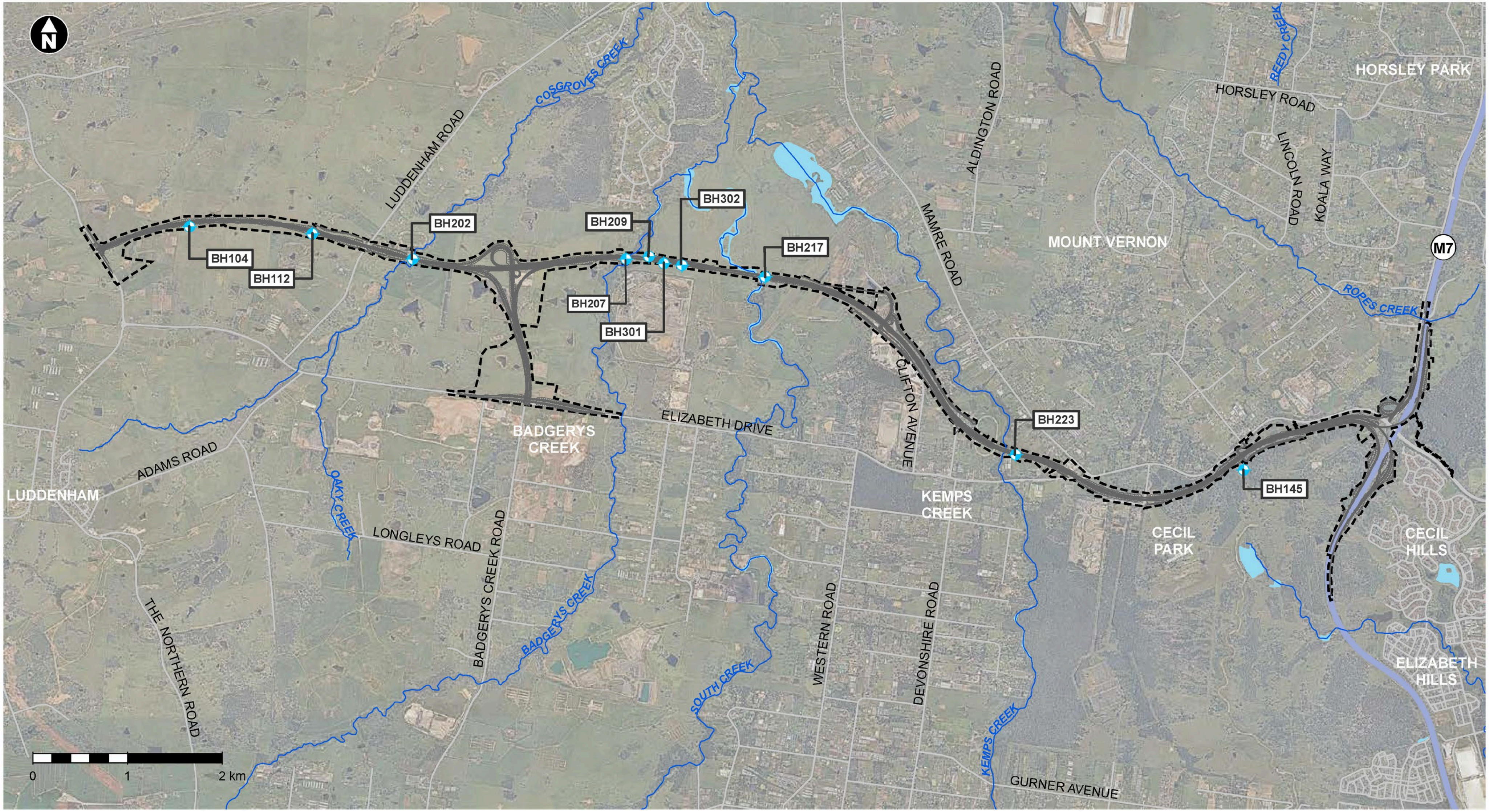

Figure 7-135 Location of project groundwater bores sampled for groundwater quality

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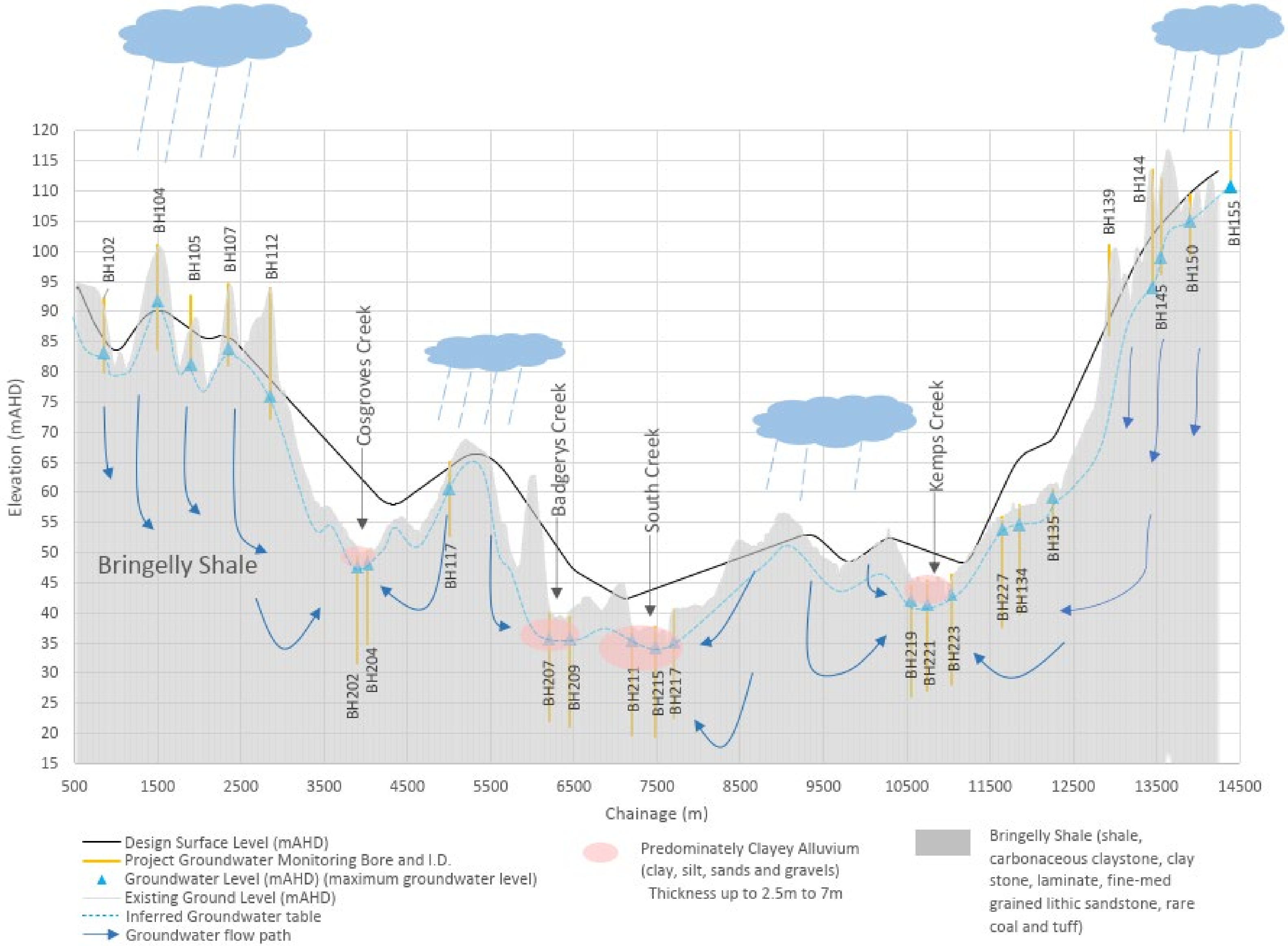

Figure 7-136 Conceptual cross-section of groundwater systems

Impact assessment methodology

De-watering assessment

The primary project activity that could result in changes (reductions) to groundwater levels is the de-watering of cuts that extend below the water table. De-watering, such as through drainage of road cuttings, results in depressurisation of the groundwater system and has the potential to cause changes to groundwater flows and levels.

A de-watering assessment was carried out to estimate potential groundwater inflows and reductions to groundwater levels where road cuttings (excavations) would extend below the water table. The impact assessment assumed a worst-case design scenario, where road cuttings below the baseline water table level would be permanently drained.

The de-watering inflow assessment was based on:

- The application of Darcy's law (which describes flow through porous media)
- Inputs informed by project groundwater bore monitoring results
- Project design levels of the road.

As well as estimating groundwater inflow rates into the road cuttings, the associated areal extent of groundwater level reduction (referred to as 'radius or extent of influence') was estimated using the Cooper-Jacob (1946) equation. Further details on the equation are provided in **Appendix N**.

The estimated groundwater inflow rates and the extent of accompanying groundwater level reductions resulting from the construction activities and project operation were used to assess potential impacts on interactions between groundwater and surface water, GDEs and existing groundwater supply bores.

Other groundwater impacts

In addition to the de-watering assessment, a range of other project activities with potential to cause impacts on groundwater levels and quality were assessed. Such risks were assessed qualitatively due to low risks and anticipated negligible impacts, and included:

- Potential groundwater level increases due to fill placement
- Potential groundwater level changes due to bridge piles causing groundwater flow obstruction
- Potential changes to groundwater quality as a result of accidental spills or leaks, recharge from project stormwater basins or mobilisation of potential contaminants by bridge pile drilling
- Potential changes to soil and groundwater salinity
- Potential cumulative groundwater level and quality impacts due to accumulation of impacts from surrounding projects.

Impact assessment of the above risks was completed for both construction and operation phases of the project.

Criteria

The groundwater quality objective for the project is to ensure design, construction and operation of the project has a neutral or beneficial effect to groundwater quality. For the purpose of this assessment, a neutral or beneficial effect to groundwater quality is defined as an effect that does not lower the beneficial use category of the groundwater system, or an effect that raises the beneficial use category of the groundwater system.

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

As such, existing groundwater quality in this assessment is compared to:

- HRC water quality objectives for total nitrogen (0.7 milligrams per litre) and total phosphorus (0.035 milligrams per litre) (HRC guidelines only covered these two analytes)
- The Australian and New Zealand Environment Conservation Council water quality guidelines (ANZECC/ARMCANZ, 2000) (commonly referred to as the 'ANZECC Water Quality Guidelines'), for analytes other than total nitrogen and total phosphorus. The project's catchment is considered to represent a "slightly modified freshwater system" (ANZECC/ARMCANZ, 2000). Therefore, for assessment of toxicants, a protection level of 95 per cent for freshwater ecosystems is used. ANZECC Water Quality Guidelines trigger values for lowland rivers are also used.

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

In addition to the HRC and ANZECC Water Quality Guidelines, the NSW Aquifer Interference Policy (AIP) minimal impact considerations (NSW DPI Office of Water, 2012a) was adopted as the criteria to assess potential impacts on groundwater level, pressure and groundwater quality. As outlined in the AIP, different minimal impact considerations apply depending on the productivity of the groundwater source. The project is considered to be within a 'less productive groundwater source' on the basis of:

- Low numbers of water supply bores
- Expected low yields
- Expected moderate to high salinity.

As a result, minimal impact considerations for a 'less productive groundwater source' were incorporated into the criteria to assess groundwater level, pressure and groundwater quality.

In relation to groundwater quality, the AIP minimal impact consideration states that 'any change in groundwater quality should not lower the beneficial use category of the groundwater source beyond 40 metres from the activity'. 'Beneficial use category' is discussed in **Table 7-146** in relation to the Guidelines for Groundwater Quality Protection in Australia (DAWR, 2013) and is synonymous with the term 'environmental value'.

The application of the minimal impact criteria relating to the project is shown in **Table 7-145** for groundwater levels and pressure and in **Table 7-146** for water quality.

Table 7-145 Minimal impact considerations (groundwater level and pressure)

Minimal impact considerations		Response
Water level/ table	Less than or equal to 10 per cent 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. A maximum of a two metre decline cumulatively at any water supply work.	Appendix 2 of the water sharing plan legislation indicated no High Priority GDEs (karst and wetlands) or high priority culturally significant sites are mapped within about 10 kilometres of the study area. No water table decline is predicted at any water supply work.

Minimal impact considerations		Response
	If more than 10 per cent 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 if appropriate studies demonstrate to the Minister's satisfaction that the variation will not prevent the long-term viability of the dependent ecosystem or significant site. If more than a two metre decline cumulatively at any water supply work then make good provisions should apply.	As per above response
Water pressure	A cumulative pressure head decline of not more than a two metre decline, at any water supply work.	No pressure decline is predicted at any water supply work.
	If the predicted pressure head decline is greater than the requirement above, then appropriate studies are required to demonstrate to the Minister's satisfaction that the decline will not prevent the long-term viability of the affected water supply works unless make good provisions apply.	As per above response

7.10.3 Existing environment

This section includes a description of the existing environment and was informed by the desktop investigations and field inspections carried out for the project. Additional existing environment details are documented in **Appendix N**.

Topography

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

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

- Rolling Hills Terrain
- Flat to Gently Undulating Terrain
- Creek Channels/Alluvial Floodplain Terrain.

Further information relating to topography within the study area is discussed in **Section 8.1**.

Geological setting

Based on review of the Penrith 1:100,000 geological map (Clarke and Jones, 1991) and completed project geotechnical borehole logs, the study area includes two surface geological units:

- Quaternary Alluvium (Qal and Qpn)
  - Located in the vicinity of the project's proposed crossing at Cosgroves, Badgerys, South and Kemps Creeks
  - Consists of fine to medium-grained sand, silt and clay

- Bringelly Shale bedrock (part of Rwb)
  - Underlies the rest of the operational footprint
  - Consists of shale, carbonaceous claystone, claystone, laminate, fine to medium-grained lithic sandstone, rare coal and tuff.

Project boreholes adjacent to the proposed crossing of Cosgroves, Badgerys, South and Kemps Creeks encountered silty sand, sandy clay, gravelly clay, silty clay, clayey silt, sandy silt, clayey sand and sandy gravel above the bedrock, which occurred at depths ranging from about 2.5 metres below ground level (BGL) to seven metres BGL. Therefore, the alluvium deposits are relatively thin.

Remaining project boreholes encountered siltstone, sandstone and interlaminated siltstone and sandstone at typical depths of about one metre BGL to five metres BGL. Based on project boreholes and regional experience, it is expected that where Bringelly Shale is present near the surface, ground conditions would comprise one metre to five metres of high plasticity, low permeability residual clays over highly weathered bedrock.

Based on a review of the 1:100,000 scale Soil Landscape Map for Penrith (Bannerman and Hazelton, 1990), the study area includes four soil landscapes as follows:

- South Creek soil landscape: fluvial deposits which are located along and adjacent to all four creek channels
- Blacktown soil landscape: residual soils located in the flat to gently undulating terrain between creek channels and adjacent floodplains
- Luddenham soil landscape: residual soils located on the low rolling hills at both ends of the project
- Picton soil landscape: residual and colluvial soils located at the eastern end of the project.

A small area is also mapped as Disturbed Terrain.

Further information relating to geology, soil landscapes, igneous intrusions, faulting and folding within the study area is discussed in **Section 8.1**.

Hydrogeological setting

Catchment description

The project would be located primarily within the Hawkesbury-Nepean surface water catchment, with a small portion of the project located within the Georges River catchment. The project would lie within the South Creek subcatchment in the Lower Nepean River Management Zone of the Hawkesbury-Nepean catchment. The South Creek subcatchment covers around 490 square kilometres and is one of the most degraded subcatchments of the Hawkesbury-Nepean. Catchment vegetation clearance and increasing urbanisation has dramatically altered the hydrological and sediment regimes.

The surface water hydrology of the subcatchment was significantly altered due to increasing impervious surfaces which has in turn altered the geomorphology and ecology of South Creek. Additional flow is also derived from a number of major sewerage treatment plants (STPs) which discharge into the catchment (HNCMA, 2007).

The surface water catchment and hydrology is described further in **Section 7.9.3**.

Key watercourses and geomorphology

The project would intersect Cosgroves Creek, Badgerys Creek, South Creek, Kemps Creek and Ropes Creek. These creeks drain into South Creek which then flows north to join the Hawkesbury River at Windsor. The far eastern extent of the project drains to Hinchinbrook Creek. There are also numerous farm dams in the area.

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

A summary of the watercourse geomorphology and stream order is provided in **Section 7.9.3**.

Groundwater systems

Based on project geological conditions, project groundwater investigations and registered groundwater bores, two main groundwater systems exist in the study area, Alluvial groundwater systems and Bringelly Shale groundwater system. The features of each are described below.

Alluvial groundwater systems are unconfined (not under pressure) to semi confined (partially pressurised) alluvial groundwater systems associated with Cosgroves Creek, Badgerys Creek, South Creek and Kemps Creek. Noting that Ropes Creek doesn’t have any mapped alluvial deposits. This groundwater system has the following features:

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

Bedrock groundwater systems are semi-confined groundwater systems within the bedrock (Wianamatta Group Shale and Hawkesbury Sandstone). This groundwater system has the following features:

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

The above groundwater systems are conceptualised in a cross section in **Figure 7-136**.

Registered groundwater bores

A review of the BOM Australian Groundwater Explorer identified 38 registered groundwater bores within the study area. Five of the 38 bores have a purpose relating to water supply (ie irrigation, stock and domestic, water supply or commercial/industrial) and based on reported bore depth, three of these five bores are inferred to be accessing Hawkesbury Sandstone groundwater systems. The closest of these five bores is located about 400 metres away from the construction footprint.

The location of registered bores within the study area is shown in **Figure 7-137**. None of the registered groundwater bores have any data on standing water level.

Further information on registered bores is provided in **Appendix N**.

Hydraulic conductivity

Based on hydraulic conductivity testing the following conclusions were made:

- The average and maximum hydraulic conductivity for bores screened in the Bringelly Shale was 0.002 metres per day and 0.005 metres per day respectively, which is within ranges cited in the literature reviewed for this assessment.
- The average and maximum hydraulic conductivity for bores which had some of the screen interval within alluvial material was 0.017 metres per day and 0.023 metres per day respectively. The alluvial hydraulic conductivity values are an order of magnitude higher than the those from the bores screened in the Bringelly Shale.

Groundwater levels

Ordinarily, in a non-project specific context, groundwater levels in shallow groundwater systems such as the alluvial and bedrock systems applicable to the project, typically correlate to rainfall. The extent and type of correlation typically depends on groundwater level response times to the rainfall. Typically, shallow alluvial and shallow weathered rock groundwater systems have relatively short response times to rainfall and these systems may respond to individual rainfall events. These systems may sometimes show obvious reductions in groundwater level after a year or so of below average rainfall. In contrast, intermediate to deep semi confined bedrock groundwater systems typically respond slower to rainfall and may still receive recharge or show stable groundwater levels for up to a few years following a pronounced period of sustained recharge.

During the groundwater monitoring period, groundwater levels were generally stable with some locations showing slightly declining trends. Groundwater level responses to individual rainfall events were negligible. The monitored water table depth in the area of the alluvial deposits ranged from about two metres BGL to five metres BGL whilst groundwater levels in the Bringelly Shale (including associated overlying residual clay) ranged from about one metre BGL to 19 metres BGL.

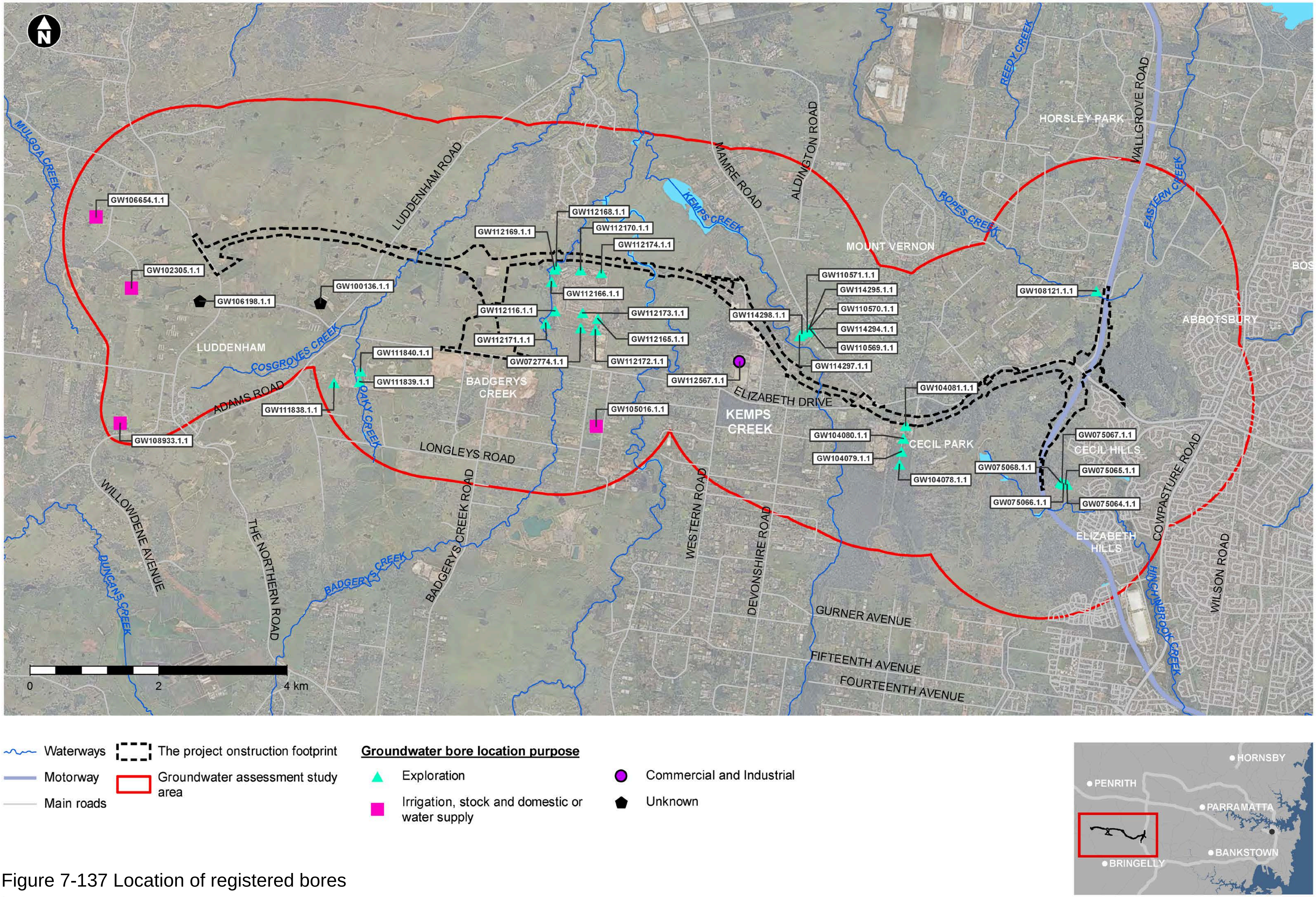

Figure 7-137 Location of registered bores

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Review of the BOM's annual rainfall statistics for the Badgerys Creek Observation Station indicated that the mean monthly rainfall for the study area ranges from 22.6 millimetres in July to 98.5 millimetres in February, with an average annual rainfall of about 681 millimetres (BOM 2018a). During the predominant groundwater level monitoring period (February to August 2018), the observed monthly rainfall at the Badgerys Creek Observation Station for each respective month was lower than the long-term monthly average values.

At a broader scale, rainfall at the Badgerys Creek Observation Station was generally below average from 1996 to the end of 2006, above average from 2007 to March 2017, below average from April 2017 to August 2018, above average from September 2018 to November 2018 and below average after November 2018. The period of above average rainfall from 2007 to March 2017 represents a pronounced recharge period, the end of which is relatively close to the project's groundwater level monitoring period.

Based on the generally stable monitored groundwater levels at project groundwater monitoring bores and lack of obvious groundwater level response to individual rainfall events, the project groundwater monitoring bores are considered to generally respond slowly to rainfall. Therefore, monitored groundwater levels, particularly in bedrock groundwater systems, whilst coinciding with below average rainfall, are expected to be influenced by the period of pronounced groundwater recharge from 2007 to March 2017. As a result, monitored groundwater levels during the project's monitoring period are considered likely to be similar to or above long-term average levels and not uncharacteristically low.

Further details on groundwater level monitoring are provided in **Appendix N**.

Groundwater quality

Based on the groundwater sampling results, the following key points were noted:

- Groundwater type is sodium chloride
- The Australian Drinking Water Guidelines (NHMRC, 2011) were exceeded for chloride, sodium and total dissolved solids
- Total dissolved solids ranged from 2650 milligrams per litre to 19,500 milligrams per litre, with an average value of 11,595 milligrams per litre. These values correspond to saline to highly saline water
- Average pH was 7.4 and ranged from 7.1 to 7.8, indicating slightly alkaline conditions.
- Further details on the groundwater quality data collected and the trigger and guideline values used in the assessment of potential groundwater quality impacts herein are provided in **Appendix N**.

Existing groundwater quality compared to assessment criteria

A summary of existing groundwater quality compared to the project's assessment criteria is provided below.

- The existing groundwater quality exceeds the adopted assessment criteria for a number of heavy metals and nutrients.
- Three out of four samples that were tested for total nitrogen (TN) exceeded the HRC water quality objective value of 0.7 milligrams per litre. The maximum tested value was 4.9 milligrams per litre
- Three of the four groundwater samples that were tested for total phosphorus were below the HRC water quality objective value of 0.035 milligrams per litre. The fourth sample had a value of <0.05, which was below the limit of laboratory reporting, but potentially marginally above HRC water quality objective value (0.035 milligrams per litre)
- The majority of project groundwater bores had copper and zinc concentrations which exceeded ANZECC Water Quality Guidelines for the protection of 95 per cent of freshwater species
- Three locations either exceeded or equalled the ANZECC Water Quality Guidelines for the protection of 95 per cent of freshwater species for nickel
- Three bores exceeded the ANZECC Water Quality Guidelines for the protection of 95 per cent of freshwater species for ammonia

- Three bores had total nitrogen values above the ANZECC Water Quality Guidelines for lowland rivers
- The ADWG (NHMRC, 2011) health criteria were exceeded for arsenic at two bores and for nickel at one bore
- Hydrocarbons, including polycyclic aromatic hydrocarbons and BTEXN concentrations were below the laboratory limit of reporting.

Groundwater contamination

The soils and contamination assessment carried out for the project (**Appendix O**) identified four moderate to high ranked areas of environmental interest (AEI), which could represent potential contamination sources:

- Former Kari and Ghossayn Pty Ltd Solid Waste Landfill
- SUEZ Kemps Creek Resource Recovery Park
- Stockpiles within Hi-quality Quarry
- Miscellaneous construction activities and stockpiles of building materials
- Area of significant fly tipped waste.

Additionally, the soils and contamination assessment (**Appendix O**) noted that historical and current potentially contaminating activities within the construction footprint include agricultural and rural land use, service stations, landfilling and waste recycling, quarries, potential areas of fill material, and industrial land use.

In relation to the heavy metals and nutrients that exceeded the adopted groundwater quality assessment criteria, the soils and contamination assessment carried out for the project (**Appendix O**) concluded that the exceedances may be associated with the widespread agricultural land use in the area, the SUEZ Kemps Creek Resource Recovery Park and potential areas of fill within the construction footprint, or alternatively represent background concentrations (discussed further in **Section 8.1.3**).

Further information relating to contamination risk of the study area and project is discussed in **Section 8.1**.

Sensitive receiving environments

Sensitive receiving environments relevant to groundwater quality and hydrology include the following:

- Cosgroves Creek
- Badgerys Creek
- South Creek
- Kemps Creek
- Hinchinbrook Creek
- Unnamed tributary of Hinchinbrook Creek
- Doujon Lake
- SEPP Coastal Wetlands (ID113, ID114, ID117)
- Hinchinbrook Creek at the downstream SEPP coastal wetland ID276.
- Potential aquatic and terrestrial GDEs (described below in the following section).

Groundwater dependent ecosystems

As discussed in **Section 7.1.3**, GDEs are communities of plants, animals and other organisms whose extent and life processes are dependent on groundwater, such as wetlands and vegetation on coastal sand dunes. GDEs might rely on groundwater for the maintenance of some or all of their ecological functions, and that dependence can be variable, ranging from partial and infrequent dependence (ie seasonal or episodic) to total continual dependence.

The BOM GDE Atlas (Australian Government BOM, 2018c) identified several areas within the study area that have a moderate to high potential to be dependent on groundwater including:

- South Creek – mapped as a high potential aquatic GDE
- In the region of the Cosgroves, Badgerys, South and Kemps Creek crossings – mapped as moderate to high potential terrestrial GDEs
- Several isolated areas away from the creeks – mapped as low to high potential terrestrial GDEs.

The potential terrestrial GDEs within the project's construction footprint were described as either Cumberland Shale Hills Woodland or Cumberland River Flat Forest.

High priority GDEs are GDEs which have a high conservation value (NSW DPI Office of Water, 2011). Appendix 2 of the Water Sharing Plan for the Greater Metropolitan Region Groundwater Sources 2011 (NSW Government, 2015b) indicated that no High Priority GDEs (karst and wetlands) are mapped within about 10 kilometres of the study area. The location of the GDEs are shown in **Figure 7-138**.

Salinity

Soil salinity is a complex issue relating to salt and water cycles both above and below the ground. When surface or groundwater dissolves, salts may be mobilised and can accumulate in other areas.

The Salinity Potential in Western Sydney 2002 Map (DLWC, 2002b) shows that the soils along the project construction footprint generally have a moderate salinity potential. Areas of moderate salinity potential are defined as where Wianamatta Group Shales or tertiary alluvial terraces are present.

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

The following areas were identified as having a high salinity potential:

- Areas of Cosgroves Creek
- Areas of low-lying land to the east and west of Cosgroves Creek
- Along Kemps Creek
- Small areas of known soil salinity along the project footprint to the east of Range Road.

Additional saline areas may be present which have not yet been identified or may occur if site conditions change adversely. Areas of current or potential soil salinity are expected along the construction footprint where there is alluvium, waterlogged ground or shallow groundwater.

Further information relating to salinity within the study area is discussed in **Section 8.1.3**. A soil salinity risk map is presented in **Figure 8-6**.

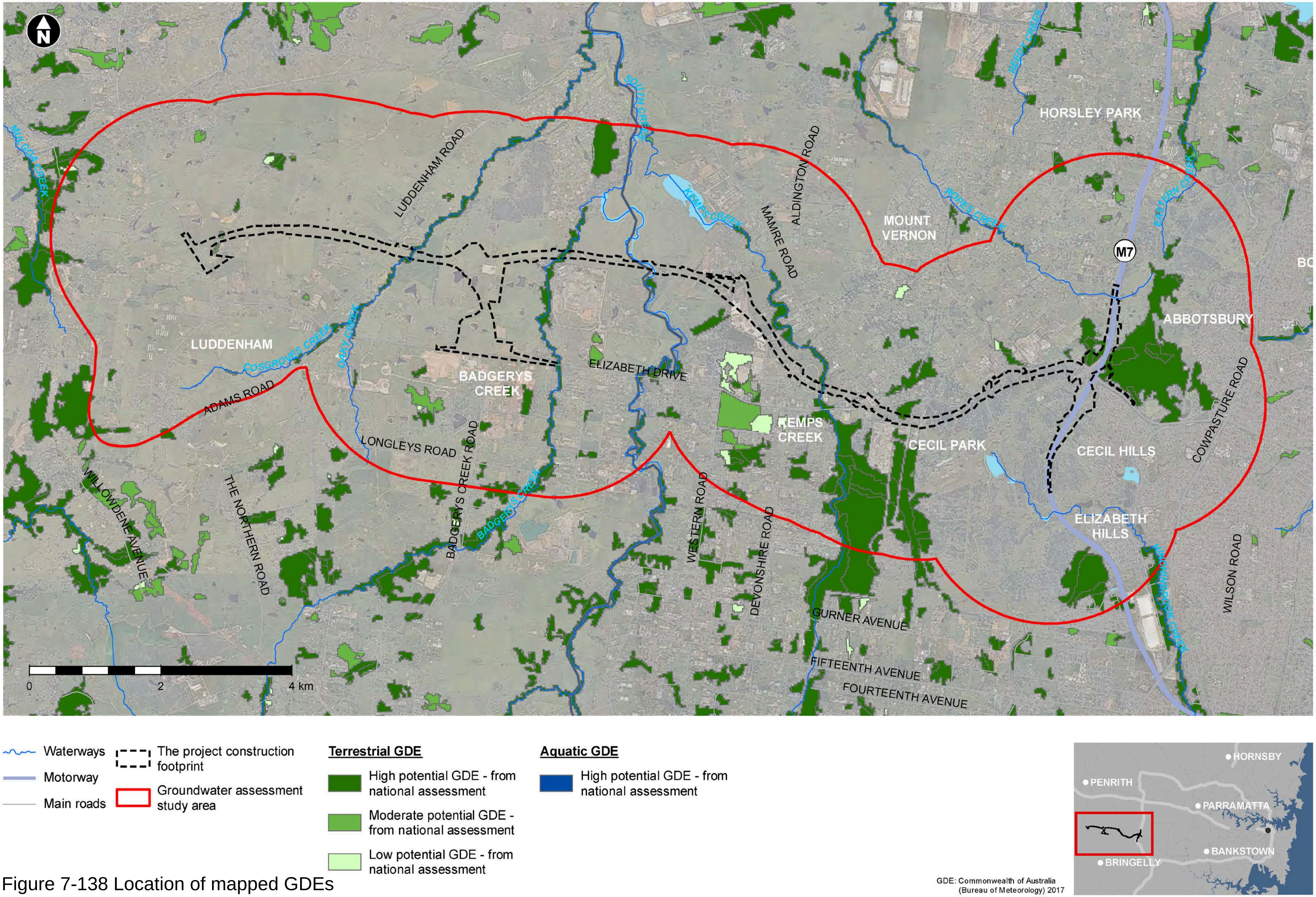

Figure 7-138 Location of mapped GDEs

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Cultural values

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

7.10.4 Assessment of potential impacts

Construction impacts

The potential impacts on groundwater quality and levels due to project construction is provided in the following sections.

Groundwater inflows into road cuttings

Based on a review of maximum monitored groundwater levels relative to the project's road design levels, only one area of road cutting is likely to intersect the water table. The area of road cutting is located about 1.5 kilometres east of The Northern Road and is hereafter referred to as the western cut (see **Figure 7-139**). The western cut base would be about 1.61 metres below the groundwater level.

The western cut is a focus of the assessment because data indicates this cut would likely intersect the water table. As shown by **Figure 7-136**, there are areas where the inferred groundwater level is relatively close to the project's road design level, including between South Creek and Kemps Creek and between Cosgroves Creek and Badgerys Creek. However, based on the average minimum depth to groundwater (about 13.9 metres), the type of activities in certain locations (ie filling) or the projects road design in these locations, the water table is unlikely to be intercepted in these locations.

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

Groundwater inflow rates into the western cut were calculated to be very low to negligible, and in many modelled scenarios below expected evaporation rates. Despite this, the assessment (see **Appendix N**) has considered the potential for cut de-watering and subsequent minor discharges during construction.

The implications of potentially discharging groundwater collected by the western cut is discussed in the groundwater quality section below.

Groundwater levels

Construction of the project has the potential to alter groundwater levels as follows:

- Drainage of the western cut has the potential to lower groundwater levels in the general area of the cut
- Bridge piling, if below the water table, may increase groundwater levels up-gradient of piles, and decrease groundwater levels down-gradient of piles. The cause of this is groundwater flow obstruction.
- Fill placement and the resulting increase in effective stress may cause short-term increases to groundwater levels in areas of fill placement, and/or permanent increases to groundwater levels if the increased stress permanently decreases the hydraulic conductivity of the underlying water-bearing ground.

The activity considered most likely to result in the largest change to background groundwater levels is drainage of the western cut.

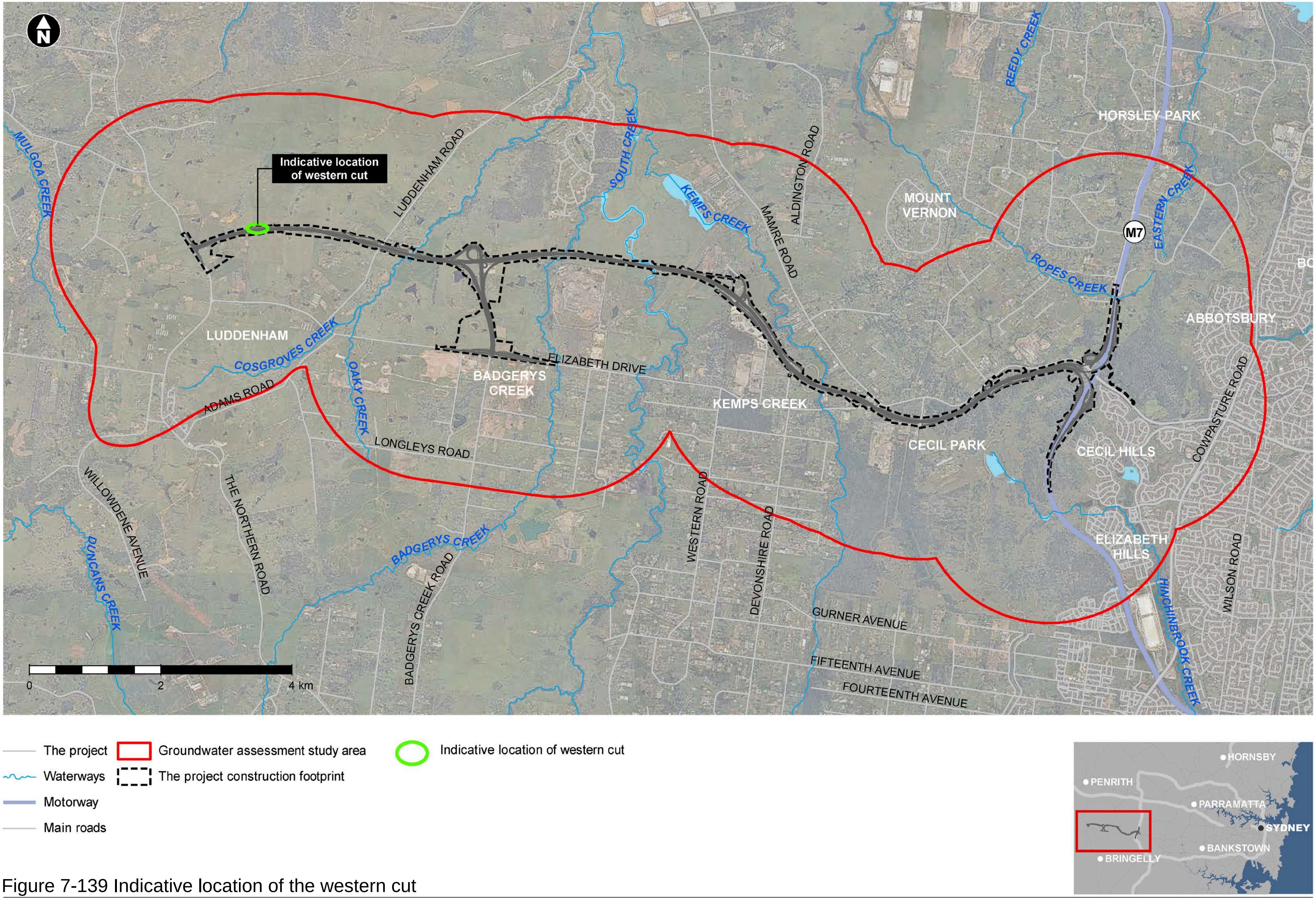

Figure 7-139 Indicative location of the western cut

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If no long-term seepage face is assumed (ie water levels are drawn down to level of road), the maximum potential change to groundwater level in the area of the western cut is estimated to be a decrease of up to about 1.61 metres. This maximum change, if it eventuated, would occur at the base of the cut. Moving away from the cut, the magnitude of the change in groundwater level would reduce until groundwater levels were no longer being influenced by the cut.

Based on regional experience, the maximum drawdown at the western cut of 1.61 metres is considered within the bounds of natural variability that would occur in response to changing long-term climate conditions. This maximum change is also less than the NSW Aquifer Interference Policy (NSW DPI Office of Water, 2012a) minimal impact consideration for water table or pressure level decline at existing groundwater bores.

The extent of the groundwater level reduction or 'radius of influence' associated with drainage of the western cut was estimated to extend about 60 metres from the base of the cut. While the extent of potential groundwater level reduction at the western cut is 60 metres, the minimum distance from the western cut to existing groundwater bores with a purpose of water supply, mapped GDEs and alluvial groundwater systems is about 1.9 kilometres, 240 metres and two kilometres respectively. Therefore, potential groundwater level reductions due to drainage of the western cut are not expected to impact on water supply bores, mapped GDEs or alluvial groundwater systems.

Potential groundwater level changes due to bridge piling are assessed to be localised to the vicinity of piles and unlikely to cause impacts on surface water-groundwater interactions. This is because piled footings would readily accommodate local groundwater flow diversion around the pile.

Potential groundwater level increases may occur due to surcharge loading associated with fill placement and the resulting increase in effective stress, and/or permanent decreases to the hydraulic conductivity of the underlying water-bearing ground.

Potential construction impacts associated with groundwater level/pressure changes were compared to the minimal impact considerations outlined in the NSW AIP (see **Section 7.10.2**). Based on the considerations, project construction impacts relating to groundwater level/ pressure are considered acceptable.

Overall, during construction the project would have a minor and acceptable impact on groundwater levels.

Groundwater quality

There is minimal potential for groundwater quality to be impacted by the project during construction, or for groundwater quality to cause impacts.

Groundwater quality may be impacted during the construction phase, or cause impacts, due to:

- Accidental spills or leakages of hazardous materials (such as fuels, lubricants and hydraulic oils) due to runoff and subsequent recharge
- Recharge from water within the project stormwater basins, if the chemistry of the stormwater basin water is different from that of the background recharge water quality
- Construction works that may mobilise contaminants (if present). This could occur due to locally altered flow directions due to drainage of the western cut, or due to bridge piling excavations, which may increase the vertical connectivity between local groundwater systems
- Western cut groundwater inflows being discharged to surface waters and impacting water quality
- Western cut groundwater inflows coming into contact with workers and impacting human health.

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

General construction activities such as accidental spills or leakages of hazardous materials (such as fuels, lubricants and hydraulic oils) have the potential to result in groundwater contamination (ie through runoff and subsequent recharge). Potential impacts from accidental spills or leaks would be mitigated by measures identified in **Section 7.10.6**, including a CEMP. With the implementation of management measures, impacts on groundwater quality associated with general construction activities are not anticipated.

Recharge from project stormwater basin water, if the chemistry of the stormwater basin water is different from that of the background recharge water quality. During construction, the chemistry of stormwater basin water is not anticipated to be materially different from that of the background recharge water quality. Therefore, impacts on groundwater quality associated with recharge from stormwater basins are not anticipated.

Bridge piling excavations may increase the vertical connectivity between local groundwater systems and therefore mobilise contaminants (if present). Bridge piling is not anticipated to mobilise potential contaminants beyond the local vicinity of the pile because potential changes to groundwater levels are anticipated to be negligible, and because the pile bore would only be open temporarily before being filled with concrete. Therefore, impacts on groundwater quality associated with bridge piling excavations are not anticipated.

Western cut groundwater inflows and subsequent discharge to surface waters could cause impacts on surface water quality if the discharge water quality is poor. Similarly, if contaminated, if workers come into contact with the discharge water, human health could be impacted. Groundwater quality data from the bore (BH104) near the western cut does not indicate a risk to human health for any of the tested parameters (ie arsenic, cadmium, chromium, copper, lead, magnesium, mercury, nickel, zinc and nutrients) and is not anticipated to impact sensitive receiving environments. The volumes of groundwater drained and discharged from the western cut are estimated to be negligible, with substantial proportions of the discharge expected to evaporate.

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

To mitigate the low risk of workers coming into contact with contaminated pile spoil, the pile spoil (soil/rock and groundwater) could be managed as one entity and undergo waste classification in accordance with NSW EPA (2014a) before determining whether the material would be reused onsite or disposed offsite. The pile spoil is to be managed as one entity because the extracted groundwater volumes would be very low and impractical to separate from soil/rock.

Potential construction impacts associated with groundwater quality changes were compared with the minimal impact considerations outlined in the NSW AIP (see **Table 7-146**). Based on the minimal impact considerations, construction impacts relating to groundwater quality are considered acceptable.

Overall, construction of the project is not anticipated to lower the beneficial use category of the groundwater.

Table 7-146 Minimal impact considerations (groundwater quality)

Minimal impact considerations		Project response
Water quality	1. Any change in the groundwater quality should not lower the beneficial use category of the groundwater source beyond 40 metres from the activity.	The project is not anticipated to result in a change in groundwater quality which would lower the beneficial use category.
	2. If condition 1 is not met, then appropriate studies will need to demonstrate to the Minister's satisfaction that the change in groundwater quality will not prevent the long-term viability of the dependent ecosystem, significant site or affected water supply works.	Not applicable - refer to above response

Salinity

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

- The project construction footprint currently generally comprises grassland with extremely limited deep rooted vegetation. Therefore, evapotranspiration rates will not decrease due to removal of deep rooted vegetation during construction.
- The construction footprint is generally compromised of low permeability material which has limited infiltration potential. Therefore, when exposed, and particularly after inadvertent and intentional compaction, increased infiltration is not anticipated.
- Low lying areas, which based on mapping (**Section 7.10.3**) are likely to be relatively saline, will generally be filled with low permeability material, limiting infiltration potential in these areas.
- Dust suppression water applied during construction would have low salinity and would be applied at rates which would not cause the water table to rise.

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

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

Groundwater use and water balance

Groundwater is not proposed to be used to meet construction water demands associated with dust suppression, earthworks compaction, wheel washing, machinery, concrete/asphalt batching plants, curing structures and onsite amenities. Potable water supplies or water from sediment basins would be used during construction to meet these demands.

Due to negligible project groundwater extraction volumes, the water balance required by the SEARs principally relates to surface water and is summarised in **Section 7.9.4** and provided in full in **Appendix M**.

Operational impacts

An assessment of potential impacts on groundwater quality and levels due to operation of the project is provided in the following sections.

Groundwater levels

Operational impacts on groundwater levels are not expected to differ from those which are likely to occur during construction of the project.

Groundwater quality

With the exception of recharge from project stormwater basin water, operational impacts on groundwater quality are not expected to differ from those which are likely to occur due to construction impacts.

During operation, groundwater quality may be altered locally near stormwater basins. This may occur due to seepage of water from stormwater basins into the groundwater which may have a different chemistry to the chemistry of the existing groundwater chemistry. If runoff from the road contains heavy metals, oil, grease or hydrocarbons from road use and/or accidental spills, the runoff would flow to stormwater basins and a small proportion may seep into the water table.

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

The risk of contaminants entering surface water would be mitigated by measures identified in **Section 7.9.6**, which include spill and leakage management measures and measures relating to stormwater design and water quality monitoring. With the implementation of these management measures, these potential impacts on groundwater quality during project operation are expected to be negligible.

Potential discharge of groundwater from the western cut during operation would have a negligible impact on sensitive receiving environments.

Groundwater dependent ecosystems

The nearest mapped GDE to the western cut is about 240 metres away, which is outside the calculated extent of groundwater level reduction (about 60 metres). Therefore, there would not be impacts on mapped GDEs as a result of potential cut de-watering and associated groundwater level changes.

Salinity

As a result of negligible impacts on groundwater level or quality during operation, salinity impacts during project operation are not expected.

Utilities

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

7.10.5 Cumulative impacts

Cumulative groundwater impacts may arise from the interaction of construction and operation activities of the project and other approved or proposed projects in the area. When considered in isolation, specific project impacts may be considered minor. These minor impacts may be more substantial, however, when the impact of multiple projects on the same receivers is considered.

Numerous projects in varying stages of delivery and planning are currently underway near the M12 Motorway corridor. These projects are relevant to the consideration of cumulative groundwater impacts both temporally and spatially as they would be in the same groundwater system and construction and/or operation may have overlapping timeframes, as discussed further below. The cumulative groundwater impacts associated with these projects are considered in **Table 7-147** and outlined in further detail in **Appendix N**. Additional details of each of the projects considered is provided in **Table 7-3**.

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

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

Table 7-147 Cumulative groundwater impacts

Project and status	Cumulative impacts
Western Sydney Airport Approved. Under construction	The Western Sydney Airport EIS groundwater assessment (GHD, 2016b) concluded that: • Impacts on surrounding bores are expected to be negligible • Impacts on artificial wetlands within the airport site are expected to be negligible • Drawdown impacts in areas of sensitive vegetation are expected to be minor • Drawdown associated with cuttings or building basements is expected to be very localised • Overall reliance on groundwater discharge by creeks is low and changes to groundwater discharge would have minor impacts • The underlying aquifer system is of low beneficial use There is a low risk of the project impacting water quality at surrounding surface water features and sensitive groundwater-reliant vegetation, and in areas of groundwater infiltration. The Western Sydney Airport EIS groundwater assessment (GHD, 2016b) indicated similar risks to groundwater are applicable during operation and construction. The precise magnitude of the cumulative impacts from the project and the Western Sydney Airport is not able to be determined as the specific level and extent of drawdown impacts from the Western Sydney Airport are subject to detailed design and further modelling. However, Western Sydney Airport EIS groundwater assessment (GHD, 2016b) concludes that it is likely to have minor drawdown impacts.
Sydney Metro Greater West Not yet approved	Construction of the Sydney Metro Greater West is likely to mean there would be both concurrent and consecutive activities with the construction of the M12 Motorway project. During timeframes where construction activities are concurrent, increased groundwater impacts may be possible. The magnitude of cumulative construction impacts would be dependent on the specific construction locations, activities and impacts which are yet to be determined for the Sydney Metro Greater West.
The Northern Road upgrade Approved. Construction has begun	Stages 1 through 4 of The Northern Road upgrade would be completed by the time construction of the project begins. Based on the existing EIS documentation for The Northern Road there is no expected drawdown to the regional shallow unconfined water table and no expected impact on groundwater users including water supply users, GDEs, riparian areas or wetlands during construction of the project (Roads and Maritime, 2017a). The construction for Stage 5 has begun and is scheduled for completion end of 2022. The construction for Stage 6 is scheduled for mid-2019 to end of 2021. Construction activities associated with Stage 5 and 6 may overlap with the project construction.

Project and status	Cumulative impacts
Other existing road network upgrades and potential road projects, including: • Elizabeth Drive upgrade • Mamre Road upgrade • Outer Sydney Orbital Not yet approved	The timing for construction of other road projects has not yet been announced. However, there is potential for overlaps in construction timing between the project and surrounding projects in the vicinity of the project. Based on current practice with 'design' of major roads, it would be expected that these projects are likely to generate similar impacts on that of the M12 Motorway– ie being localised and not expected to generate significant quality impacts beyond their respective footprints. Therefore, cumulative impacts are anticipated to be negligible.
Major land releases, including: • Western Sydney Aerotropolis • South West Growth Area • Western Sydney Employment Area Future strategic government project	The timing for construction for surrounding urban development (growth areas) has not yet been announced. However, there is potential for overlaps in construction timing between the project and surrounding projects in the vicinity of the project. Urban and commercial development may impact on groundwater quality and levels. However, such impacts are anticipated to be minor based on the nature of the development and would be part of the analysis of constraints carried out as part of strategic planning. The constraints analysis would also take into account major infrastructure such as the airport and road rail projects. If cumulative impacts on groundwater occurred, these impacts are anticipated to be minor and have limited consequences given the low value of the upper groundwater systems.

7.10.6 Environmental management measures

Groundwater monitoring program

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

The monitoring program will include collection of baseline data for comparison to construction and operational monitoring data to understand, and respond to, any impacts from the project. The requirements during each stage of the monitoring program (baseline, construction, operational) are outlined below including the frequency, location and indicators.

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

The groundwater quality indicators to be monitored are common to all stages of the monitoring program

Baseline data collection

Groundwater level monitoring by data logger is currently being carried out and will continue to be collected quarterly at 28 of the existing project groundwater monitoring bores until the start of construction, with the exception of BH301 and BH302 (primarily installed to monitor gas) and BH129 (where land access couldn't be granted). Manual groundwater level monitoring by dip meter will also be carried out concurrently with the data logger downloading.

Baseline groundwater level data and groundwater quality sampling will be carried out at a monthly interval for at least 12 months at BH145, BH104, BH107 and BH112 before the start of construction. These locations were chosen because they represent areas of relatively substantial road cuttings and therefore there is a relatively higher potential for groundwater interception by the operational footprint in these areas.

Groundwater quality monitoring indicators for the baseline monitoring period are listed in the 'Groundwater monitoring indicators' section below. The baseline data collected to date is summarised in **Section 7.10.3** and detailed in **Appendix N**.

The specific timing for the conclusion of the baseline monitoring period at each bore will vary. The baseline monitoring period for each bore will end when construction activities are within 200 metres of that bore. This distance is considered conservative and suitable to ensure data collected to inform baseline conditions is representative. The location of the project groundwater bores that would be used for baseline data collection are presented in **Figure 7-140**.

Construction phase groundwater monitoring

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

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

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

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

Operational phase groundwater monitoring

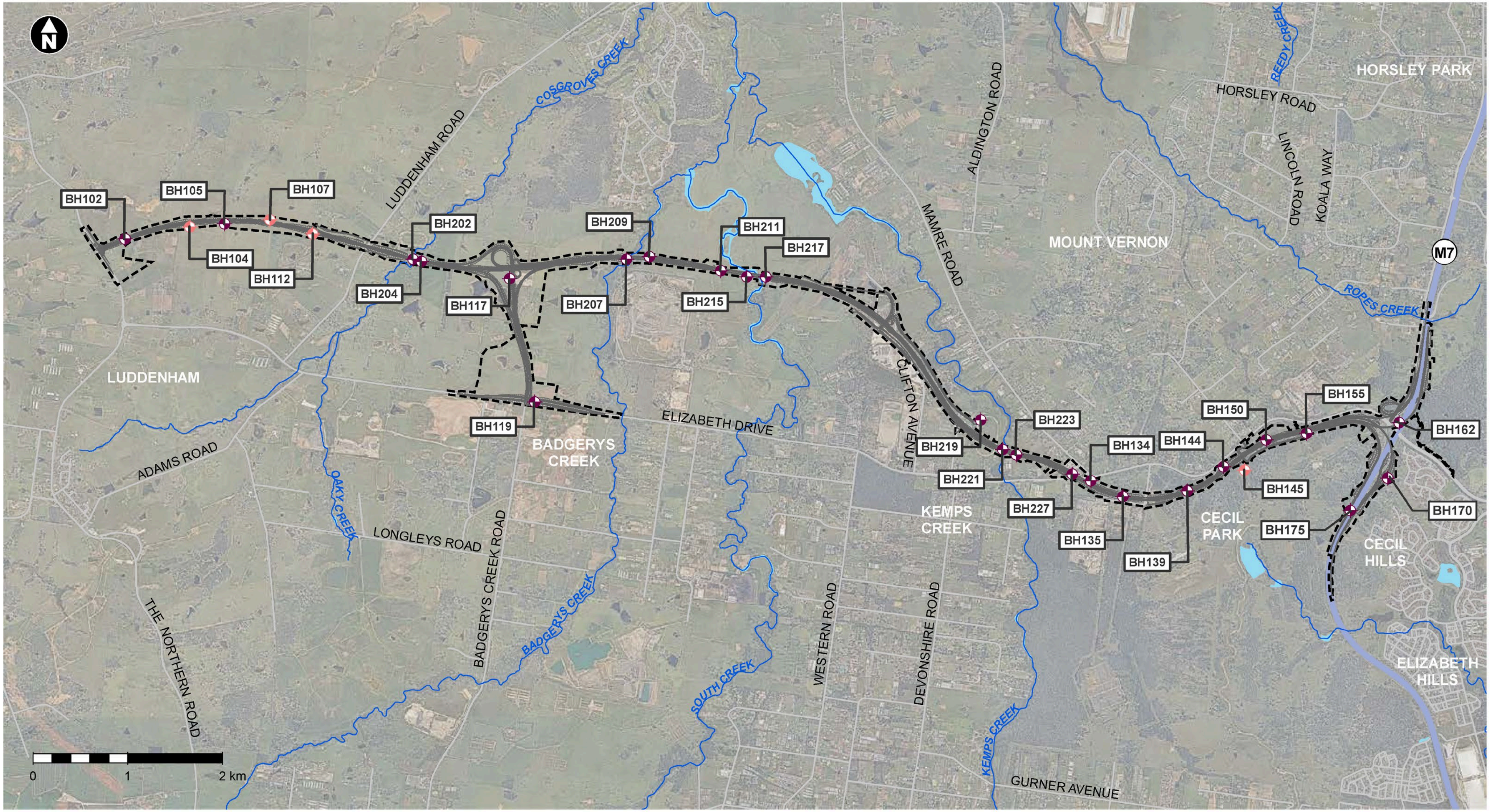
Groundwater monitoring will continue for at least the first six months of operation to verify that operational impacts on groundwater are not occurring, or alternatively, inform appropriate mitigation measures. The operational phase groundwater level monitoring will be carried out at the bores that will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

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

Groundwater monitoring indicators

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

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



The project
The project construction footprint
Waterways
Motorway
Main roads
Groundwater quality sampling and level monitoring (monitored monthly)
Groundwater level bores (monitored quarterly)

Figure 7-140 Location of the project groundwater bores to be used for future baseline data collection

Date: 1/07/2019 Path: J:\IE\Projects\04_Eastern\IA145100\08 Spatial\GIS\Directory\Templates\MXDs\Figures\EIS\Chapters\SpecialistReportChapters\JAJV_EIS_GW_F015_GroundwaterBaselineMonitoring_r2v1.mxd
Created by : HK | QA by : AA

The environmental management measures that would be implemented to minimise groundwater quality and hydrology impacts of the project, along with the responsibility and timing for those measures, are presented in **Table 7-148**. These measures would be complemented by the environmental management measures outlined in **Section 7.9.6** and **Section 8.1.6**. The environmental management measures include a groundwater monitoring program which would include collection of baseline groundwater data and groundwater monitoring during both construction and operation of the project as outlined below in the following section.

Table 7-148 Environmental management measures (groundwater quality and hydrology)

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