7.8 Hydrogeology and soils

This section provides an assessment of hydrogeology and soil impacts of the project, including details of the existing topography, geology, soils, hydrogeology, groundwater and contamination within the project area. Construction and operational impacts associated with acid sulfate soils, groundwater inflow and drawdown, contamination, ground movement and tunnel washing are assessed, and relevant mitigation measures are identified. The impacts associated with the discharge of treated groundwater are detailed in **Section 7.9** (Surface water).

The assessment has been informed by geotechnical, groundwater and contamination investigations undertaken specifically for the project.

Table 7-164 sets out the Director-General's Requirements as they relate to hydrogeology and soils, and where in the environmental impact statement these have been addressed.

Table 7-164 Director-General's Requirements – hydrogeology and soils

Director-General's Requirement	Where addressed
Soil and Water – including but not limited to:	
An assessment of construction and operational erosion and sediment and water quality impacts, taking into account impacts from both accidents and runoff (i.e. acute and chronic impacts), having consideration to impacts to surface water runoff, soil erosion and sediment transport, mass movement, and urban and regional salinity. The assessment of water quality impacts is to have reference to relevant public health and environmental water quality criteria, including those specified in the *Australian and New Zealand Guidelines for Fresh and Marine Water Quality* (ANZECC/ARMCANZ 2000), and any applicable regional, local or site-specific guidelines.	Construction and operational ground water quality impacts are addressed in **Section 7.8.3**. Surface water impacts, including erosion and sedimentation, are addressed in **Section 7.9** (Surface water).
Groundwater impacts as a result of the project (including ancillary facilities such as the tunnel control centre and any deluge systems), considering local impacts along the length of the tunnels and impacts on local and regional hydrology. The assessment must consider: extent of drawdown; impacts to groundwater quality; discharge requirements; location and details of groundwater management and implications for groundwater-dependent surface flows, groundwater-dependent ecological communities, and groundwater users. The assessment should be prepared having consideration to the requirements of the NSW Aquifer Interference Policy.	Groundwater impacts are assessed in **Section 7.8.3**. Details regarding the treatment and discharge of tunnel groundwater, a depiction of the overall water management strategy for the project, and an assessment of the hydrological changes from the loss of surface water flows are provided in **Section 7.9** (Surface water). The implications for groundwater dependent ecological communities are assessed in **Section 7.6** (Biodiversity).
A Spoil Management Strategy detailing how spoil will be managed during construction, including likely volumes, likely nature and classification of excavated material, opportunities for recycling, potential disposal sites, stockpile management, and method of transportation.	A Spoil Management Strategy is provided in **Section 8.3** (Resource management and waste minimisation).

7.8.1 Assessment methodology

The methodology for the hydrogeology and soils assessment involved

- A review of existing information to obtain an understanding of existing geotechnical conditions, including existing geological and geotechnical data from the Hills M2 Motorway Upgrade project, North West Rail Link, and the Northern Sydney Freight Corridor Epping to Thornleigh Third Track projects.
- Geotechnical investigations, to inform the design and construct tender process, which identified ground conditions for tunnelling and groundwater conditions across the project corridor. These investigations included (but were not limited to) core drilling, piezometers, seismic data collection, and laboratory testing of soil and rock samples. The scope for geotechnical investigations for the project included consideration of existing information where relevant in lieu of establishing new boreholes.

The results of the geotechnical investigations have been presented in a two-part Geotechnical Factual Report (AECOM, 2013c and AECOM, 2013d). This report presented project-specific site investigation information including field records and laboratory testing. A Groundwater Monitoring Report has also been prepared on the basis of measurements and observations initiated during the investigative fieldwork. This report included measurements of groundwater levels, and results of groundwater quality testing. Reference has been made to these reports in identifying potential geotechnical, groundwater, soil and fill issues, as well as mitigation and management measures for the construction and operation phases of the project.

A Contamination Due Diligence Assessment has been undertaken to cover the full extent of the project corridor for the purpose of informing the environmental impact statement. This assessment included a review of background and historical information, site inspections, and sampling.

Additional information sources used to inform the hydrogeology and soils assessment include:

- NSW Office of Environment and Heritage (OEH) online database for notices under the *Contaminated Land Management Act 1997* and the *Environmentally Hazardous Chemicals Act 1985*.
- Soil landscape unit mapping completed for the former Department of Conservation and Land Management (DCLM).
- Erosion and Sedimentation Management Procedure (RTA, 2008a).
- Acid sulfate soil risk maps prepared by the former Department of Land and Water Conservation (DLWC, 1997).
- Managing Urban Stormwater – Soils and Construction, Volume 1, 4th edition (Landcom, 2004) (Blue Book 1).
- Managing Urban Stormwater – Soils and Construction, Volume 2D, Main Road Construction (DECC, 2008) (Blue Book 2).

7.8.2 Existing environment

Topography

The project corridor generally follows the alignment of Pennant Hills Road which is situated along a ridge line running roughly in a north-east to south-west direction. The ridge line forms the boundary of several local drainage catchments, with steep-sided valleys present on either side of Pennant Hills Road.

The terrain along the project corridor rises from an elevation of around 144 metres Australian Height Datum (AHD) at the southern interchange to an elevation of around 180 metres AHD at the northern interchange. A number of elevated peaks occur along the project corridor, with terrain generally falling to the south-east and to the north-west away from the Pennant Hills Road ridge line.

Geology

The project is situated in the north-west of the Sydney Basin. The geology along the project corridor, as described in the Geology of the Sydney 1:100,000 Sheet 9131 (NSW Department of Mineral Resources, 1983) and confirmed by the project-specific site investigations undertaken in November 2013, is dominated by the Wianamatta Group and the underlying Hawkesbury Sandstone Formation. These two main geological units are separated intermittently by the Mittagong Formation.

The Wianamatta Group geological unit comprises Ashfield Shale, which corresponds to the existing ridge line and is present along the majority of the project corridor. The Ashfield Shale layer ranges in thickness up to a maximum of about 60 metres to 70 metres and consists of siltstone and laminate subgroup units.

Hawkesbury Sandstone is present along the alignment at depth, with outcropping occurring within the steep sided valleys either side of the project corridor. The Hawkesbury Sandstone is a medium to coarse grained quartz sandstone deposited in beds one metre to three metres thick. Shale breccia is common at the contacts between beds, and siltstone interbeds form a minor part of the unit.

The Mittagong Formation separates the Ashfield Shale from the underlying Hawkesbury Sandstone. The formation represents the transition from the fluvial or terrestrial environment of the Hawkesbury Sandstone deposition to the marine delta deposition of the Ashfield Shale, with boundaries often not clearly distinguishable. The Mittagong Formation comprises an upper, thin very fine grained brown sandstone unit (typically 0.5 metres to 1.5 metres thick) over a lower unit of fine grained sandstone and siltstone (typically one metre to three metres thick, but can be up to ten metres thick).

Igneous dykes and breccia diatremes (volcanic vents filled with breccia, formed by subterranean explosions) of Jurassic Age are sparsely distributed throughout the Sydney Region. The Geology of the Sydney 1:100,000 Sheet 9131 (NSW Department of Mineral Resources, 1983) indicates the presence of 25 diatremes and over 100 dykes. The dykes are understood to range in age from about 50 to 170 million years and pre-date many of the major faults within the Sydney Basin. A possible breccia diatreme was identified during the site investigation in the vicinity of Pennant Hills Railway Station, and may be encountered during tunnelling works.

Previous experience in tunnelling through the formations of the Sydney Basin suggests that igneous dykes should be anticipated during excavation of the tunnels. The Geology of the Sydney 1:100,000 Sheet 9131 (NSW Department of Mineral Resources, 1983) indicates that a dyke crosses the alignment, and is expected to be encountered during tunnelling works, about 100 metres to 200 metres south of Thornleigh Railway Station, extending north-west within a drainage line. The dykes within the Sydney region generally consist of linear basaltic rock bodies intruded into the surrounding country rock. The dykes are typically extremely weathered and altered to white kaolintic clay to a depth of some ten to 20 metres below ground level. **Figure 7-74** shows the proposed alignment in the regional geology context.

The geology of the area was influential in determining the tunnel vertical alignment. Hawkesbury Sandstone is considered an excellent tunnelling and excavation medium and as a result, the tunnel has been designed to maximise the length of tunnel within Hawkesbury Sandstone.

A detailed geological long section showing subsurface and geological structures in relation to the vertical alignment of the tunnel is provided in **Appendix C**.

Soils

The soil landscapes and characteristics have been determined based on the Soil Landscapes of the Sydney 1:100,000 Sheet 9130 (Chapman, G.A. and Murphy, C.L., 1989).

This mapping indicates that the project corridor is underlain by three categories of soil landscape (residual, colluvial, and erosional), as defined by the former Department of Land and Water Conservation, including:

- Residual (Lucas Heights).
- Colluvial (Hawkesbury and West Pennant Hills).
- Erosional (Glenorie and Gymea).

Within these three categories, five soil landscape units are present in the study area and are described in **Table 7-165** and shown in **Figure 7-63**.

The Glenorie soil landscape covers the majority of the corridor, with minor areas of the West Pennant Hills, Gymea, Lucas Heights and Hawkesbury soil landscapes. Relevant characteristics of each soil landscape are described in **Table 7-165**.

Table 7-165 Soil landscapes

Soil landscape	Characteristics
Glenorie	• Occurs on undulating to rolling hills on Wianamatta Group Shales. • High soil erosion hazard.
West Pennant Hills	• Occurs on rolling to steep sideslopes on Wianamatta Group Shales. • High soil erosion and mass movement hazard.
Gymea	• Occurs on undulating to rolling rises and low hills on Hawkesbury Sandstone. • Localised steep slopes. • High soil erosion hazard.
Lucas Heights	• Occurs on gently undulating crests and ridges on the Mittagong Formation. • Generally a moderate erosion hazard but can range from slight to extreme.
Hawkesbury	• Occurs on rugged, rolling to very steep hills on Hawkesbury Sandstone. • Extreme soil erosion and mass movement (rock fall) hazard.

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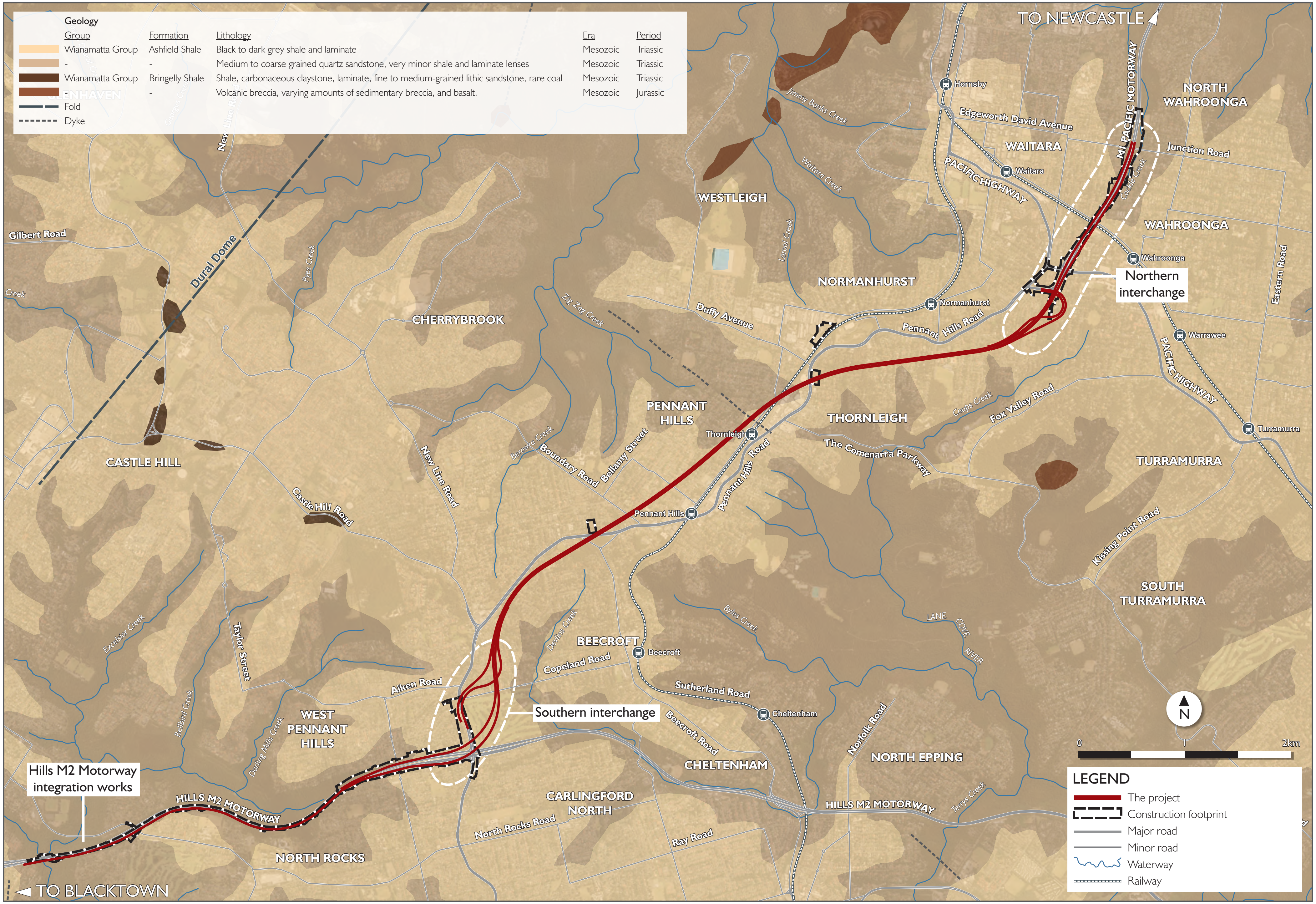

Figure 7-74 Regional geological context

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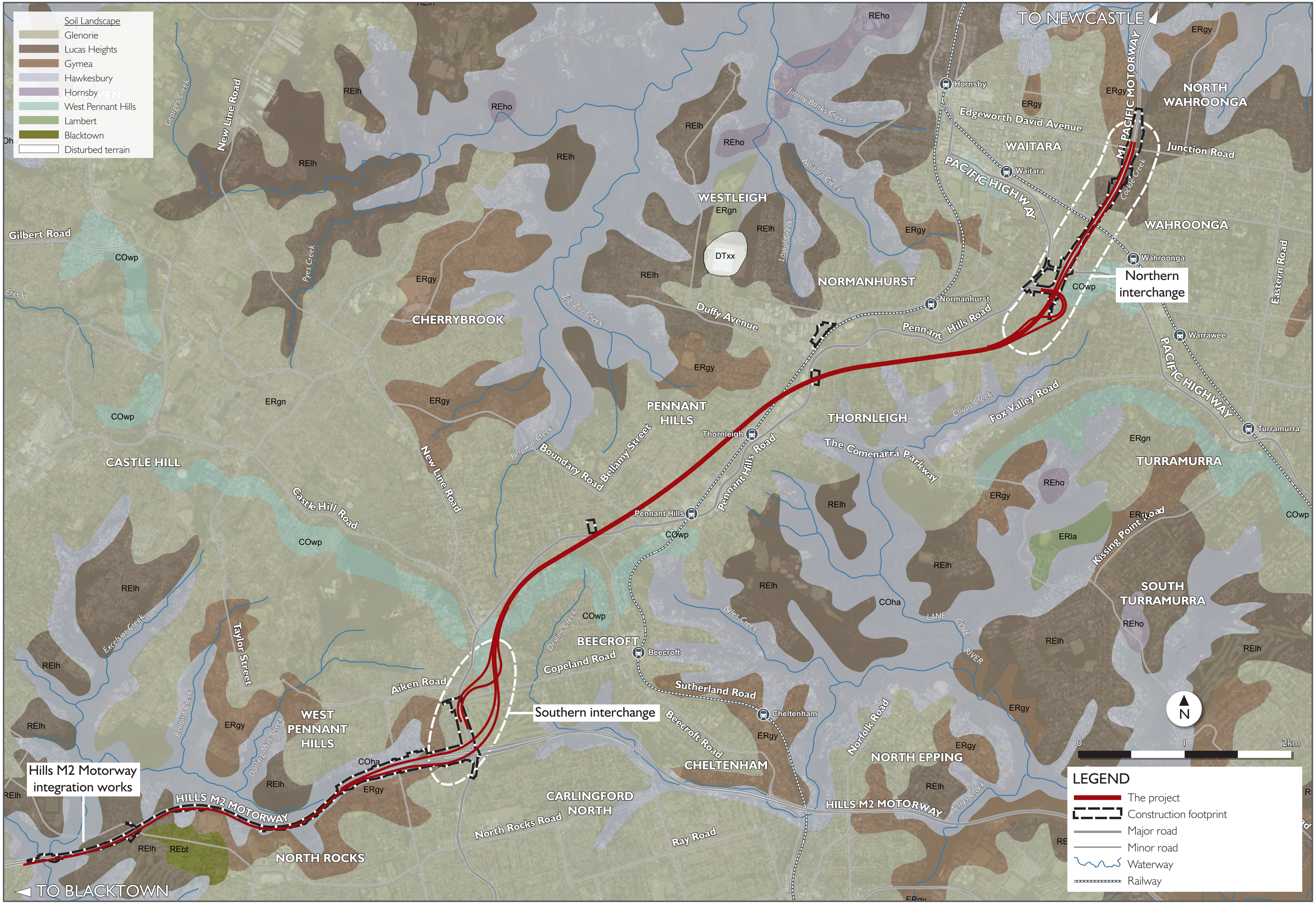

Figure 7-75 Soil landscapes

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Acid sulfate soils

Acid sulfate soils and potential acid sulfate soils are naturally occurring soils that contain iron sulfides which, on exposure to air, oxidise and create sulfuric acid. This increase in acidity can result in the mobilisation of aluminium, iron and manganese from the soils. Other impacts include the de-oxygenation of water.

Acid sulfate soils are not expected to occur within areas likely to be affected by the project, with a search of the Australian Soils Resource Information System (ASRIS) indicating there is a low probability of occurrence across the project (ASRIS, 2013). Further, the project area is not mapped on NSW Office of Environment and Heritage Acid Sulfate Soil Risk Maps for coastal NSW.

Hydrogeology

Three principal aquifers occur in the region being an alluvial aquifer, a shale aquifer (associated with the Ashfield Shale) and a sandstone aquifer (associated with the Hawkesbury Sandstone). The alluvial aquifer occurs locally around watercourses and generally exhibits good water quality and high flows. Due to the location of the project corridor along a ridge line, the alluvial aquifer is unlikely to be encountered.

The aquifer associated with the Ashfield Shale is a fractured rock aquifer, possessing low hydraulic conductivity (ie low water flow) with water flows along the laminate (bedding layers within rock) as well as obliquely along fractures (joints or faults in the rock). The shale aquifer has little groundwater flowing into it and also creates a partial barrier to groundwater flowing into the underlying sandstone aquifer. Due to its deposition in a marine environment, the Ashfield Shale tends to contain groundwater that is generally of higher salinity than that of Hawkesbury Sandstone. Saline groundwater may also have permeated into groundwater bodies within the sandstone in places. The quality of groundwater in the shale of the Wianamatta Group tends to be inferior to groundwater in sandstone in this part of the Sydney Basin, as detailed in the groundwater quality section below.

The Hawkesbury Sandstone is a formation of horizontally bedded sandstone, with variable hydraulic conductivity, which hosts a generally confined fractured rock aquifer (ie groundwater stored in the fractures, joints, bedding planes and cavities of the rock mass). The majority of groundwater within the Hawkesbury Sandstone migrates through features such as fractures, joints, shears and bedding planes, however some intra-granular flow (groundwater flow between grains in rock) also occurs. The water in the sandstone aquifer often has naturally elevated concentrations of iron and manganese, and is generally acidic with a pH varying between 4.5 and 6.5. Salinity levels are low, although the salinity of the upper part of the aquifer may be elevated due to flows from the shale aquifer.

The site investigations found that the quality of the rock profile across the project, in terms of strength and number of defects, generally improves with depth. Fifty-seven packer tests (a test of water pressure and permeability) have been carried out across the 22 project boreholes in order to gain an understanding of the rock permeability. Packer tests have been carried out in both the Ashfield Shale and the Hawkesbury Sandstone. Based on previous experience within Sydney and the results of the packer tests, the permeability of the intact shale and sandstone is expected to be low, with some areas of higher permeability associated with isolated defects in the rock. Groundwater inflows would primarily occur via structural features including bedding partings (ie the separation of sedimentary rock along bedding planes), sub-vertical and inclined joints, and faults. Based on the site investigations and the preferred design, the best estimate permeability for Ashfield Shale was determined to be 0.005 metres per day (5.8×10^{-5} millimetres per second) and 0.01 metres per day (1.2×10^{-4} millimetres per second) for Hawkesbury Sandstone.

Ten existing bores have been identified in close proximity to the project from a search of the NSW Natural Resources Atlas (as shown on **Figure 7-76**). The bores within the vicinity of the project tunnels, and the depths expressed as metres below ground level, include:

- Two recreation bores with depths of 216 metres and 162 metres located around the northern interchange.
- One recreation bore with a depth of 180 metres located in the valley to the east of the project.
- One domestic bore with a depth of 4.2 metres located near the Pennant Hills Road / Beecroft Road intersection.
- One monitoring bore with a depth of 5.7 metres located at Thompsons Corner.
- One monitoring bore with a depth of 45 metres located in Beecroft to the east of the project.
- One abandoned test bore with a depth of 180 metres located in Pennant Hills Golf Course.

Three existing bores have been identified within one kilometre of the Hills M2 Motorway integration works. These three bores are all located within Muirfield Golf Course and include:

- One test bore with a depth of 306 metres.
- Two irrigation and recreation bores with depths of 186 metres and 240 metres.

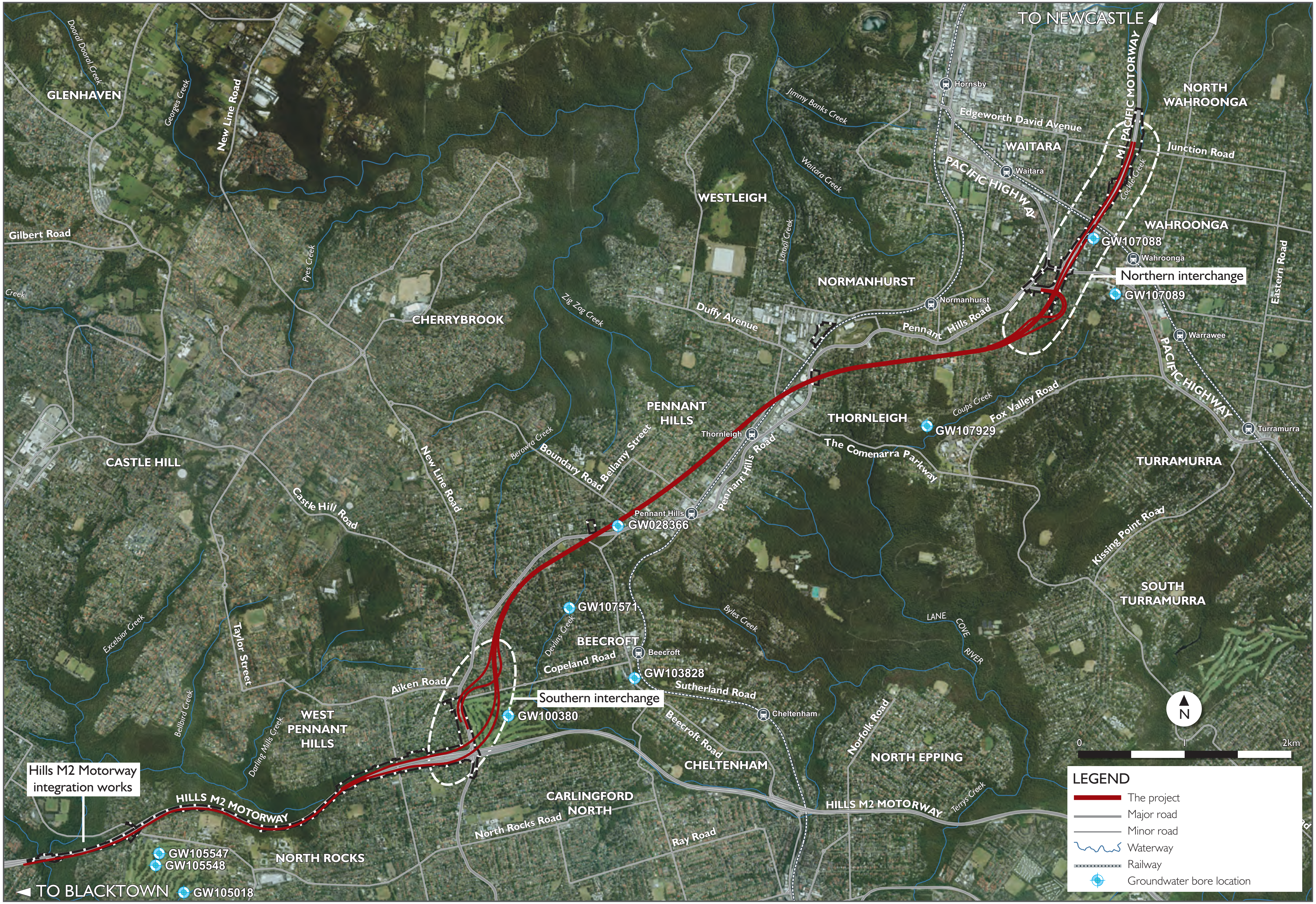

Figure 7-76 Existing bores surrounding the project

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Groundwater levels

Groundwater levels were measured during the site investigations at 12 groundwater monitoring wells along the project, located with the aim of focusing on areas of risk and uncertainty relevant to tunnel design. Water levels were measured manually using an electronic dip-meter.

Measured standing groundwater levels vary from about two metres to 30 metres below ground level, indicating that the main alignment tunnels would generally sit below the groundwater table. The main alignment tunnel depths along the corridor would vary depending on geological constraints, however the tunnel crown (top of the tunnel) would vary up to a maximum depth of around 90 metres below ground level with shallower sections approaching the northern and southern portals.

Seasonal variations in groundwater levels are also anticipated to occur in response to rainfall, which may influence seepage rates. Variations in groundwater levels in the order of ten metres occur within the Hawkesbury Sandstone.

Groundwater quality

Groundwater sampling has been undertaken to identify potential groundwater contamination and characterise groundwater quality within the project corridor.

Based on previous experience, groundwater within Hawkesbury Sandstone across the Sydney basin is typically of low to moderate salinity, with electrical conductivity generally between 500 microsiemens per centimetre (µS/cm) and 2,000 µS/cm. The groundwater is also slightly acidic with pH generally varying between 4.5 and 6.5. The groundwater tends to have naturally elevated iron concentrations.

The quality of groundwater in the shale of the Wianamatta Group tends to be inferior to groundwater in sandstone, with electrical conductivity varying between 2,000 µS/cm to in excess of 10,000 µS/cm in the Sydney Basin.

The groundwater quality analysis included testing for aggressivity, heavy metals and hydrocarbons. Samples have been tested for the following:

- Electrical conductivity.
- pH.
- Total alkalinity as $CaCO_3$.
- Sulfate.
- Chloride.
- Major cations, including:
  - Calcium.
  - Magnesium.
  - Sodium.
  - Potassium.

- Dissolved metals, including:
  - Arsenic.
  - Cadmium.
  - Copper.
  - Nickel.
  - Lead.
  - Zinc.
- Ionic balance.

Randomly selected samples were also analysed for:

- Dissolved iron.
- Nutrients, including:
  - Nitrite and nitrate.
  - Total phosphorous.
  - Total Kjeldahl nitrogen.
- Polychlorinated biphenyls.
- Organochlorine pesticides.
- Polynuclear aromatic hydrocarbons.
- Total petroleum hydrocarbons.
- Benzene, toluene, ethylbenzene and xylene.
- Volatile organic compounds.
- Sulfate reducing bacteria.

Collected groundwater samples were transported to an external NATA accredited laboratory for testing and analysis.

The key results from the groundwater quality analysis include:

- With the exception of heavy metals, all parameters are below laboratory detection limits or below the ANZECC guidelines for freshwater ecosystems at a 95 per cent confidence level.
- The dissolved heavy metal concentrations are typical of background levels present in the geology within the Sydney basin.
- The groundwater sampling indicates that there was no contaminated groundwater encountered.
- Electrical conductivity levels within the Ashfield Shale range from 1,380 µS/cm to 4,850 µS/cm indicating that the groundwater in this geology is generally brackish.
- pH values in the Ashfield Shale are generally neutral, ranging from 5.98 to 8.71.
- Electrical conductivity levels within the Hawkesbury Sandstone are variable with a range of 1060 µS/cm to 4420 µS/cm. Higher readings correlate with samples taken closer to the sandstone-shale interface.
- pH values in the Hawkesbury Sandstone are generally neutral, ranging from 6.89 to 8.72.

The groundwater along the project is not considered suitable for drinking water. However, in an urban environment the water may be used for non-potable domestic purposes such as watering gardens or washing cars. Groundwater also naturally discharges to local freshwater creeks.

Measured groundwater quality from each aquifer is indicative of the water quality that would be intersected by the project. The actual quality of groundwater encountered during construction and operation of the project would vary and would be dependent on the location of water bearing fractures and local hydrogeochemical conditions. Based on groundwater monitoring results, the project is likely to encounter areas of groundwater characterised with elevated salinity or slightly acidic or basic pH.

Contamination

The assessment of known and potentially contaminated sites included:

- Online search of record of notices issued by the NSW Environment Protection Authority under the *Contaminated Land Management Act 1997* (CLM Act).
- Online search of sites notified to the Environment Protection Authority under the CLM Act.
- A review of current and former land uses along and adjacent to the project, including the potential for asbestos containing materials, synthetic mineral fibres, lead-based paint and polychlorinated biphenyls in properties to be demolished.

Known and potentially contaminated sites identified along the project alignment are presented in **Figure 7-77**.

Where a ‘notice’ has been issued by the Environment Protection Authority, it indicates that a site is known to be contaminated to an extent that warrants regulation. A ‘notified site’ indicates that the landowner or person whose activities have contaminated land, has informed the Environment Protection Authority that a site may be contaminated at a level triggering regulatory action. Notified sites may or may not be contaminated to an extent to warrant regulation by the Environment Protection Authority.

An online search of the record of notices returned no results for any of the suburbs along the project alignment. A search of the same suburbs identified that there are three sites within the project corridor which have been notified to the Environment Protection Authority. The three notified sites within the project corridor are petroleum service stations located along Pennant Hills Road.

A number of current and former land uses have been identified within the project corridor which may have resulted in contamination. Of these, one site, Brickpit Park, is known to be contaminated.

Brickpit Park, located on Pennant Hills Road in Thornleigh (refer to **Figure 7-77**), was previously used as a municipal landfill facility. The Brickpit Park Plan of Management (Hornsby Shire Council, 2004) identifies that the landfill may be in excess of 25 metres deep in certain parts of the site. Land settlement, landfill gas and leachate are recognised as potential development constraints on the site. The Plan of Management also notes that the "area of land formerly used as a putrescible waste tip has been covered with an impervious layer of clay, designed to minimise water infiltration to the landfill body and resultant generation of gases and leachate". In addition, landfill gas and leachate extraction / treatment systems have been previously installed by Hornsby Shire Council in the vicinity of the landfill to manage the landfill leachate and gas being produced at this location.

The presence of contamination underlying Brickpit Park was a key factor considered in the design of the main alignment tunnels. As a result, the preferred design of the tunnels has avoided direct interactions with this site.

Construction of the Pioneer Avenue compound (C8) would require partial demolition of the former Thornleigh Maltworks (the Maltworks). An inspection of the Maltworks has been undertaken to identify potential areas and contaminants of concern. A number of structures have been identified which contained hazardous materials including asbestos, lead based paint, metals and other potentially hazardous equipment such as transformers and electrical infrastructure.

Based on the review of available information and observations made during the site inspection the following potentially contaminated areas have been identified:

- The historic settling / treatment ponds (contents unknown) and effluent disposal areas located to the north of the germination building.
- Two abandoned (and possibly concrete filled underground oil storage tanks located to the north of the germination building.
- One abandoned above ground effluent storage tanks located to the east of the settling / treatment ponds.
- The presence of fill material of unknown origin across the site.
- Historic use of the site as a railway siding for the transfer and transport of grain and potential contamination associated with the use of oils, lubricant and asbestos brake liners.
- Presence of oil and lubricants on production infrastructure, particularly in the vicinity of the workshop.
- Presence of a workshop and waste oil separator, including staining on the concrete ground surface.
- Storage of a small volume of chemicals, including paints, oils and solvents.
- Land uses surrounding the Maltworks, including a concrete batching plant on the adjacent property to the south west.

The main potential contaminants of concern identified at the site include asbestos, organochlorine pesticides / organophosphate pesticides and polychlorinated biphenyls.

Other current and former land uses within the project corridor which may have resulted in contamination include service stations, industrial facilities and a landscaping business located within the southern interchange. Initial desktop contamination investigations have been undertaken to assess the likelihood of impacts to the project as a result of existing land use and potential contamination. Contaminants associated with these sites may include petroleum hydrocarbons, lead and potentially chlorinated hydrocarbons. Hydrocarbon contamination from these sites is likely to be limited to the shallow soils and Ashfield Shale groundwater aquifer. Based on the surrounding topography, many of the sites have also been filled, therefore contaminated materials may also be present.

The Thornleigh industrial area includes a variety of premises, including one currently licensed under the *Protection of the Environment Operations Act 1997* for waste generation and chemical and pharmaceutical production. In addition, there is a smaller, light industrial park located within Pennant Hills. Contaminants of concern within these areas would be specific to the site activities and may include volatile and semi-volatile organic compounds and potential metals.

The project would involve the demolition of residential and commercial properties at the two interchanges, the two tunnel support facilities. There is a moderate risk that asbestos containing materials, synthetic mineral fibres, lead-based paint and polychlorinated biphenyls would be encountered during this demolition work.

A summary of the potential contamination at project construction sites is provided in **Table 7-166**.

Table 7-166 Potential contamination at project construction sites

Site	Contamination likelihood
Southern interchange (C5) and Hills M2 Motorway integration works	
Residential properties	Low soil and groundwater contamination risk, moderate potential for asbestos containing materials, synthetic mineral fibres, lead-based paint and polychlorinated biphenyls in buildings.
Commercial property (landscape supplies)	Moderate risk of soil and groundwater contamination if fuel or agricultural chemicals stored on-site.
Wilson Road compound (C6)	
Residential properties	Low risk of contaminated soil or groundwater, moderate potential for asbestos containing materials, synthetic mineral fibres, lead-based paint and polychlorinated biphenyls in buildings.
Trelawney Street compound (C7)	
Residential properties	Low risk of contaminated soil and groundwater, moderate potential for asbestos containing materials, synthetic mineral fibres, lead-based paint and polychlorinated biphenyls in buildings.
Commercial properties	Moderate risk of contaminated soil and groundwater at a motor vehicle workshop site.
Pioneer Avenue compound (C8)	
Industrial / residential buildings (associated with former maltworks)	Moderate potential for asbestos containing materials, synthetic mineral fibres, lead-based paint, organochlorine pesticides and polychlorinated biphenyls
Northern interchange (C9) and M1 Pacific Motorway tie in	
Sites at the M1 Pacific Motorway connectors – residential properties	Low risk of contaminated soil and groundwater, moderate potential for asbestos containing materials, synthetic mineral fibres, lead-based paint and polychlorinated biphenyls in buildings.
Bareena Avenue compound – residential property	Low risk of contaminated soil and groundwater, moderate potential for asbestos containing materials, synthetic mineral fibres, lead-based paint and polychlorinated biphenyls in buildings.
Two sites at Burns Road – residential properties	Low risk of contaminated soil and groundwater, moderate potential for asbestos containing materials, synthetic mineral fibres, lead-based paint and polychlorinated biphenyls in buildings.
Junction Road compound – vegetated, vacant land	Low risk of contaminated soil and groundwater

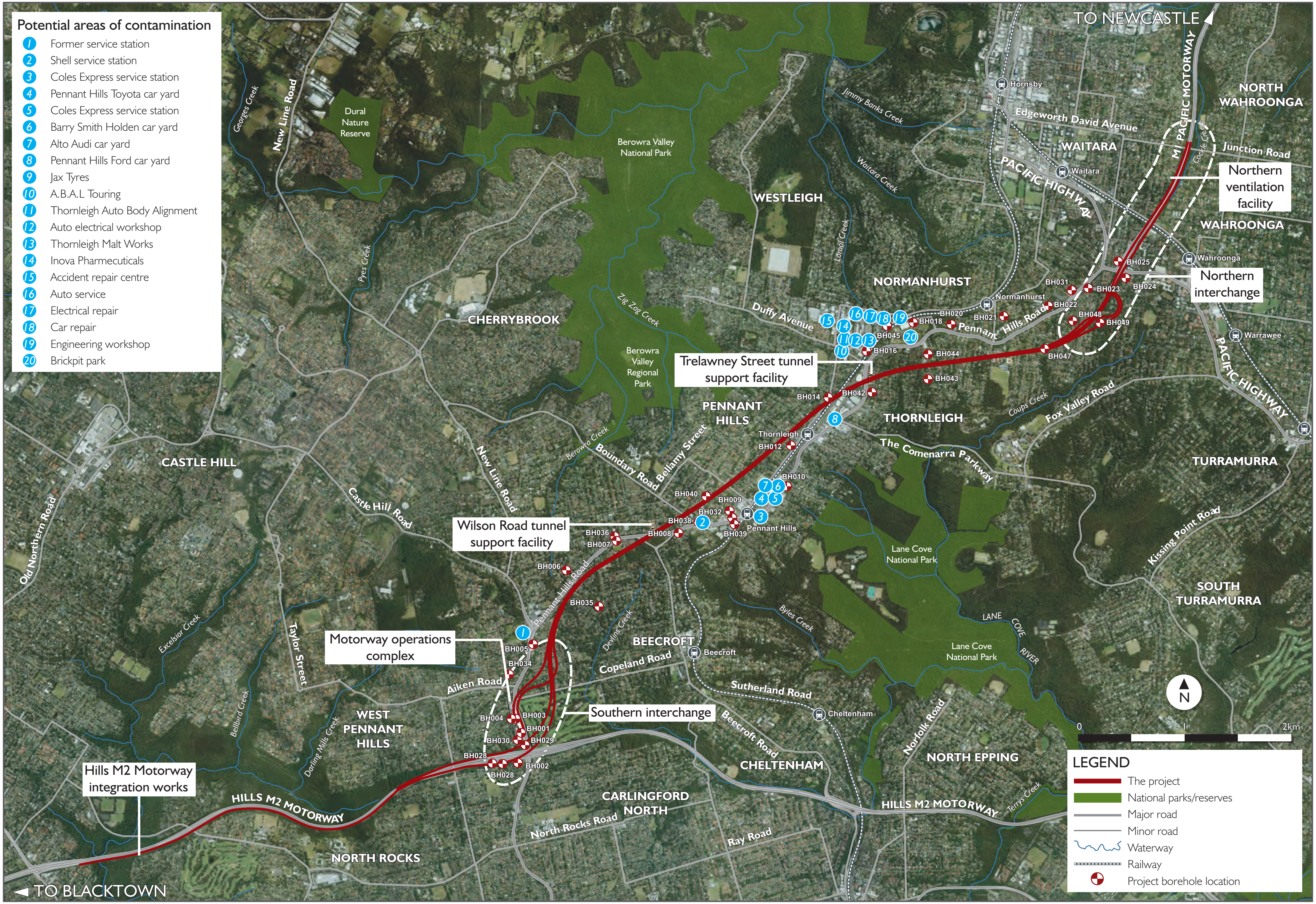

Figure 7-77 Known and potentially contaminated sites

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7.8.3 Assessment of potential impacts

Construction

Erosion and sedimentation

The proposed construction associated with the northern and southern interchanges, construction compounds, and operational surface infrastructure would involve surface excavation and earthmoving. Proposed construction works (as described in **Chapter 4** Project development and alternatives) would result in surface disturbance and, therefore, have the potential to result in erosion from the construction site and sedimentation impacts to downstream watercourses. Further details regarding erosion and sedimentation are provided in **Section 7.9** (Surface water).

Acid sulfate soils

Although acid sulfate soils or potential acid sulfate soils are not expected to occur within the project corridor, should acid sulfate soil be encountered during excavation, potential impacts may include:

- Weakening of concrete and steel infrastructure, resulting in increased maintenance and replacement costs.
- Damage to aquatic environments due to release of sulfuric acid generated from oxidised acid sulfate soils during construction.
- Mobilisation of aluminium, iron and manganese from soils as a result of increased acidity from disturbance of acid sulfate soils.

In the event that acid sulfate soils are encountered, they would be effectively managed in accordance with the Acid Sulfate Soil Manual (Acid Sulfate Soil Management Advisory Committee, 1998).

Groundwater

The tunnelling works are anticipated to intercept the groundwater aquifers which would result in groundwater inflow into the tunnels and necessitate dewatering. Dewatering of the tunnel would result in a lowering of the water table and the production of a water stream requiring management.

The project would take groundwater as a consequence of the interception of the aquifer. Roads and Maritime are exempt from the requirement to obtain a water access licence under clause 2, Schedule 5 of the *Water Management (General) Regulation 2011*.

The rules of the Sydney Basin Central groundwater source as part of the *Water Sharing Plan for the Greater Metropolitan Region Groundwater Sources* (NOW, 2011a) and their application to the project have been considered in **Table 7-167**.

The potential impacts to groundwater have been assessed against the minimal impact considerations of the NSW Aquifer Interference Policy (Department of Primary Industries, 2012). Under this policy the groundwater aquifer is considered to be a less productive groundwater source and a porous rock water source. The minimal impact considerations and their application to the project are provided in **Table 7-168.** The term 'water supply work' as it is used in **Table 7-168** and defined in the *Water Management Act 2000*, broadly encompasses works constructed for the purpose of taking, storing, conveying, diverting or impounding water from a water source.

The volume of groundwater inflow into the tunnels would vary depending on the geological unit, the extent of tunnel excavation and the presence of geological faults. However, based on the rock permeability and the preferred design, the inflow is generally expected to be in the order of one litre per second per kilometre of tunnel, which equates to around 0.09 mega litres per day per kilometre of excavated tunnel. Localised inflows around faults may be significantly higher than this value.

Based on the groundwater quality identified through monitoring in the area, the collected groundwater is anticipated to have elevated levels of salinity, may have either a slightly acidic or slightly basic pH, and may have elevated iron levels. Due to the interaction of this water with the tunnelling process, the water would become alkaline (due to contact with shotcrete) and have elevated levels of suspended solids. Tunnel dewatering programs would involve the collection of tunnel groundwater inflow and pumping to construction water treatment plants located at the four surface tunnel support sites, being:

- The southern interchange compound (C5).
- Wilson Road compound (C6).
- Trelawney Street compound (C7).
- The northern interchange compound (C9).

These water treatment plants would treat groundwater as well as construction water and surface runoff that drains into the tunnel. It is currently anticipated that a ten litre per second water treatment plant at each of the four sites would be sufficient to treat the volume of water expected from the tunnel excavation works. Further details regarding the treatment and discharge of collected groundwater are provided in **Section 7.9** (Surface water).

The lowering of the water table (or groundwater drawdown) has the potential to impact on nearby groundwater bores and on groundwater dependent ecosystems. Localised groundwater drawdown may lower the water table below the extent of a water bore, resulting in the bore being not viable. Due to the location of the bores in relation to the tunnel alignment, this is considered unlikely. However, in the event this does occur consultation would be undertaken with the bore owner to develop appropriate mitigation measures which may include development of a new, deeper water bore. Potential impacts of groundwater drawdown on groundwater dependent ecosystems are described in **Section 7.6** (Biodiversity).

Table 7-167 Groundwater sharing plan rules

<table>
<tr><th>Rule</th><th>Application to project</th></tr>
<tr><td colspan="2">Access rules</td></tr>
<tr><td>Granting of access licences may be considered for the following:
• Local water utility, major water utility, domestic and stock, and town water supply.
• These are specific purpose access licences in clause 19 of the Water Management (General) Regulation 2004.
• Aquifer (Aboriginal cultural), up to 10 ML/yr.
• Commercial access licences under a controlled allocation order made in relation to any unassigned water in this water source.</td><td>Not applicable. Roads and Maritime are exempt from the requirement to obtain a water access licence under clause 2, Schedule 5 of the Water Management (General) Regulation 2011.

Despite this, the project has considered the potential impact on the rules of the groundwater sharing plan in this table.</td></tr>
<tr><td colspan="2">Rules for managing water allocation accounts</td></tr>
<tr><td>Carryover
• Up to 10 per cent entitlement allowed.

Carryover is not allowed for domestic and stock, major utility, local water utility or specific purpose access licences.</td><td>Not applicable. The aquifer interference is not a carryover water allocation.</td></tr>
<tr><td colspan="2">Rules for managing access licences</td></tr>
<tr><td>Managing surface and groundwater connectivity
• From year 7 of the plan, for areas adjoining unregulated water sources (i.e. rivers and creeks), existing works within 40 metres of the top of the high bank of a river or creek, except existing works for, local water utility, town water supply, food safety or essential dairy care purposes, will have conditions which establish:
  – the flow class of the river established under the water sharing plan for the corresponding unregulated water source, or
  – in the absence of a flow class, visible flow in the river at the closest point of the water supply works to the river.
• These distances and rules may be varied for an applicant if the work is drilled into the underlying parent material and the slotted intervals of the works commences deeper than 30 metres or no minimal impact on base flows in the stream can be demonstrated.
• For major utility and local water utility access licences these rules apply to new water supply works from plan commencement.</td><td>Not relevant. The plan has not yet reached year 7.

The project is not anticipated to impact on the base flow of any waterway above the tunnel alignment.</td></tr>
</table>

Rule	Application to project
Rules for granting and amending water supply works approvals	
To minimise interference between neighbouring water supply works No water supply works (bores) to be granted or amended within the following distances of existing bores: • 400 metres from an aquifer access licence bore on another landholding, or • 100 metres from a basic landholder rights bore on another landholding, or • 50 metres from a property boundary (unless written consent from neighbour), or • 1,000 metres from a local or major water utility bore, or • 200 metres from a NSW Office of Water monitoring bore (unless written consent from NSW Office of Water). The plan lists circumstances in which these distance rules may be varied and exemptions from these rules.	The project is not a water supply work. Consideration has been given the potential impact on surrounding water supply works (bores). **Table 7-170** concludes that there may be limited impacts to some existing bores. In the event the project does render an existing bore unviable, consultation would be undertaken with the bore owner to develop appropriate mitigation measures.
To protect bores located near contamination No water supply works (bores) are to be granted or amended within: • 250 metres of contamination as identified within the plan, or • 250 metres to 500 metres of contamination as identified within the plan unless no drawdown of water will occur within 250 metres of the contamination source, • a distance greater than 500 metres of contamination as identified within the plan if necessary to protect the water source, the environment or public health and safety. The plan lists circumstances in which these distance rules may be varied and exemptions from these rules.	The project is not a water supply work. Consideration has been given the potential impact on surrounding water supply works (bores). **Table 7-170** concludes that there may be limited impacts to some existing bores. In the event the project does render an existing bore unviable, consultation would be undertaken with the bore owner to develop appropriate mitigation measures.

Rule	Application to project
To protect water quality To minimise the impact on water quality from saline interception in the shale aquifers overlying Sydney basin sandstone, the bore being used to take groundwater must be constructed with pressure cement to seal off the shale aquifer as specified by the Minister.	The project is not likely to impact on existing groundwater quality. Groundwater extracted would be tested and treated to meet the requirements of: an environmental protection licence issued for the project during construction. The project has been designed to achieve a maximum water discharge quality equivalent to the 95 per cent protection level specified for freshwater eco-systems in accordance with ANZECC guidelines (ANZECC & ARMCANZ, 2000). The discharge water quality level would be determined in consultation with the NSW Environment Protection Authority during the detailed design phase taking into consideration the current water quality of the receiving watercourses. This discharge water quality would be higher quality than the receiving surface water environment

Rule	Application to project
To protect bores located near sensitive environmental areas No water supply works (bores) to be granted or amended within the following distances of high priority Groundwater Dependent Ecosystems (GDEs) (non Karst) as identified within the plan: • 100 metres for bores used solely for extracting basic landholder rights, or • 200 metres for bores used for all other access licences. The above distance restrictions for the location of works from high priority GDEs do not apply where the GDE is a high priority endangered ecological vegetation community and the work is constructed and maintained using an impermeable pressure cement plug from the surface of the land to a minimum depth of 30 metres. No water supply works (bores) to be granted or amended within the following distances from these identified features: • 500 metres of high priority karst environment GDEs, or • a distance greater than 500 metres of a high priority karst environment GDE if the Minister is satisfied that the work is likely to cause drawdown at the perimeter of the high priority karst GDE, or • 40 metres of a river or stream or lagoon (3rd order or above), • 40 metres of a 1st or 2nd order stream, unless drilled into underlying parent material and slotted intervals commence deeper than 30 metres (30 metres may be amended if demonstrate minimal impact on base flows in the stream), or • 100 metres from the top of an escarpment. The plan lists circumstances in which these distance rules may be varied and exemptions from these rules.	The technical working paper: biodiversity includes an assessment of potential groundwater dependant ecosystems. This assessment concluded that there are no groundwater dependent ecosystems in the vicinity of the tunnel alignment.

Rule	Application to project
To protect groundwater dependent culturally significant sites No water supply works (bores) to be granted or amended within the following distances of groundwater dependent cultural significant sites as identified within the plan: • 100 metres for bores used for extracting for basic landholder rights, or • 200 metres for bores used for all other aquifer access licences The plan lists circumstances in which these distance rules may be varied and exemptions from these rules.	No groundwater dependant culturally significant sites have been identified in the vicinity of the project tunnels.
Rules for replacement groundwater works A replacement groundwater work must be constructed to take water from the same water source as the existing bore and to a depth specified by the Minister. A replacement bore must be located within: • 20 metres of the existing bore; or • If the existing bore is located within 40 metres of the high bank of a river the replacement bore must be located within: – 20 metres of the existing bore but no closer to the high bank of the river or a distance greater if the Minister is satisfied that it will result in no greater impact Replacement works may be at a greater distance than 20 metres if the Minister is satisfied that doing so will result in no greater impact on the groundwater source and its dependent ecosystem. The replacement work must not have a greater internal diameter or excavation footprint than the existing work unless it is no longer manufactured. If no longer manufactured the internal diameter of the replacement work must be no greater than 110 per cent of the existing work	Not applicable. The project is not a replacement groundwater work. In the event that a replacement bore is required for an existing user, the project would consult with the NSW Office of Water and would consider these relevant rules.

Rule	Application to project
Rules for the use of water supply works approvals	
To manage bores located near contaminated sites The maximum amount of water that can be taken in any one year from an existing work within 500 metres of a contamination source is equal to the sum of the share component of the access licence nominating that work at commencement of the plan.	Not applicable.
To manage the use of bores within restricted distances The maximum amount of water that can be taken in any one year from an existing work within the restricted distances to minimise interference between works, protect sensitive environmental areas and groundwater dependant culturally significant sites is equal to the sum of the share component of the access licence nominating that work at commencement of the plan.	Not applicable.
To manage the impacts of extraction The Minister may impose restrictions on the rate and timing of extraction of water from a water supply work to mitigate the impacts of extraction.	Not applicable.
Limits to the availability of water	
Available Water Determinations (AWDs) • 100 per cent stock and domestic, local and major utilities and specific purpose access licences • 1ML/unit of share aquifer access licences AWD for aquifer access licences may be reduced in response to a growth in use.	Inflow during construction would vary according to the progression of the tunnelling works. The inflow rate would be 0.09 ML / day / kilometre. Inflow during operation would be around 170 to 700 mega litres per year in total for two nine kilometres tunnels. Viable re-use options for this water would be investigated, however it is currently expected that the majority of the water would be returned to the environment through surface water flows.
Trading rules	
INTO groundwater source Not permitted	Not applicable.
WITHIN groundwater source Permitted subject to local impact assessment	Not applicable.
Conversion to another category of access licence Not permitted	Not applicable.

Table 7-168 NSW Aquifer Interference Policy minimal impact considerations

No	Consideration	Potential impact
Water table		
1	Less than or equal to 10 per cent cumulative variation in the water table, allowing for typical climatic “post-water sharing plan” variations, 40 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.	The project would not be located within 40 metres of any high priority groundwater dependent ecosystems or high priority culturally significant site. The project may potentially result in a decline of the water table at existing bores in the vicinity of the project, however the impacts are considered to be limited.
2	If more than ten 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.	In the event that drawdown of the water table does impact on the viability of existing bores consultation would be undertaken with the bore owner to develop appropriate mitigation measures which may include development of a new, deeper bore.
Water pressure		
1	A cumulative pressure head decline of not more than a two metre decline, at any water supply work.	The project may potentially result in a decline in head pressure at existing bores in the vicinity of the project, however the likelihood is considered low.
2	If the predicted pressure head decline is greater than requirement one 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.	In the event that drawdown of the water table does impact on the viability of existing bores, including a decline in head pressure, consultation would be undertaken with the bore owner to develop appropriate mitigation measures which may include development of a new, deeper bore.
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 impacts to groundwater quality.

No	Consideration	Potential impact
2	If condition one above 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.

Ground movement

Ground movement may occur as a result of:

- Tunnel induced movement caused by the relief of stress from tunnelling through intact rock.
- Settlement induced from groundwater drawdown.

The risk to individual structures would be dependent on the geotechnical conditions, the depth of the tunnel, the number of storeys of the building, and the position, condition, and masonry of the structure itself.

Settlement resulting from groundwater drawdown would be less than three millimetres in all cases. As outlined in **Table 7-169** settlement of up to ten millimetres is considered negligible (Burland et al, 1977). Consequently, settlement resulting from groundwater drawdown would be considered negligible.

Preliminary ground movement investigations indicate that there may be potential settlement of up to a maximum of 20 millimetres in areas where the main alignment tunnels and the on and off-ramp tunnels are approaching the surface. The remainder of the tunnel alignment would be expected to experience settlement impacts of less than five millimetres.

Table 7-169 provides typical impacts based on preliminary assessments which would be expected in relation to potential ground movement values, the anticipated angular distortion and typical associated impacts for settlement.

Table 7-169 Typical impacts of ground movement

Settlement (millimetres)	Angular distortion (%)	Degree of impact	Typical impact
Up to 10	Up to 0.03	Negligible	Hairline cracks less than around 0.1 millimetres
10 to 20	0.03 to 0.13	Very slight to slight	Fine cracks which are easily treated during normal decoration. Typical crack widths up to 5 millimetres

Note: Degree and typical impact adopted from Burland et al (1977)

This indicates that, in all cases, ground movement is likely to result in cosmetic damage only. For the majority of properties, the anticipated impacts are negligible, typically resulting in hairline cracking only. For a limited number of properties, ground movement may result in fine cracking of up to five millimetres.

However, these results are preliminary and do not take into account the specifics of the property itself. Further assessments would be undertaken during detailed design to determine the level of potential impact on structures and to identify feasible and reasonable mitigation and management measures required to minimise potential ground movement impacts.

Contamination

As detailed above, a number of sites exist across the construction footprint with a moderate potential to be contaminated as a result of historical land uses and development. These include:

- Fuels and agricultural chemicals at the commercial landscape supply business at the southern interchange.
- Fuels, oils and degreasing agents (including chlorinated compounds) at the motor vehicle workshops at the Trelawney Street compound (C7).
- Asbestos containing materials, synthetic mineral fibres, lead-based paint and polychlorinated biphenyls, organochlorine pesticides and organophosphate pesticides within structures to be acquired and demolished for the project.

The contamination due diligence assessment concluded that there is a low potential for surface soil and groundwater contamination to impact on the proposed tunnel alignment due to the tunnel ranging in depth up to a maximum of around 90 metres below ground surface. Additionally, within the areas where surface disturbance is proposed, no contaminating land uses or activities that have the potential to adversely impact on the project have been identified.

The potential to cause further contamination through accidents or spills of fuels, oils and chemicals during construction and operation of the project is considered to be negligible. Refer to **Section 8.2** (Hazards and risk) for further details regarding dangerous goods and hazardous substances.

Operation

Groundwater inflow

As the main alignment tunnels would be operated as drained tunnels, there would be an ongoing inflow of groundwater. This would require the project to accommodate capture, removal, treatment and discharge of groundwater during the operational phase. The tunnel drainage system and operational water treatment plant, located near the southern interchange, would also manage deluge system water (as part of the fire and life safety system) in the unlikely event of an emergency in the tunnels, and tunnel washing water from regular maintenance activities.

Groundwater inflows would primarily occur via structural features including bedding partings (ie the separation of sedimentary rock along bedding planes), sub-vertical and inclined joints, and faults. Previous experience in the Sydney region is that long term groundwater inflows into drained tunnels are typically around one litre per second per kilometre. Sustained groundwater inflow rates significantly higher than this typical value have occurred where there are adverse structural features intersecting with the tunnel. Inflows are also expected to vary according to climate, with inflows increasing during periods of rainfall and decreasing during drier periods.

The anticipated inflow to the tunnels has been calculated using the Heuer (1995) method. Based on the rock permeability and the preferred design, the long term steady state groundwater inflow into the main alignment tunnels would be around:

- 0.39 to 1.66 litres per second per kilometre for the first tunnel.
- 0.195 to 0.83 litres per second per kilometre for the second tunnel as the first tunnel would partially dewater the rock stratum.

This equates to around 170 to 700 mega litres per year in total for two nine kilometres tunnels. However, based on experience from other tunnelling projects in the Sydney region such as the Epping to Chatswood Rail Link, localised inflows in the order of three to five litres per second can be expected to occur for short durations in the vicinity of geological faults.

The tunnel drainage system would flow to one sump with a capacity of 420 cubic metres. The sump would be located at the tunnel low point where water would then be pumped to a water treatment plant located near the southern interchange for treatment and discharge to the local stormwater system.

The project would take groundwater as a consequence of the interception of the aquifer. Roads and Maritime are exempt from the requirement to obtain a water access licence under clause 2, Schedule 5 of the *Water Management (General) Regulation 2011*.

Further details regarding the treatment and discharge of collected groundwater are provided in **Section 7.9** (Surface water).

Groundwater drawdown

The ongoing inflow of groundwater into the tunnel may result in localised groundwater drawdown. This level of drawdown and the lateral extent of influence would be determined by the tunnel depth.

Where the tunnel is located below the lower groundwater table within the sandstone, the groundwater drawdown in the shale would be limited, and the zone of influence for groundwater drawdown in shale would be limited to the area directly above the tunnel.

Where the tunnel is close to or within the shale, the groundwater drawdown in the shale would be significant, and the zone of lateral influence would be four to five times that of the natural groundwater depth above the tunnel. For example, if the groundwater depth above the tunnel is two metres then the lateral influence would be around eight to ten metres.

Potential operational impacts resulting from groundwater drawdown include:

- Impacts to groundwater dependent ecosystems (further assessment of this issue is provided in **Section 7.6** Biodiversity).
- Loss of supply to existing groundwater bores in the event drawdown is beyond the depth of the bore.

The likelihood of the project resulting in loss of surface water flows as a consequence of groundwater drawdown would be low because of:

- The depth of the main alignment tunnels.
- The general position of the project in the catchment, along a ridgeline.
- The limited number of watercourses under which the main alignment tunnels pass.

Table 7-170 provides an assessment of the potential impact to the existing bores surrounding the project. Generally, due to the location of the surrounding bores in relation to the tunnel alignment, it is also unlikely that the project would impact on the viability of these bores. However, in the event that this does occur consultation would be undertaken with the bore owner to develop appropriate mitigation measures which may include development of a new, deeper bore.

The main alignment tunnels would cross underneath the alignment of the North West Rail Link project. There is potential for cumulative groundwater drawdown in this area.

The North West Rail Link is proposing to construct undrained tunnels (ie tunnels which are lined and minimise the ongoing inflow of water). The North West Rail Link construction methodology involved the erection of tunnel lining segments immediately following tunnel boring. As such, the potential for cumulative impacts would be limited to the concurrent construction phase of the project and the short period between North West Rail Link tunnel boring and tunnel lining.

Table 7-170 Impact on groundwater bores

Bore hole	Bore type	Borehole depth (metres)	Ground water depth (metres below ground level)[1]	Borehole aquifer	Tunnel geology	Horizontal distance from tunnel (metres)	Potential impact
100380	Test bore (abandoned)	180	12	Sandstone	Shale	197	As this borehole is abandoned it would not be impacted on by the project. Additionally, in this location the tunnel would be located in the shale and would be unlikely to impact on the sandstone aquifer.
103828	Monitoring	5.7	19.8	Alluvial	Sandstone	139	As the tunnel is located within the sandstone, groundwater drawdown within the alluvial aquifer is unlikely.
107571	Monitoring	45	-	Sandstone	Sandstone	390	As the tunnel is located within the sandstone, the groundwater drawdown would typically be restricted to a zone in the immediate proximity to the tunnels As this borehole is located a significant distance (390 metres) from the tunnel, drawdown impacts are unlikely.
028366	Domestic	4.2	52.5	Shale	Sandstone	67	As the tunnel is located within the sandstone, the zone of influence for the groundwater drawdown in the shale would be limited to the area directly above the tunnel. As the borehole is located 67 metres from the tunnel, the groundwater drawdown within this borehole is expected to be limited.
107929	Recreation	180	58	Sandstone	Sandstone	500	As the tunnel is located within the sandstone, the groundwater drawdown would typically be restricted to a zone in the immediate proximity to the tunnels As this borehole is located a significant distance (500 metres) from the tunnel, drawdown impacts are unlikely.

Bore hole	Bore type	Borehole depth (metres)	Ground water depth (metres below ground level)[1]	Borehole aquifer	Tunnel geology	Horizontal distance from tunnel (metres)	Potential impact
107089	Recreation	216	65	Sandstone	Sandstone	479	As the tunnel is located within the sandstone, the groundwater drawdown would typically be restricted to a zone in the immediate proximity to the tunnels As this borehole is located a significant distance (479 metres) from the tunnel, drawdown impacts are unlikely.
107088	Recreation	162	78.5	Sandstone	Sandstone	55	As the tunnel is located within the sandstone, the groundwater drawdown would typically be restricted to a zone in the immediate proximity to the tunnels As this borehole is located 55 metres from the tunnel, drawdown impacts would be limited.

Note 1 groundwater depth is taken from borehole data from the NR Atlas where available. Groundwater depth for BH 103828 and BH 028366 are based on geotechnical investigations undertaken for this project.

7.8.4 Environmental management measures

The construction of a road tunnel would result in an unavoidable interface with groundwater, including the ongoing inflow of groundwater into the tunnels. The assessment has shown that impacts associated with groundwater would be minimal. Additionally, the project has committed to make good provisions in the event that groundwater drawdown results in an existing bore becoming unviable. Impacts associated with settlement are anticipated to be negligible.

Environmental management measures relating to hydrogeology and soils for the construction and operational periods are provided in **Table 7-171.**

Table 7-171 Environmental management measures – hydrogeology and soils

Impact	No.	Environmental management measure	Timing
Construction			
General	HS1	A Construction Soil and Water Quality Management Plan would be prepared to manage surface and groundwater impacts during construction of the project.	Pre-construction and construction
Acid sulfate soils	HS2	If acid sulfate soils are encountered, they would be managed in accordance with the Acid Sulfate Soil Manual (Acid Sulfate Soil Management Advisory Committee, 1998).	Construction
Contamination	HS3	A Construction Environmental Management Plan prepared for the project would include provisions to manage unexpected finds and hazardous materials identified during site preparation and / or construction works.	Pre-construction
	HS4	Potentially contaminated areas directly affected by the project would be investigated and managed in accordance with the requirements of the *Contaminated Land Management Act 1997* and Contaminated Sites: Guidelines for Consultants Reporting on Contaminated Sites (EPA, 1997).	Pre-construction
	HS5	Appropriate mitigation measures including stockpiling and management of potentially contaminated material would be undertaken at building demolition sites to prevent movement of material into receiving waters.	Construction
	HS6	If excavation and off-site disposal of soil is to take place in an area of potential contamination, further delineation and / or waste classification would be undertaken.	Construction
	HS7	Hazardous Materials Assessments would be undertaken, and Hazardous Materials Management Plans implemented, prior to and during the demolition of buildings. Demolition works would be undertaken in accordance with Australian and NSW WorkCover Standards.	Pre-construction and construction

Impact	No.	Environmental management measure	Timing
Groundwater management	HS8	A groundwater monitoring plan would be prepared for the duration of the construction period. Parameters to be monitored would include groundwater levels and groundwater quality with field parameters, laboratory parameters and sample frequency to be developed prior to construction.	Pre-construction and construction
	HS9	A groundwater monitoring network to monitor groundwater levels and groundwater quality would be established during the construction phase. The groundwater monitoring network would contain monitoring wells along the project corridor intersecting groundwater in both Ashfield Shale and Hawkesbury Sandstone.	Construction
	HS10	Groundwater captured during construction would be tested, treated and discharged to meet the requirements of the project EPL.	Construction
	HS11	The management of groundwater and surface water inflow into the tunnels, including the design of capture, treatment and discharge methods would be undertaken in consultation with the Environment Protection Authority.	Construction
	HS12	Where available, and of appropriate chemical and biological quality, subject to a health risk assessment, stormwater, recycled water, groundwater inflows to tunnels or other water sources would be used in preference to potable water for construction activities, including concrete mixing and dust control.	Construction
	HS13	Compliance records of groundwater monitoring undertaken would be retained.	Construction
Ground movement and settlement	HS14	Further assessments would be undertaken during detailed design to determine the level of potential impact on structures and to identify feasible and reasonable mitigation and management measures required to minimise potential ground movement impacts.	Construction
	HS15	Prior to the commencement of tunnelling works, existing condition surveys would be undertaken on properties and structures within the preferred project corridor (the zone on the surface equal to 50 metres from the outer edge of the tunnels) and within 50 metres of surface works.	Construction
Operation			
General	OpHS1	Operations personnel would be competent and trained in systems and procedures.	Operation

Impact	No.	Environmental management measure	Timing
Contamination	OpHS2	Procedures to address spills, leaks and tunnel washing would be developed and implemented during operation of the project.	Operation
Groundwater management	OpHS3	The project has been designed to achieve a maximum water discharge quality equivalent to the 95 per cent protection level specified for freshwater eco-systems in accordance with ANZECC guidelines. The discharge water quality level would be determined in consultation with the NSW Environment Protection Authority during the detailed design phase taking into consideration the current water quality of the receiving watercourses.	Detailed design
	OpHS4	Feasible and reasonable opportunities would be identified for the reuse of captured groundwater.	Operation