CrossRiverRail

12. Groundwater

Cross River Rail

CHAPTER 12

GROUNDWATER

JULY 2011

Contents

12 Groundwater

12.1 Introduction

12.1.1 Methodology

This Chapter addresses Section 3.5.1 of the Terms of Reference (ToR). The assessment of groundwater resources has referenced available groundwater data, previous studies for tunnels in Brisbane, geotechnical drilling undertaken for the Project and data obtained through a review of the DERM reports and records. This assessment extends beyond the study corridor identified in the ToR. This is referred to in this report as the study area. The study area includes that area within the study corridor plus an additional 5 km buffer zone. A review of available groundwater information relevant to the study area includes the following sources:

- Department of Environment and resource Management (DERM) groundwater facility (GWDB) and licensing databases 2010
- preliminary groundwater and geotechnical investigations undertaken for the Project, including
  - hydrogeology and groundwater issues issues report reports prepared by Australian Groundwater and Environmental Consultants (AGE) for TMR (2004 and 2006)
  - preliminary draft geotechnical investigations undertaken by AECOM (2010)
- groundwater and geotechnical investigations undertaken for other projects within or near to the study area, including
  - Boggo Road Busway near Dutton Park and Woolloongabba (Douglas and Partners 2007)
  - Inner Northern Busway (INB HUB Alliance 2005)
  - S1 Sewer Tunnel (Brisbane City Council 1996)
  - North South Bypass (now known as Clem Jones tunnel) Tunnel and Airport Link projects (AGE Consultants 2004 and 2006)
  - Northern Link Project (SKM-Connell Wagner Joint Venture 2008a) – now known as Legacy Way
  - Eastern Busway Project (SKM 2009)
- geotechnical and contaminated land assessments undertaken (or commissioned) in the locality by BCC City Design (2000)
- available geotechnical data from TMR archives and BCC archives
- published geographical information system (GIS) datasets, including digital terrain model, topography, geology and aerial photography
- Queensland Geological Survey's published 1:100,000 Brisbane geology map sheet.

The groundwater investigation for this EIS was also supplemented by geotechnical investigations and groundwater testing undertaken for the Project in July 2010. This information is detailed in the *Preliminary Geotechnical Interpretive Report* for the Project (AECOM 2010).

A conceptual hydrogeological model was developed as a means of describing the existing groundwater resources in the study area. A three dimensional finite difference groundwater model, based on the conceptual model, was then developed to assess the potential for, and impacts of, the long term inflow of groundwater to the tunnel.

12.2 Description of existing groundwater environment

12.2.1 Aquifers

A review of the available geological data indicates that the hydrogeological regime of the study area comprises two broad aquifer types (from oldest/deepest to youngest/shallowest):

- fractured rock (secondary porosity) aquifer systems comprising Neranleigh-Fernvale Beds, Brisbane Tuff, Aspley and Tingalpa Formations, Woogaroo Sub-Group
- alluvial (primary porosity) aquifer systems overlying bedrock aquifers.

In fractured rock aquifers, groundwater is typically stored in geological structural features such as fractures, joints, bedding planes and cavities of the formation. The availability of water in these systems is largely dependent on the nature of the fractures (size, geometry, hydraulics) and their degree of interconnection.

Groundwater in alluvial systems exists between the grains of unconsolidated sediments, eg sand, and in some circumstances between the grains within sedimentary rock. The porosity of a unit, and hence availability of water, will be influenced by the grain size, size sorting, grain shape and fabric of the sediment and the degree of mineral cementation.

In some cases, a layer of low-permeability material, eg clay, may exist as a lens above the main water table. Recharging water moving downward through the higher permeability unsaturated zone may accumulate on top of these lenses to form a localised aquifer that is perched above the main water table, giving this aquifer its name ie a perched aquifer. Perched aquifers are hydraulically disconnected from the underlying water table aquifer system and, as such, are usually unaffected by processes that impact on the underlying aquifer.

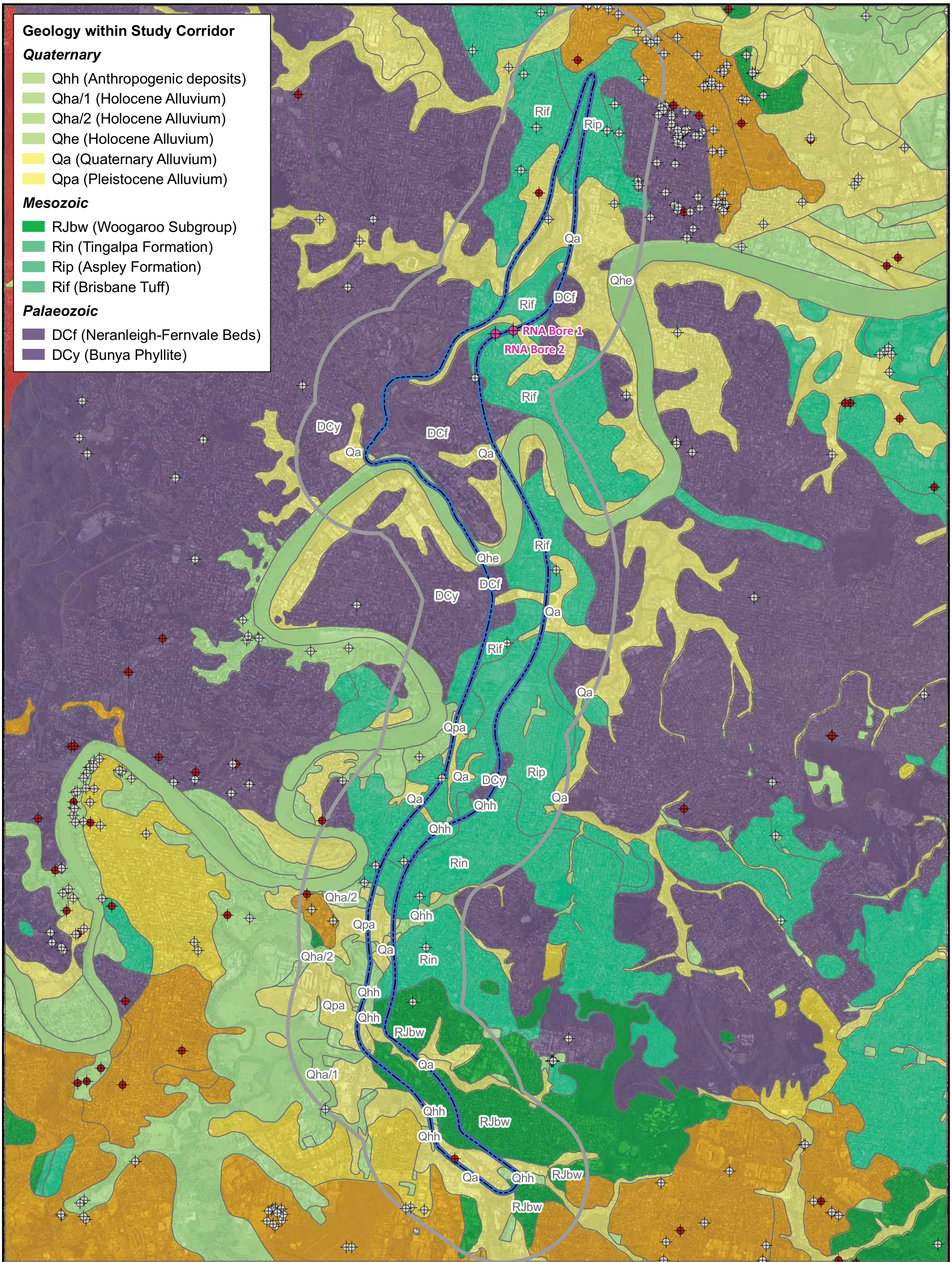
Whilst the specific thicknesses of aquifers are unknown, the hydrogeological characteristics of the various geological units within the study area are described in this section and indicated on **Figure 12-1.**

Neranleigh-Fernvale Beds

The Neranleigh-Fernvale Beds (NFB) is one of the oldest bedrock units of the Brisbane area and is exposed over much of the area between Brisbane and the Gold Coast. Within the study area, the NFB outcrops near the Brisbane CBD and Spring Hill, and near Woolloongabba. Groundwater occurrence in the NFB is typically limited to secondary porosity associated with localised zones of structural deformation. Fractures can occur at depths down to more than 60 m, mostly close to drainage lines. Due to the complex variety of rock types, groundwater characteristics vary considerably in NFB (Swann 1997). Groundwater yields in the NFB are generally low and can range from 0 to 1.0 L/second (Swann 1997).

In general, the rocks of the NFB can be described as an aquifer of very low to low permeability with isolated areas of higher permeability (AGE 2004, 2006). A more detailed presentation on permeability is contained in *Technical Report No. 4 – Groundwater Assessment*[1].

[1] SKM-Aurecon CRR JV, Technical Report No. 4 Groundwater Assessment.



LEGEND

- Study Corridor
- Study Area
- Existing Groundwater Bores
- Extraction Bores
- Abandoned and Destroyed Groundwater Bores

CROSS RIVER RAIL
ENVIRONMENTAL IMPACT STATEMENT

Figure 12-1

Existing Groundwater Users and Geology

0 0.5 1 1.5 2 2.5 km

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Brisbane Tuff

Brisbane Tuff outcrops near Fortitude Valley and Bowen Hills, and between the Brisbane River and Park Road, Dutton Park. Groundwater within the Brisbane Tuff is contained within fractures and joints but aquifers are not widespread (Swann 1997). The Brisbane Tuff is considered to have reasonable groundwater supplies (EHA 2006). Groundwater yields from this unit range from 0.1 to 1.5 L/second.

Data from previous investigations indicates variable permeability of the rock, with packer test results (an aquifer test performed in an open borehole), ranging from negligible water loss to instances where water losses were so great that no test could be completed (AGE 2004, 2006). The average results range from <8.6×10^{-3} m/day to 0.2 m/day, which is indicative of very low to high permeability.

Future hydrogeological investigations will aim to further characterise the hydraulic interactions/ connectivity of overlying and underlying units with the Brisbane Tuff. The term ‘connectivity’ refers to the physical hydraulic connection between groundwater in an aquifer and surface water in a river (Evans 2007). This is influenced by depth to water table and the hydraulic conductivity of the aquifer and stream bed sediments.

Aspley and Tingalpa Formation

The Aspley and Tingalpa Formations have a similar geological and depositional history and are considered as one in this assessment. Within the vicinity of the study area, the Aspley Formation outcrops near Albion Station and to the south of the Brisbane River near Yeronga and Fairfield Stations. The Tingalpa Formation outcrops to the south of Brisbane River near Moorooka, Yeerongpilly and Fairfield Stations.

Data from other studies (Airport Link, North South Bypass Tunnel (NSBT)) indicate a low to moderate permeability. The primary porosity of the Aspley and Tingalpa Formations is considered to be essentially zero. The permeability of the rock is governed by the number of fractures and the degree to which fracture zones are interconnected.

Future hydrogeological investigations will aim to further characterise the hydraulic interactions/ connectivity of overlying and underlying units with the Aspley and Tingalpa Formations.

Woogaroo Sub-Group

The Woogaroo Sub-Group consists of porous sandstones with both primary inter-granular permeability and fracture permeability (EHA 2006). The Woogaroo Sub-Group outcrops in the southern part of the study area near Moorooka, Rocklea and Salisbury.

Groundwater yields in this aquifer range from 0.1 to 1.5 L/second (Swann 1997). Larger yielding supplies are generally encountered where both secondary fracture and primary permeability exist. The Woogaroo Sub-Group represents a relatively heterogeneous system of aquifers in terms of both hydraulics and hydrochemistry (EHA 2006).

It is anticipated that the majority of the construction work for the Project over this geological unit will be surface works that will not interact with the water table. Consequently, the groundwater environment of Woogaroo Sub-Group is not discussed in further detail in this chapter of the EIS.

Quaternary Alluvium

The Quaternary Alluvium (<2 million years old) is the youngest unit in the study area and comprises sediments associated with watercourses. The four main areas of alluvium have been identified as the Brisbane River, Norman Creek, Yorks Hollow Creek and Enoggera Creek (AGE 2004, 2006). Groundwater potential in the alluvial aquifers is related to their depositional characteristics and parent material. Groundwater in the alluvial aquifers is expected to be in direct hydraulic connection with the adjacent rivers and creeks within the study area.

Locally, moderate groundwater yields may exist. However, the low overall storage within these systems limits long term sustainable yields. In general, these alluvial sediments form unconfined and perched aquifers overlying less permeable basement rocks with groundwater occurrence primarily a function of matrix porosity.

Data from investigations undertaken for previous projects, eg S1 Sewer Tunnel (BCC 1996) Inner Northern Busway (INB HUB Alliance 2005), Eastern Busway Project (SKM 2009)), indicates that average hydraulic conductivity data for the alluvium ranges from 0.15 m/day to 86.4 m/day. This is indicative of high to extremely high permeability.

It is anticipated that future hydrogeological investigations will aim to further characterise the hydraulic interactions/ connectivity of adjacent and underlying units with the Quaternary Alluvium.

Fill material

Anthropogenic fill materials occur throughout the study area and are predominantly associated with areas of urban development. The nature, consistency, depth and extent will vary greatly across the site. Significant depths are apparent where intensive development/re-shaping of landforms has taken place, such as at pre-development drainage lines where extensive valley infill has occurred (AECOM 2010b). Particular depths of fill of this nature are expected at the Woolloongabba Goprint site and along Albert Street (AECOM 2010b). Previous assessments within the study area have identified moderately transmissive and localised perched aquifer systems in these materials. Field investigations will be required to confirm the presence and significance of these aquifers within the study corridor. The hydrogeological characteristics of these deposits are dependent upon composition, source and degree of compaction. Accordingly, the occurrence and nature of perched aquifers within the fill deposits is likely to vary significantly. These perched aquifers are limited in areal extent and are typically ephemeral in nature, and consequently have not been considered further.

12.2.2 Groundwater recharge and discharge

Recharge to the alluvial aquifers is controlled by weather and geology. Direct vertical recharge in the alluvial aquifers is likely to occur from rainfall or overland flows. The primary source of recharge is considered to be via in-stream recharge, ie recharge that occurs within stream channels during periods of stream flow. As most of the streams, such as Norman Creek, Breakfast Creek, Oxley Creek and Brisbane River in the study area are tidal, both recharge and discharge processes are likely to occur within the alluvial aquifer during high and low tides respectively, where hydraulic connections exist.

Discharge may also occur via evapotranspiration (from vegetation) and infiltration to underlying aquifers. With the large area of paved surfaces in the study area, it is likely that evapotranspiration contributes only a small component to the total discharge from the aquifer.

The fractured rock aquifers may be hydraulically connected with the overlying alluvial aquifer. Recharge in these aquifers may occur as a result of infiltration from rainfall in rock outcrop areas, or from the overlying alluvial aquifer if they are in hydraulic connection. Discharge is expected to occur as seeps along the base of slopes or by through-flow to the alluvial aquifer where they are in hydraulic connection. Specific areas where this is occurring are unknown.

In an urban environment there is significant potential for localised recharge from leaking water mains, stormwater systems and sewage pipes. Within the Brisbane CBD area, basement dewatering represents an additional, potential source of discharge for the surrounding aquifers. However, specific areas where this is occurring are unknown.

12.2.3 Groundwater users

Groundwater facilities encompass water bores, wells, groundwater interception trenches and other infrastructure constructed to allow extraction of groundwater. There are 402 registered groundwater facilities identified within a 5 km radius of the study corridor (DERM 2010b). Of these, 331 are existing and 71 are abandoned and destroyed facilities. A search of water entitlement data was undertaken from the Water Management System (WMS) to identify volumetric allocations applied to individual bores. Results indicated that none of the groundwater facilities identified in **Table 12-1** have volumetric allocation limits applied to them. The spatial distribution of the groundwater facilities in and around the study area is shown in **Figure 12-1.**

There are 35 existing groundwater facilities within a 1 km radius of the study corridor. A summary of these is provided in **Table 12-1.**

Table 12-1 Groundwater facilities within a 1 km radius of the study corridor

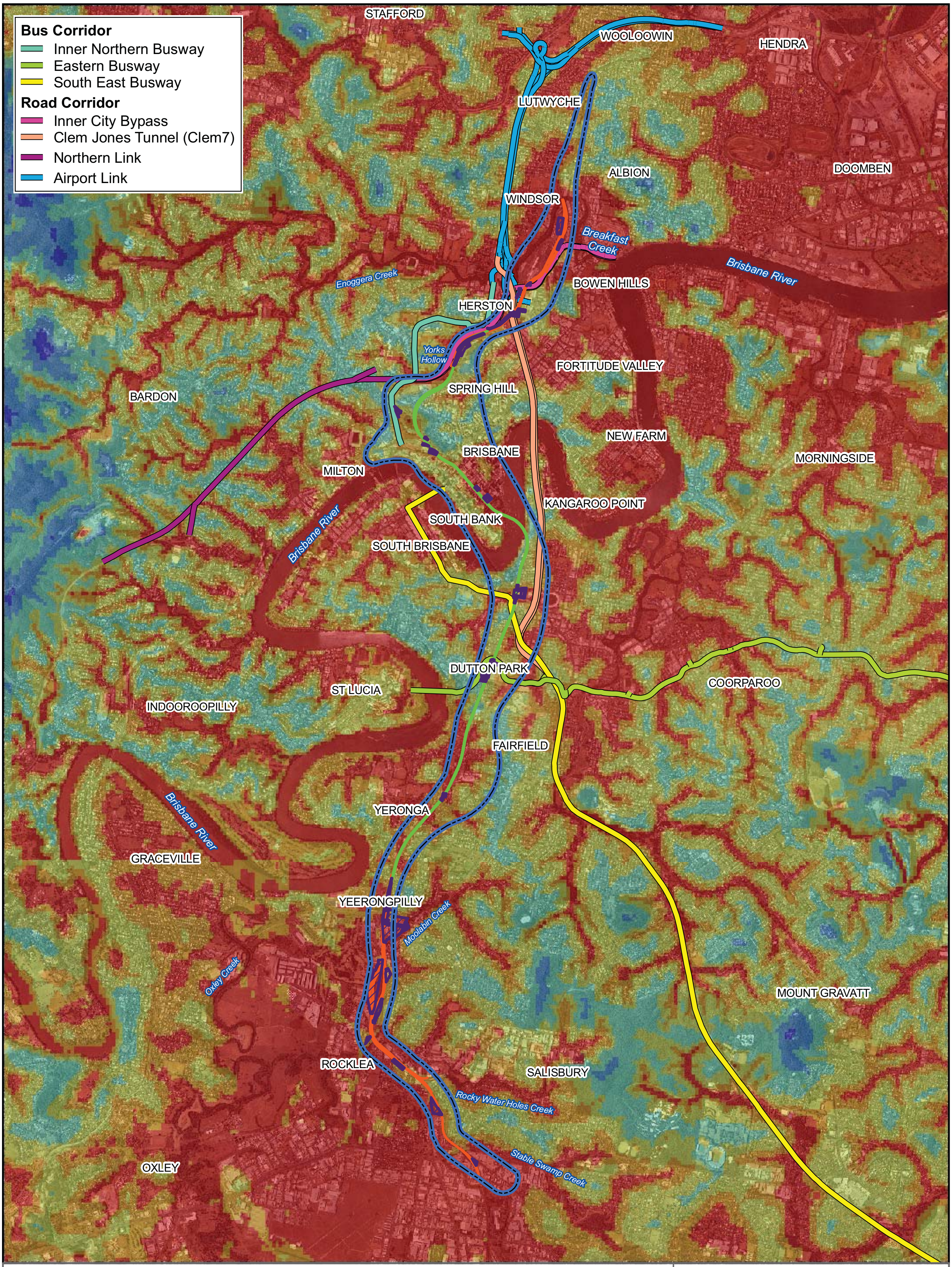
Section of study corridor	Number of bores	Range of Total Depth of Bore	Geology	Range of Yield
Northern section	17	8 to 80 m	Aspley Formation, Alluvium, Neranleigh- Fernvale Beds	0.06 to 1.88 L/s
Central section	5	12 to 36 m	Aspley Formation, Brisbane Tuff, Alluvium, Neranleigh-Fernvale Beds	0.03 to 0.38 L/s
Southern section	13	5.1 to 48 m	Aspley/ Tingalpa Formation, Alluvium, Woogaroo Sub-group	0.05 to 4.4 L/s

Source*:* DERM 2010b

Some bores within the Brisbane Tuff have been utilised for irrigation purposes for a long period of time, such as the Brisbane Exhibition Ground and Perry Park extraction bores (EHA 2006). One historical bore constructed within the Neranleigh–Fernvale Beds was recorded in the Fortitude Valley supplying a commercial laundry at approximately 2 L/second (EHA 2006).

Groundwater extraction during construction for dust suppression and other construction activities is not envisaged for the Project.

Mapping of the depth to water table is provided in **Figure 12-2.** Based on **Figure 12-2**, a shallow groundwater table (< 5 m BGL) is generally encountered along and in association with drainage lines. From available data the inferred groundwater levels in the alluvial aquifer range from 0.52 to 8.22 m BGL. Groundwater levels in the Aspley and Tingalpa Formations range from 1.59 to 9.81 m BGL. The groundwater levels in the Brisbane Tuff ranges from -0.03 to 24.5 m BGL. The Bunya Phyllite groundwater levels range from 0 to 20.70 m BGL. Groundwater levels in the NFB vary from -0.06 to 20.7 m BGL. Given the lack of long term groundwater level monitoring data available for this Project, seasonal trends in groundwater levels are unknown.



LEGEND

Study Corridor

Depth to Water Table (m)

- 0 - 5
- 5 - 10
- 10 - 20
- 20 - 50
- 50 - 100
- > 100

Alignment

- Above Ground
- Underground
- Worksites

CROSS RIVER RAIL
ENVIRONMENTAL IMPACT STATEMENT

Figure 12-2

Depth to Water Table

0 0.5 1 1.5 2 2.5 km

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12.2.4 Groundwater levels

Broad trends in groundwater levels for the hydrogeological units can be inferred from geotechnical and groundwater drilling undertaken for previous projects and for the Project. Groundwater levels in the study area are variable and are a subdued reflection of topography, except in areas where the water table has been impacted by existing infrastructure, eg basement dewatering). A summary of groundwater levels from previous investigations is provided in **Table 12-2.**

Table 12-2 Groundwater levels within the study area

Project	Year	Approximate location within / from Study Corridor (Refer to Figure 12-2)	Geological unit	Groundwater Level or Range (m BGL*)
North South Bypass Tunnel (Clem Jones tunnel)	2004	500 m east of study corridor. Intersects study corridor around Herston and Woolloongabba	Alluvium	1.02 – 5.33
			Brisbane Tuff	0.25 – 24.5
			Neranleigh–Fernvale Beds	4.01
			Open tidal hole	2.93 – 6.13
Northern Link	2008	Intersects western portion of study corridor near Milton. Less than 1 km from Roma Street Station	Alluvium	0.52 – 1.80
			Bunya Phyllite	0 – 20.70
			Neranleigh–Fernvale Beds	5.8 – 20.7
Airport Link	2006	500 m north west of study corridor from Herston through to Wooloowin. Intersects study corridor at Herston	Alluvium	1.66 – 8.22
			Brisbane Tuff	-0.03 – 10.94
			Tingalpa Formation	1.59 – 9.81
			Aspley Formation	5.33
			Neranleigh–Fernvale Beds	10.93
Inner Northern Busway	2000	Intersects study corridor in Brisbane City from Queen Street to Roma Street	Alluvium	2.8 – 6.5
			Bunya Phyllite	13.5
			Neranleigh–Fernvale Beds	13.1
Eastern Busway	2009	Less than 1.5 km east of study corridor from Woolloongabba	Alluvium	1.07 – 3.55
			Neranleigh–Fernvale Beds	-0.06 – 3.54
			Brisbane Tuff	2.82

Project	Year	Approximate location within / from Study Corridor (Refer to Figure 12-2)	Geological unit	Groundwater Level or Range (m BGL*)
Boggo Road Busway	2007	Intersects study corridor near Dutton Park	Aspley Formation	7.9
			Brisbane Tuff	12.2 – 18.6

Notes:
**m BGL - metres Below Ground Level*
Sources:
Sinclair Knight Merz (May, 2009) “Hydrogeological Investigations Phase 1 Report Eastern Busway” Brisbane, Australia.
Douglas Partners (October, 2007) “Report on additional Geotechnical Investigation Boggo Road Busway – Stage 2 Dutton Park” Brisbane, Australia.
City Design (May, 2000) “Inner Northern Busway Section 1 (King George Square) Geotechnical Investigation” Brisbane, Australia.
Australasian Groundwater & Environmental Consultants Pty Ltd (May, 2006) “Hydrogeological Environmental Impact Assessment Airport link Project” Brisbane, Australia.
Sinclair Knight Merz (October, 2008) “Hydrogeological Assessment – Technical Report for Reference Design Northern Link Tunnel” Brisbane, Australia.
Australasian Groundwater & Environmental Consultants Pty Ltd (October, 2004)
“Hydrogeological Environmental Impact Assessment North-South Bypass Tunnel” Brisbane, Australia.

In addition to the data drawn from previous studies, a number of boreholes were drilled at Dutton Park as part of the initial Project geotechnical investigations (Phase 1). Three groundwater monitoring bores were installed as part of these investigations and are shown in **Figure 7-10** of **Chapter 7 Topography, Geology, Geomorphology and Soils**. Details of these bores are provided in **Table 12-3.**

Table 12-3 Groundwater bore details – Phase 1

Borehole No.	Location	Total Depth of Bore (m)	Lithology
CRR101	Near alignment in Cornwall Street	30	Tuff, Breccia, Sandstone
CRR102	East of existing corridor at the End of Cope Street	20	Fill, Sandstone, Conglomerate, Siltstone
CRR103	West of existing corridor in Nobel Street	20	Fill, Tuff, Sandstone, Breccia, Siltstone

A long-section has been developed from the above information showing the likely water table profile along the study area in relation to topography. This long-section is shown in **Figure 12-3.**

Additional boreholes were installed as part of the Phase 2 Geotechnical Investigations (Golder Associates Pty Ltd 2010). Details of these additional bores are provided in **Table 12-4.**

Table 12-4 Groundwater bore details - Phase 2

Borehole No.	Easting	Northing	Top Screen (m, AHD)	Bottom Screen (m, AHD)	SWL (m, BGL)	SWL (m, AHD)	Aquifer(s)
CRR201	502129	6961818	5.4	-22.2	7.46	5.24	Neranleigh-Fernvale
CRR202	502732	6961305	22.5 mbgl	45 mbgl	-	-	Neranleigh-Fernvale
CRR203	502763	6961178	24.5 mbgl	44.55 mbgl	-	-	Neranleigh-Fernvale
CRR204	503036	6960985	-16.1	-45.7	4.3	-0.29	Neranleigh-Fernvale
CRR205	502841	6961116	-9.8	-39	-	-	Neranleigh-Fernvale
CRR207	503413	6960804	-10.05	-47.05	-	-	Brisbane Tuff
CRR208	503296	6959926	-0.85	-27.55	-	-	Brisbane Tuff/ Neranleigh-Fernvale
CRR209	503264	6959897	3.73	-22.17	-	-	Brisbane Tuff/ Neranleigh-Fernvale
CRR210	502960	6958824	24.44	-6.76	10.15	23.09	Brisbane Tuff
CRR211	502416	6957252	-15.66	-36.86	-	-	Aspley and Tingalpa Formation
CRR212	501997	6956616	-4.38	-31.58	-	-	Aspley and Tingalpa Formation
CRR213	501820	6956414	3.1	-24.7	-	-	Aspley and Tingalpa Formation
CRR214	501624	6956103	6.57	-15.33	-	-	Aspley and Tingalpa Formation
CRR215	501491	6955728	11.67	-1.43	-	-	Aspley and Tingalpa Formation

Borehole No.	Easting	Northing	Top Screen (m, AHD)	Bottom Screen (m, AHD)	SWL (m, BGL)	SWL (m, AHD)	Aquifer(s)
CRR216	502827	6958586	25.13	2.33	-	-	Aspley and Tingalpa Formation
CRR217	501525	6955903	8.04	-6.86	-	-	Aspley and Tingalpa Formation
CRR218	503284	6959923	0.11	-29.17	-	-	Brisbane Tuff/ Siltstone
CRR219	502119	6961821	3.71	-27.09	7.22	5.69	Siltstone

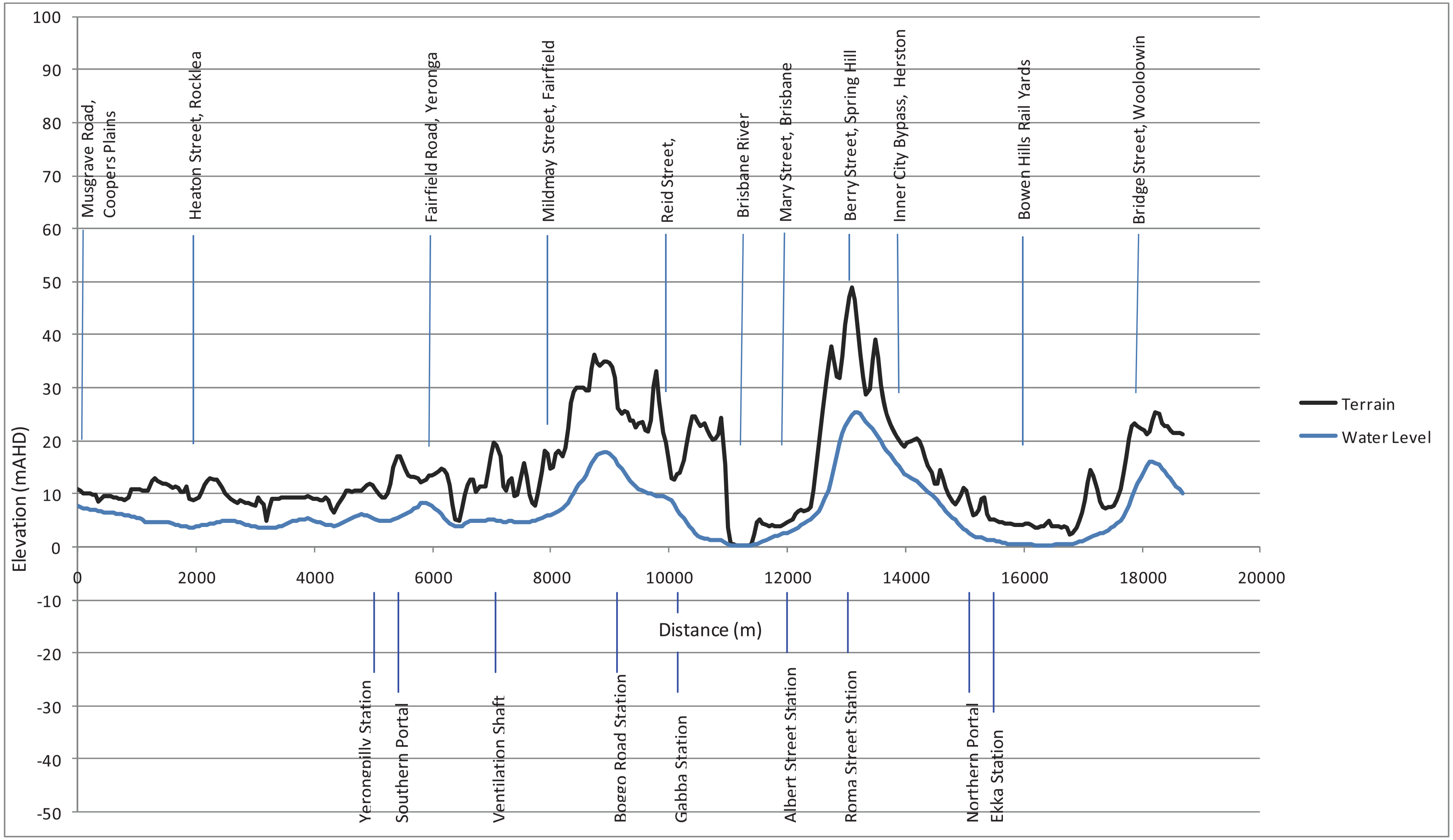
Source: Golder Associates Pty Ltd 2010

A review was undertaken as part of the Project geotechnical investigations with respect to the CBD basement construction. In areas of soft-compressible soils, lowering of groundwater levels via dewatering has the potential to result in ground settlement. Settlement can result in impacts to existing structures, such as cracks in buildings. This review identified that in areas where basements are draining groundwater, there were no reported/obvious signs of impacts to existing structures due to settlement as a result of lowering groundwater levels. Therefore, it is considered that recharge (predominantly from the river) is sufficient to maintain groundwater levels in the vicinity of any pockets of soft compressible soils; or basements that are draining groundwater are not in the vicinity of any pockets of soft-compressible soils. Further details of potential settlement within each section of the study corridor are summarised in **Section 7.3.3** to **Section 7.3.5** of **Chapter 7 Topography, Geology, Geomorphology and Soils.**

The available hydrogeological data has been compiled to provide a preliminary indication of depth to water table for the study area using derived secondary variables from a Digital Terrain Model (DTM)[2].

A number of modelled surfaces were compiled and then calibrated against the available bore data. The underlying hypothesis was that in unconfined aquifers flowing under topographic gradients, the water table would be a smoothed and subdued reflection of topography (Desbarats *et al.* 2001). That is, the water table would be proportionally deeper under locally higher topographic features.

[2] Field investigations will provide site specific data against which it can be more broadly calibrated.



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ENVIRONMENTAL IMPACT STATEMENT

Figure 12-3

Water Table Profile along Study Area: Long-Section

12.2.5 Groundwater flow

A groundwater elevation contour map has been developed based on the available groundwater data described above (*Figure 3-4* within *Technical Report No. 4 – Groundwater Assessment* provides an indication of groundwater flow direction).

In general, groundwater flows from areas of higher water table elevation, down-gradient towards the Brisbane River, creeks and drainage channels which comprise discharge zones (AGE 2004, 2006). As a generalisation, regional groundwater flow is towards the Brisbane River. Considering the heterogeneous nature of the alluvial aquifer sediments and the variability in annual and seasonal recharge, the rate of this down valley flow is expected to be spatially and temporally non-uniform. The majority of flows are likely to be constrained to higher permeability pathways where sands and gravels are present, with much smaller volumes discharged through lower permeability sediments.

The groundwater monitoring program will provide site specific hydrogeological data to characterise groundwater flow at drained locations including underground station sites, Fairfield shaft and tunnel portals (see **Section 12.3.5**).

Surface water – groundwater interaction

The dominant hydrological feature in the study area is the Brisbane River. Three major waterway catchments exist on either side of the Brisbane River which are the Oxley Creek Catchment, Norman Creek Catchment and the Breakfast/Enoggera Creek Catchment. Within the study area, these rivers and creeks are tidal in nature. Drainage from the study area is either direct to the Brisbane River or into one of the three the main waterways catchments which ultimately drain to the Brisbane River (AGE 2004, 2006).

Surface water – groundwater connectivity may occur at the creeks and rivers associated with the catchments. This is influenced by depth to water table and the hydraulic conductivity of the aquifer and stream bed sediments. A review of available data shows that shallow groundwater monitoring bores within the vicinity of the Brisbane River display groundwater level fluctuations consistent with tidal levels. This suggests that the shallow aquifers adjacent to the Brisbane River are in hydraulic connection with the River.

The groundwater monitoring program to be undertaken will provide site specific hydrogeological data to characterise surface water - groundwater interaction at the underground worksites (refer to **Section 12.3.5**).

12.2.6 Groundwater quality

Water quality data obtained for boreholes located within the vicinity of the study area is available from existing groundwater facilities recorded in the DERM groundwater database and from the Eastern Busway and NSBT projects. A review of groundwater quality results from other projects within the general Brisbane area has also been undertaken for comparison, and the results are presented in **Table 12-5**.

Table 12-5 Groundwater quality data within the Brisbane area

Aquifer	No. of Monitoring Bores	pH (range)	Total Dissolved Solids mg/L (range)
Airport Link			
Alluvial	6	5.89 – 7.90	540 – 3819
Brisbane Tuff	5	4.34 – 7.14	293 – 1717
Neranleigh-Fernvale Beds	1	6.49 – 7.98	334 – 368
Tingalpa Formation	4	5.91 – 7.89	161 – 1042
S1 Sewer Tunnel			
Neranleigh-Fernvale Beds	1	6.7	3540
NSBT			
Alluvium	4	5.4 – 6.8	570 – 3200
Brisbane Tuff	4	6.4 – 6.9	860 – 3200
Neranleigh-Fernvale Beds	2	6.7 – 7.3	15000 – 22000
Northern Link			
Alluvium	-	6.52 – 7.27	1494 – 2508
Bunya Phyllite	-	4.6 – 7.7	300 – 5000
Neranleigh-Fernvale Beds	-	6.7	300 – 30000
Eastern Busway			
Alluvium	3	6.79 – 8.03	1762 – 6821
Brisbane Tuff	1	6.18	1983
Neranleigh-Fernvale Beds	3	5.87 – 7.07	2909 – 7732
DERM Groundwater Database			
Not specified	17	4.5 – 8.4	33 - 9896

In general, the quality of groundwater within the NFB and the Brisbane Tuff is spatially variable and considered poor, and ranging from fresh to brackish. Available pH data indicate that groundwater ranges from acidic to neutral conditions.

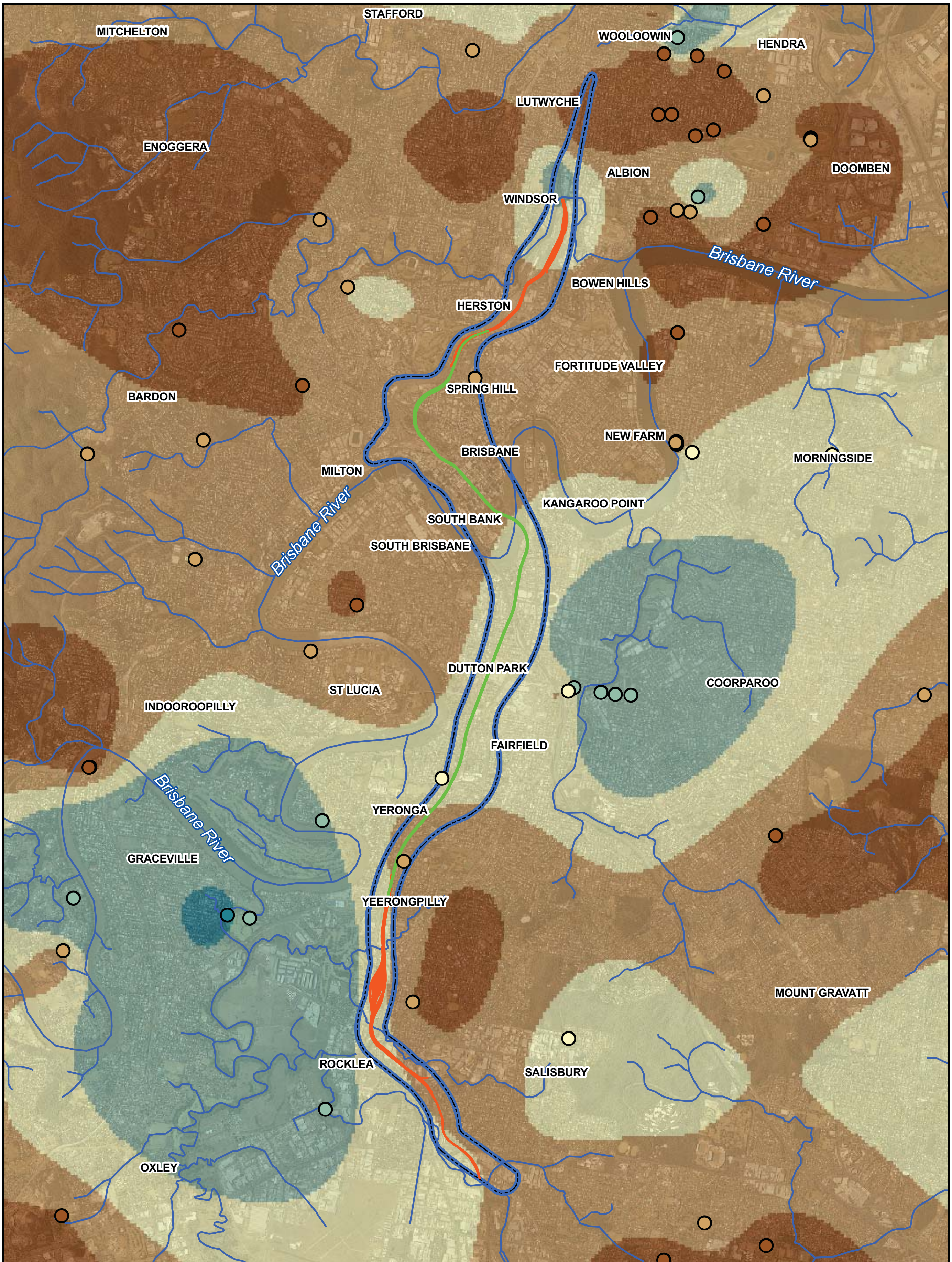
A groundwater salinity map has been developed based on existing available data and Groundwater Database records (refer to **Figure 12-4)**.

Groundwater within the alluvial aquifer is fresh to brackish, with the pH ranging from acidic to slightly alkaline. Groundwater quality in the alluvial aquifers is variable and will be dependent on the proximity of creeks or rivers and associated tidal influences, including saline intrusion.

Groundwater quality monitoring collated by AGE (2004, 2006) from the NSBT and Airport Link projects suggests there will be a marked difference in water quality along the study area, as the Project intersects a variety of geological units and passes under the Brisbane River.

The groundwater quality results indicate that groundwater quality in the fractured rock will generally be of poor quality that is unsuitable for drinking water. In the older, highly urbanised areas, nutrient levels can also be expected to be elevated due to the application of fertilisers on gardens.

The groundwater monitoring program to be undertaken will provide site specific hydrogeological data to characterise groundwater quality in areas disturbed by tunnelling or other subsurface works (refer to **Section 12.3.5**).



LEGEND

Study Corridor

Sample Sites (mg/L)
- 10 - 500
- 500 - 1,500
- 1,500 - 3,000
- 3,000 - 14,000
- 14,000 - 16,000

Groundwater Salinity
- 10 - 500
- 500 - 1,500
- 1,500 - 3,000
- 3,000 - 14,000
- 14,000 - 16,000

Alignment
- Above Ground
- Underground

CROSS RIVER RAIL
ENVIRONMENTAL IMPACT STATEMENT

Figure 12-4
Groundwater Salinity

0 0.5 1 1.5 2 2.5 km
N

1:75,000 at A4

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Groundwater contamination

An assessment of potential contaminated land risk to groundwater quality is based on the assessment of the Environmental Management Register (EMR) and the Contaminated Land Register (CLR) presented in **Chapter 8 Land Contamination**. The assessment sought to identify whether there is a potential risk of a historical or existing land use to have contaminated groundwater resources. The assessment included the study corridor and a surrounding 1 km buffer area located outside the study corridor to account for potential groundwater drawdown.

The contaminated site investigation identified the presence of a number of sites within the study area with an existing or historical land use with the potential to cause land and hence groundwater contamination. Due to the point source nature of the contaminants, it would be extremely difficult to identify the location of all potential contaminant plumes. From the findings presented in **Chapter 8 Land Contamination**, it is highly likely that groundwater is contaminated within the vicinity of contaminated sites.

Hydrocarbon and nutrient contaminants have been identified in Norman Creek, Brisbane River and Breakfast Creek. Groundwater connectivity may occur at the creeks and rivers associated with the catchments. A review of available data shows that shallow groundwater monitoring bores within the vicinity of the Brisbane River have been identified as displaying groundwater level fluctuations consistent with tidal levels. This suggests that the shallow aquifers are in hydraulic connection with the River and there is a potential for contaminants to be admitted into the Project tunnels.

Areas of localised groundwater contamination, particularly of petroleum hydrocarbons are likely to be located in the rockmass along the study area (AGE 2004, 2006).

Acid Sulphate Soils (potential – groundwater acidification)

The occurrence of actual Acid Sulphate Soils (ASS) and Potential Acid Sulphate Soils (PASS) is reported in **Chapter 7 Topography, Geology, Geomorphology and Soils**.

ASS is present within the study area, including along Breakfast/ Enoggera Creek, Norman Creek, Oxley Creek and Brisbane River. Based on the *Queensland Acid Sulfate Soil Technical Manual* (Dear, D. E. *et al,* 2004), harmful substances can be transferred from the site of acid generation by surface water and/or groundwater. The mixing of acid deposits with surface water or groundwater results in the formation of acidic waters. The disturbance or dewatering of ASS can result in a degradation of the aquatic environment and poses both short and long term risks to riverine, estuarine and near-shore marine biota.

Considering the existing land use and highly developed nature of the study area, some groundwater acidification is likely to have occurred in some areas. It is also likely that ASS in some areas has already been excavated and in-filled with fill (clean) material for new developments and hence no longer exists.

12.2.7 Groundwater dependent ecosystems

Groundwater Dependant Ecosystems (GDEs) are ecosystems which have their species composition and their natural ecological processes determined by groundwater (ANZECC and ARMCANZ 2000). **Chapter 11 Nature Conservation** provides an overview of the sensitive terrestrial and aquatic ecosystems within the study area. The key findings indicate that:

- during dry seasons, terrestrial vegetation particularly large remnant trees, may be dependent on groundwater where the water table is close to the surface
- shallow water tables occur to the north of Brisbane River near the Brisbane CBD and City Botanic Gardens. The main species that may be influenced by groundwater are large remnant Forest red gums.

- wetlands at Yorks Hollow, City Botanic Gardens and Roma Street Parklands are all constructed and appear to be perched well above the regional water table
- the mangrove forests along Breakfast Creek/Enoggera Creek and the Brisbane River may be groundwater dependent ecosystems, however the degree of freshwater dependency is generally unknown for such systems.

The greatest potential for groundwater dependency is likely to be within shallow alluvial sequences associated with drainage lines. In these areas the water table is likely to be permanently shallow and above the maximum rooting depth of established vegetation. Given that the drainage lines within the study area are mostly saline to brackish and tidal in nature, it is anticipated that groundwater in these areas also has a saline nature. Groundwater levels in these areas are likely to be tidally influenced and the water table is likely to fluctuate accordingly.

The level of groundwater dependency in these areas is likely to be relatively low and opportunistic at best, with mostly salt-tolerant species potentially utilising groundwater in these saturated zones. Given the local climatic conditions and drainage characteristics of these areas it is considered that surface water runoff and infiltrated rainfall represent the primary source of flux required to satisfy plant water requirements.

Established vegetation on residual soil or imported fill within park areas may also potentially utilise groundwater opportunistically during dry periods, however, the potential level of dependency is likely to be even less than for vegetation in the vicinity of drainage lines, as shallow groundwater in non-alluvial sequences is likely to represent interface drainage which persists only following rainfall events.

12.2.8 Groundwater – environmental values

Section 6 of the *Environmental Protection (Water) Policy 2009* defines environmental values to be enhanced or protected. For the Project, environmental values are defined for the following water systems:

- Brisbane River, including all tributaries of the Brisbane River estuary other than Oxley Creek (Basin No. 143)
- Brisbane Creeks – Bramble Bay, including Bald Hills, Cabbage Tree, Downfall, Kedron Brook, Nudgee and Nundah creeks (Basin No. 142)
- Oxley Creek, including all tributaries of the creek (Basin No. 143).

The environmental values applicable to these water systems are described in the following sections and include aquatic ecosystems, drinking water, irrigation, stock water and farm supply. Neither the values of stock water nor farm supply are potentially affected by the Project.

Aquatic ecosystems

Groundwater quality within the investigation area is likely to be ‘non pristine’ due to the level of anthropogenic development and associated artificial recharge. Furthermore, the area has been significantly disturbed as a result of surface development. Given the saline to brackish nature of groundwater which is influenced by the tidal creeks and rivers within the study area, any aquatic ecosystems that may exist within the study area are considered to be salt tolerant. Based on this, groundwater quality as a function of aquatic ecosystem health is considered negligible.

Drinking water

Comparison of the existing groundwater quality to the Australian drinking water guideline indicates that the groundwater within the alluvium and basement rocks is generally unsuitable for potable use, primarily due to elevated salinity levels. Opportunities for groundwater extraction and use are also considered negligible due to the low yields associated with the primary hydro-stratigraphic units.

Irrigation

Based on the available water quality data, groundwater sourced from the study area generally is considered to be too saline for general irrigation use as outlined in the ANZECC and ARMCANZ document (2000) water quality guidelines. However, it has been identified that the RNA Showgrounds source groundwater from a shallow alluvial aquifer for irrigation purposes. This has been taken into consideration in this assessment.

12.3 Potential impacts and mitigation measures

12.3.1 Potential impacts

Groundwater modelling was undertaken for the construction and operation phases of the Project. The construction phase was simulated only for excavation areas and not the tunnelling. Tunnelling was not simulated, as the method of construction using the Tunnel Boring Machine (TBM) would result in inflows that are no greater than those expected during normal tunnel operation. Groundwater drainage mitigation during construction is as follows:

- TBM driven tunnels would be lined with pre-cast segmental concrete linings. Gaskets would be included wherever these linings are used to create a waterproof lining.
- The cross-passages linking the TBM driven tunnels would be undrained.
- All tunnel sections would be constructed by TBM and as a consequence, would be undrained.
- Only station locations would be drained in the rock and undrained in the alluvium.

Modelling approach

The model is aimed at quantifying the following potential impacts associated with tunnel inflows:

- depressed groundwater levels at the underground stations and ventilation shaft locations, affecting existing groundwater users or GDEs
- drawdown in groundwater levels affecting areas of ASS (particularly along Brisbane River)
- reduced discharge to streams and rivers
- increased flux of saline water from the Brisbane River into the aquifer and potentially into the tunnel itself.

Supply of construction water is anticipated to be sourced off-site. However, it is anticipated that some off-site sourcing can be offset against groundwater recovered from the excavations on-site. No active dewatering or groundwater pumping would be undertaken to source water for construction purposes. Groundwater recovered on-site will be treated prior to discharge.

A groundwater risk assessment has been undertaken and the outcomes are presented in *Technical Report No.4 – Groundwater Assessment*.

The available hydrogeologic information was used to calibrate the groundwater model. A modelling approach was been adopted that uses information gained from recently completed tunnelling projects elsewhere in Brisbane to supplement the data collected thus far for the Project. The model was calibrated by matching model predicted groundwater levels to the simulated potentiometric surface, as well as the observed dataset.

Based on the above information, the reference design was simulated. This model was based on the design summarised in **Table 12-6**.

Table 12-6 Summary of groundwater drainage

Section	Groundwater Drainage
Yeerongpilly portal	Dive structures at portal trough – drained; cut and cover approach tunnels immediately north of portal – undrained
Yeerongpilly – Boggo Road tunnels	Undrained – segmental linings with gaskets; undrained cross-passages
Ventilation and emergency access building	Undrained in soil – base of shaft in rock – drained.
Boggo Road Station	Drained
Boggo Road – Woolloongabba Station tunnels	Undrained –segmental linings with gaskets; undrained cross-passages
Woolloongabba Station	Undrained section for cut and cover elements protruding above rock (station sited in paleo-channel) - base of box and cavern elements drained (i.e. openings in rock drained)
Woolloongabba – Albert Street Station tunnels	Undrained – segmental linings with gaskets; undrained cross - passages
Albert Street Station	Undrained section for cut and cover elements protruding above rock – base of boxes and cavern elements drained
Albert Street – Roma Street tunnels	Undrained – segmental linings with gaskets; undrained cross-passages
Roma Street Station	Drained (southern shaft/central shaft may require groundwater cut-off to rock depending on profile)
Roma Street – north portal tunnels	Undrained – segmental linings with gaskets; undrained cross-passages; mined tunnels immediately south of portal/dive structure – drained
Northern portal	May require groundwater cut-off to rock depending on site (near paleochannel) - openings in rock drained

Source: AECOM, 2010b

Reference should be made to **Figure 12-6**, **Figure 12-7** and **Figure 12-8** for the predicted groundwater drawdown for 1 year, 5 years and 10 years following tunnel construction. *Technical Report No. 4 – Groundwater Assessment* presents full details of the modelling results.

12.3.2 Estimated groundwater inflow

The groundwater models were set-up to provide an estimate of groundwater inflow into the drained tunnel areas during construction and operation. **Figure 12-5** presents the model results.

As shown in **Figure 12-5**, the rate of groundwater inflow into the drained sections of the tunnel is shown to decrease over time. The average groundwater inflows post-construction is <1 L/second.

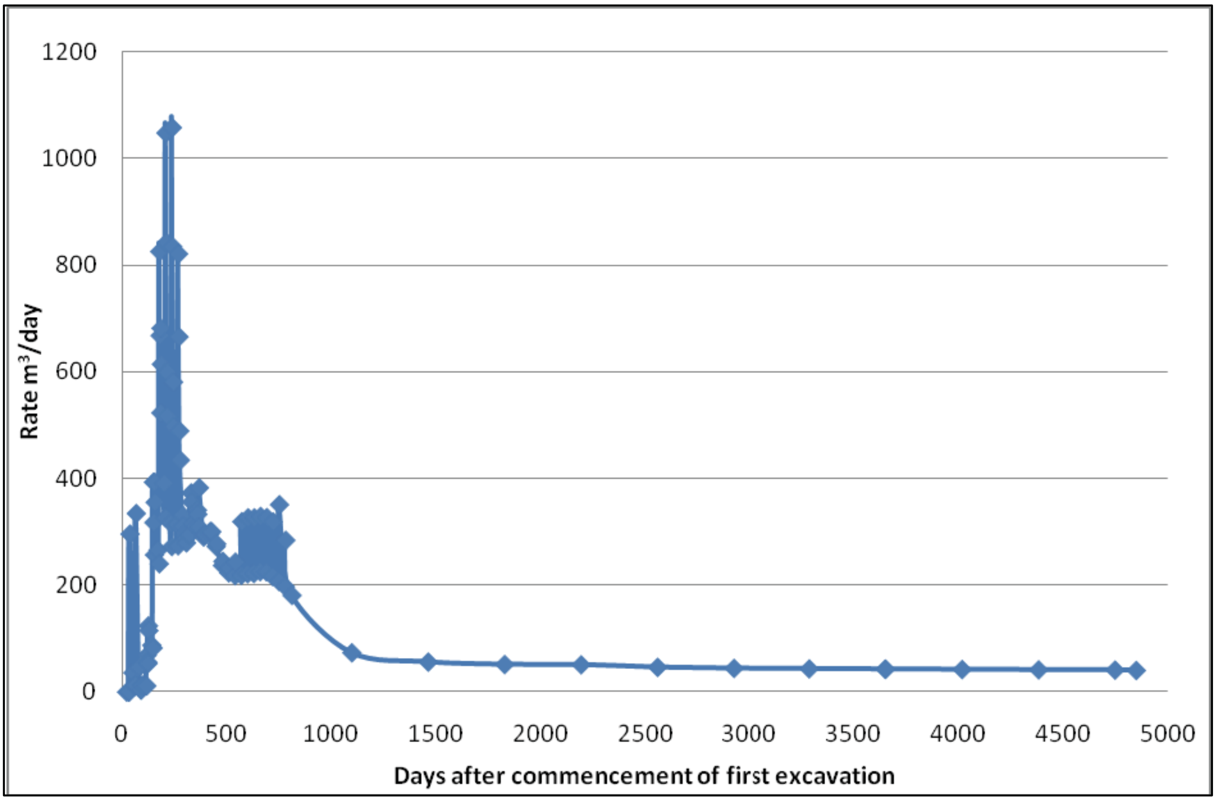

Figure 12-5 Estimated daily groundwater inflows into the entire tunnel system

12.3.3 Groundwater flow

For the operation phase of the Project, groundwater heads for each of the modelled scenarios have been predicted for the first 10 years, or 3650 days.

Each of the modelled scenarios indicates a falling hydraulic gradient towards the Brisbane River during steady state. A review of modelled groundwater heads at 3650 days following construction shows there would be little change in groundwater flow over time for all of the modelled scenarios.

Locally in drained tunnel areas, steep vertical downward hydraulic gradients are predicted to develop between the alluvial aquifer and the fractured rock aquifer in proximity to the tunnel sections of the Project. Leakage of groundwater from the alluvial aquifer to the fractured rock aquifer and ultimately to the tunnel itself may result.

River leakage prediction

Drainage of groundwater into the tunnel may cause leakage of water from the Brisbane River into the groundwater system. Drawdown associated with nearby drained sections (underground stations) of the tunnel is predicted to alter the hydraulic gradient and flow regime of groundwater resulting in potential discharge of saline water into these sections of the tunnel. However, based on the model results, changes in baseflow and/or increases in leakage from the Brisbane River are expected to be minimal and below detection levels.

12.3.4 Groundwater drawdown

Groundwater drawdown has been predicted for 1 year, 5 years and 10 years following tunnel construction. Groundwater drawdown occurs around the drained sections of each tunnel and the station locations. Groundwater modelling suggests that some of these drawdown areas would occur below alluvium.

There is a possibility that shallow alluvial aquifers may exist in these areas. Groundwater drawdown in the underlying rock to drained portions of a tunnel therefore may impact upon groundwater in the shallow alluvial systems (if they are hydraulically connected).

Settlement resulting from tunnel excavation/construction activities may arise due to:

- elastic ground settlements caused by the excavation of the tunnel
- consolidation settlements caused by dewatering of porous rock formations or compressible soil layers that are hydraulically connected to groundwater drawn down into the tunnel excavations.

A preliminary review of the settlement effects of construction based on preliminary finite element analyses, empirical relationships between shaft and tunnel depths, ground conditions and with allowances for initial disturbance due to excavation/pile installation is listed in **Table 7-10** of **Chapter 7 Topography, Geology, Geomorphology and Soils**. Higher risk locations include Lower Albert Street Station, Gabba Station and Boggo Road Station.

Predicted drawdown for 1 year, 5 years and 10 years after construction are shown in **Figure 12-6, Figure 12-7** and **Figure 12-8** respectively. The refinement of drawdown gradation is limited by the coarseness of the model, which utilises 100 m by 100 m grid squares. As such, refinements to the modelling would be developed further during detailed design to characterise and assess drawdown propagation based upon site knowledge.

Northern Portal to Roma Street Station

The groundwater drawdown predicted from Roma Street Station towards Herston in the north would be in the range of 1 to 5 m after the first year post-construction. The areal extent of drawdown would range from 150 m from the centre of the alignment after the first year post-construction to 350 m from the centre of the alignment after 10 years post-construction.

Groundwater drawdown of greater than 5 m in the northern part of the study area would be concentrated around the Roma Street Station. Following the first year post-construction, groundwater drawdown would be localised around a 500 m section of the tunnel centred on Roma Street Station.

Following 10 years post-construction, groundwater drawdown would extend along the length of the rail alignment up towards Herston to the north and down towards Albert Street Station to the south. Drawdown in the range of 5 to 10 m would be experienced within close proximity to the tunnels with localised areas of 10 to 20 m of drawdown. The aerial extent of groundwater drawdown (> 5 m) is less than 50 m from the tunnel for both year 1 and 5. The aerial extent of drawdown (> 5 m) following 10 years of tunnel operation is approximately 125 m from the tunnel.

Roma Street Station to Albert Street Station

The predicted groundwater drawdown for that section between Roma Street Station and the City Botanic Gardens would be 1 to 5 m after the first year post-construction. The areal extent of drawdown would range from 150 m from the centre of the alignment following the first year of operation to 350 m from the centre of the alignment following 10 years of operation.

LEGEND

- Study Corridor
- Tunnel Alignment
- Existing Groundwater Bores
- Extraction Bores
- Watercourse

CROSS RIVER RAIL
ENVIRONMENTAL IMPACT STATEMENT

Figure 12-6

Modelled Drawdown at 300 days (1 year)

0 0.5 1 1.5 2 2.5 km

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LEGEND

- Study Corridor
- Tunnel Alignment
- Existing Groundwater Bores
- Extraction Bores
- Watercourse

CROSS RIVER RAIL
ENVIRONMENTAL IMPACT STATEMENT

Figure 12-7

Modelled Drawdown at 1800 days (5 years)

0 0.5 1 1.5 2 2.5 km

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LEGEND

- Study Corridor
- Tunnel Alignment
- Existing Groundwater Bores
- Extraction Bores
- Watercourse

CROSS RIVER RAIL
ENVIRONMENTAL IMPACT STATEMENT

Figure 12-8

Modelled Drawdown at 3650 days (10 years)

0 0.5 1 1.5 2 2.5 km

1:75,000 at A4

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Groundwater drawdown in excess of 5 m is predicted for a 1 km section along Albert Street in the first year post-construction. After 10 years post-construction, groundwater drawdown in excess of 5 m is predicted to extend along the length of the tunnels towards Roma Street Station in the north and to the City Botanical Gardens in the south. Groundwater drawdown is predicted to reach tunnel invert level (-20 m to -30 m) in the immediate vicinity of Albert Street Station within 5 years post-construction. The areal extent of groundwater drawdown (>5 m) is approximately 50 m during the first year post-construction. The extent of drawdown (>5 m) increases up to 150 m from the tunnel following 10 years post-construction.

Drawdown associated with Albert Street Station has the potential to impact on potential GDEs identified in the City Botanic Gardens. The impact on GDEs is assessed in *Technical Report No. 4 – Groundwater Assessment.* Drawdown has the potential to cause settlement at Albert Street Station which has been identified as a higher risk location. Settlement may impact on surrounding buildings. Potentially contaminated land parcels may also impact on groundwater quality, ultimately reducing the beneficial use of groundwater in this area.

Gabba Station

Groundwater drawdown is expected to occur around the Gabba Station. Groundwater drawdown of 1 to 5 m would extend approximately 200 m from the main tunnels and underground station at one year post-construction. The extent of drawdown would increase up to 350 m from the main tunnels and underground station by 10 years post-construction.

Groundwater drawdown in the range of 5 to 10 m is predicted to extend approximately 50 m from the main tunnels at one year post-construction. After 10 years, the extent of groundwater drawdown would increase up to 200 m from the main tunnels. Localised areas of 10 to 20 m drawdown within the immediate vicinity of the Gabba Station are predicted 5 years after construction.

Drawdown associated with Gabba Station has the potential to impact on potential GDEs identified along the Brisbane River. The impact on GDEs is assessed in *Technical Report No. 4 – Groundwater Assessment.* Drawdown has the potential to cause settlement at the Gabba Station and Boggo Road Station which have been identified as higher risk locations. Settlement may impact on surrounding buildings. Drawdown associated with the Gabba Station has the potential to cause groundwater acidification within the vicinity of the Brisbane River, if ASS materials exist. Potentially contaminated land parcels may also impact on groundwater quality, ultimately reducing the beneficial use of groundwater in this area.

Fairfield to southern portal

Groundwater drawdown is predicted along the main tunnel alignment between Yeronga and Yeerongpilly. Groundwater drawdown in the range of 1 to 5 m would extend approximately 300 m from the main tunnel alignment at one year post-construction. Following 10 years post-construction, groundwater drawdown would extend up to 1.5 km from the main tunnel alignment.

Groundwater drawdown in excess of 5 m is predicted to occur locally within the vicinity of the main tunnel alignment. The predicted areal extent of groundwater drawdown at one year post-construction would be approximately 100 m from the main tunnel alignment. The extent of groundwater drawdown at 5 years post-construction would be approximately 300 m and would increase up to 1 km at 10 years post-construction.

Drawdown associated with this area has the potential to cause groundwater acidification within the vicinity of the Brisbane River, should ASS materials exist. Potentially contaminated land parcels may impact on groundwater quality, ultimately reducing the beneficial use of groundwater in this area.

Localised drawdown is predicted at the ventilation and emergency access building. Groundwater drawdown of 1 to 5 m extends up to 75 m following the first year of tunnel operation. Following the fifth year of tunnel operation the extent of groundwater drawdown of 1 to 5 m is approximately 100 m. Following 10 years of tunnel operation, groundwater drawdown of 1 to 5 m extends up to approximately 125 m from the shaft. Groundwater drawdown of greater than 5 m occurs locally within the immediate vicinity of the shaft.

Drawdown associated with the ventilation and emergency access building at Fairfield has the potential to impact on groundwater quality. Potentially contaminated land parcels may also impact on groundwater quality, ultimately reducing the beneficial use of groundwater in this area.

Groundwater users

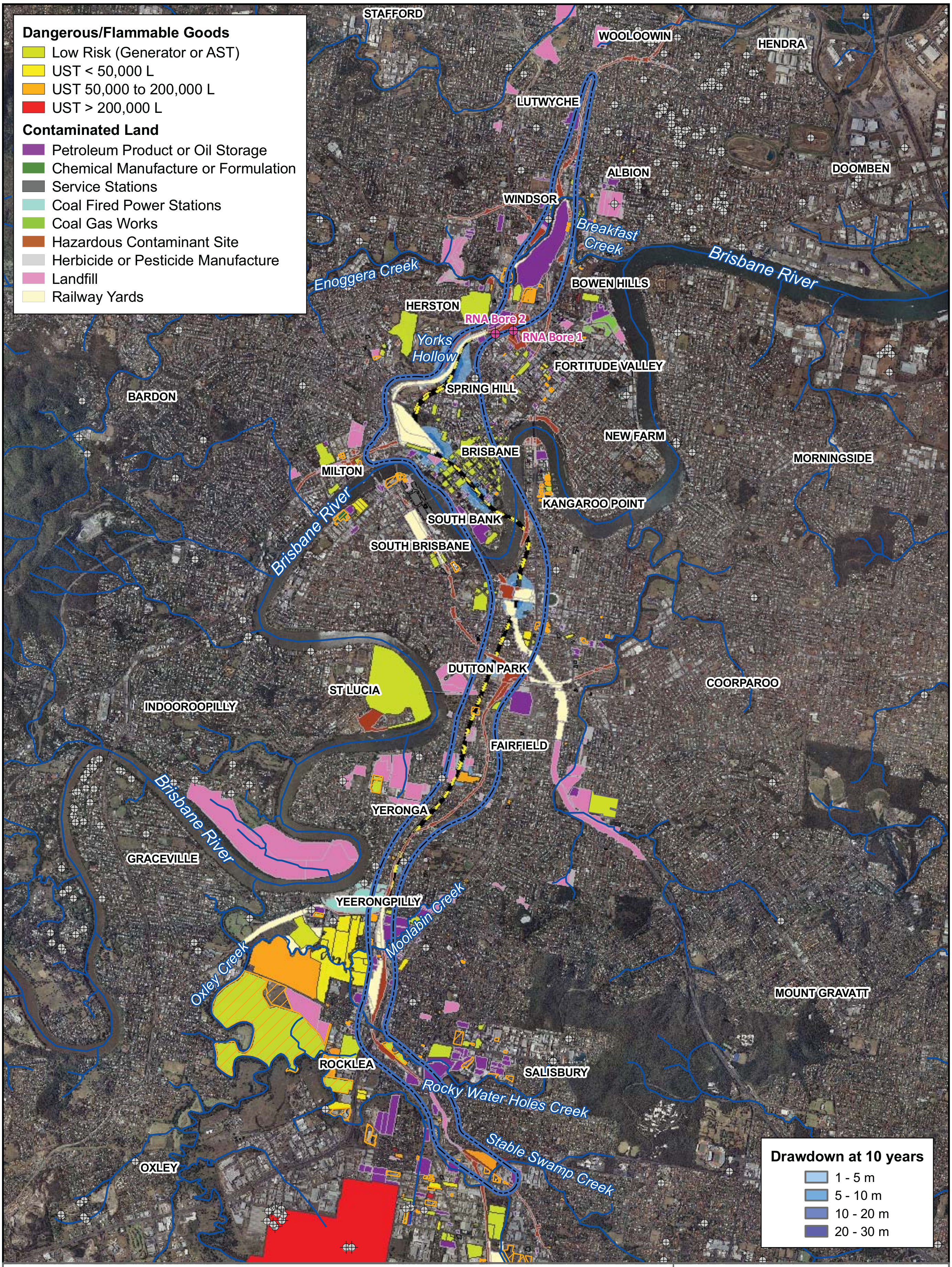
Based on the known groundwater levels in the existing bores in the RNA Showgrounds, there would be no noticeable change in head for either bore #1 or bore #2 in the 10 years post-construction for the reference design scenario. That the Project would be constructed largely at grade or above grade through the RNA site, and to the north of the RNA would influence this outcome. The tunnel construction works to the south, for the reference design, would not influence groundwater levels in either of the RNA bores.

Monitoring of head in either bore should continue as part of the RNA operations.

Groundwater contamination

As the extent of the groundwater drawdown cone extends so does the area in which contaminants in the groundwater potentially may be impacted. It is important to note that the capture zone is not totally dependent on the drawdown cone. Groundwater may be flowing towards the tunnel alignment regardless of drawdown so would ultimately be captured by the tunnel.

Potentially contaminated land parcels exist within the study area, as shown in **Figure 12-9**. Mobile groundwater contaminants within the tunnel “capture zone”, ie that volume of aquifer within which water flows to and discharges into the tunnel, will eventually discharge into the tunnel. The capture zone is effectively that region of aquifer that is within the “cone of depression” of the water table that forms in response to groundwater discharge into the tunnel. The tunnel capture zone can therefore be illustrated as that part of the aquifer that is subject to drawdown in response to seepage into the tunnel. These areas can be seen at 1, 5 and 10 years after tunnel construction in **Figure 12-6** to **Figure 12-8** respectively. Should there be dissolved contaminants in groundwater within the region of drawdown, then it would be expected that the contamination would eventually appear as seepage into the tunnel. However, given that the total expected inflow to the tunnel is <1 L/sec, the influx of contaminants entering the tunnel is likely to be small. Further discussion on potential impacts and mitigation measures associated with contaminants in groundwater is provided in **Chapter 8 Land Contamination**.



CROSS RIVER RAIL
ENVIRONMENTAL IMPACT STATEMENT

Figure 12-9

Potential Groundwater Contamination

Potential for disturbance of ASS

Areas where potential ASS may exist include Breakfast/Enoggera Creek, Norman Creek, Oxley Creek and Brisbane River. Considering the existing land use and highly developed nature of the study area, groundwater acidification is likely to have occurred to some extent. The extent of groundwater drawdown associated with underground construction would not reach Breakfast/Enoggera Creek, Norman Creek or Oxley Creek. The potential to lower groundwater levels in these areas and expose potentially acidic soils is therefore considered negligible. The extent of drawdown does however extend out to the Brisbane River in some areas. There is potential for groundwater acidification to occur in these areas if ASS materials exist. A groundwater monitoring program would be developed, as described in **Section 12.3.5**. Further quantification and characterization would be undertaken in drawdown zones within the vicinity of the Brisbane River where areas of ASS may exist. In the event that any ASS are encountered and disturbed during tunnel excavations, management plans would be put in place to contain these soils.

Groundwater Dependent Ecosystems (GDE)

The level of groundwater dependency in the study area is considered to be relatively low with terrestrial vegetation, river baseflow systems and aquifer systems potentially utilising groundwater in the saturated zone only during drought conditions where surface water flux is uncommon.

For the reference design, with the undrained, or lined tunnels, groundwater drawdown is predicted to be limited.

Groundwater drawdown may impact on GDEs identified within the City Botanic Gardens and Brisbane River areas (as previously noted). The decline in the rate of groundwater discharge as evapotranspiration is less than 0.1% and thus considered negligible.

Chapter 11 Nature Conservation provides an overview of the sensitive terrestrial and aquatic ecosystems within the study area. A summary of the nature conservation findings with respect to GDEs is provided in **Section 12.2.7**. The key findings indicate that the main species that may be influenced by groundwater are the large remnant Forest red gums. The Brisbane River is saline and tidal in nature. It is anticipated that shallow aquifers within the vicinity of the Brisbane River are also to some extent, brackish to saline. Groundwater levels in these areas are likely to be tidally influenced and the water table is likely to fluctuate accordingly. It is difficult to determine what, if any, influence groundwater plays in the survival of the remaining remnant trees. It is considered however that the level of groundwater dependency in these areas is likely to be relatively low (opportunistic at best) with only salt tolerant species potentially utilising groundwater in these saturated zones.

12.3.5 Mitigation measures

The key mitigation measures proposed are the methods of construction for the main tunnels and the underground stations.

The main tunnels would be considered to be ‘dry’ tunnels with groundwater inflow predicted to be less than 1 L/second. With the application of pre-cast concrete segments with gaskets as the preferred lining for the main tunnels, the impacts of potential groundwater drawdown are mitigated to the fullest extent practicable.

The cross-passages, spaced at 240 m, would be lined with a waterproof membrane and supported by cast-insitu concrete lining, again presenting the best, practicable mitigation against groundwater inflow.

The proposed method of construction for each of the underground stations entails the application of cut-off sheeting on the sidewalls where the shallow aquifers might be intercepted. The cut-off sheeting would extend to the station floor situated in rock. While the inflow rates would be greater than for the main tunnels, the impact to potential sensitive receptors would still be mitigated effectively and to the extent practicable in each location.

Groundwater inflow to the tunnel and station voids would be captured by a drainage system.

In order to minimise potential impacts on the groundwater resource during construction, a variety of control measures would be implemented. The control measures for groundwater would be developed within the overall construction Environmental Management Plan (EMP) (refer to **Chapter 24 Draft Outline EMP)** and would include:

- prior to the commencement of construction, a water quality monitoring program must be established using the following guidelines:
  - *Australian and New Zealand Guidelines for Fresh and Marine Water Quality 2000*
  - *Queensland Water Quality Guidelines 2009*
  - *Monitoring and Sampling Manual 2009 Environmental Protection (Water) Policy 2009* (see proposed groundwater monitoring program)
- preparing and implementing specific management plans for construction works that may disturb groundwater. These would include, but not be limited to, measures to address the potential for, and prevent environmental impact from, groundwater drawdown
- identifying registered and unregistered water bores in the area potentially affected by groundwater drawdown and implementing measures to manage potential effects on identified bores
- designing and constructing a dedicated groundwater control system, ensuring that potential seepage into underground works is captured and treated prior to release
- storing oils and fuels within impervious storage bunds (or double skinned tanks) to contain spillages or leaks
- implementing appropriate practices and procedures for waste handling, storage and disposal, accidental spillages and use of concrete and grout to avoid contamination of groundwater.

Groundwater monitoring program

A monitoring program would be implemented to inform and support the construction and operations phases for managing and mitigating the groundwater effects of the Project. Groundwater monitoring would be required to inform the detailed design process and would be maintained during construction and operation to address issues pertaining to drawdown and quality. The monitoring program would also include triggers to identify any mobilisation of contaminated groundwater both in-situ and at collection points.

A network of monitoring bores has been established as part of the geotechnical investigations for the Project (refer to **Chapter 7 Topography, Geology, Geomorphology and Soils**). The groundwater monitoring network based on existing bores is summarised in **Table 12-7**. Additional bores may be installed for future investigations.

Table 12-7 Recommended groundwater monitoring network based on existing bores

Borehole	Location
CRR101	Cornwall Street, Fairfield
CRR102	Cope Street, Annerley
CRR201	Roma Street
CRR204	Botanic Gardens (River Bank)
CRR207	Kangaroo Point Cliffs (River Bank Park)
CRR208	Land Reserve between Vulture Street off-ramp and Vulture Street
CRR209	Goprint Site
CRR210	Boggo Road Busway/Ecosciences Precinct

Borehole	Location
CRR211	Land Reserve at corner of Brogham Street and Fairfield Rd
CRR212	Land Reserve between Fairfield Road and Park Road (north of Ovendean Street)
CRR213	Yeronga Park and Ride
CRR214	Car park at the end of Christensen Street (Corner of Christensen Street and Lake Street)
CRR216	Boggo Road Busway/Ecosciences Precinct
CRR217	Railway end of School Road Yeronga
RNA Bore 1	RNA Showgrounds*
RNA Bore 2	RNA Showgrounds*

Note:
**Monitoring of RNA Bores should continue as part of RNA Operations*

A review would be undertaken of available bore construction records and target aquifers to determine the suitability of the monitoring bores installed during the geotechnical investigations. Following this review, additional bores may be proposed to address any gaps identified in the existing groundwater monitoring network. Groundwater monitoring prior to the construction phase would be undertaken to establish baseline groundwater conditions. The collected baseline groundwater data would serve as guideline levels to identify potential impacts during the construction and operations phases. In the event a 'groundwater feature', eg areas of high groundwater flow/yield, is identified along the Project alignment, detailed groundwater monitoring would be undertaken to characterise the feature and identify potential impacts to the environment. Additional management measures would be developed, where required.

Groundwater levels monitored would be referenced to both mAHD and mBGL. Automated groundwater level data recorders are proposed for groundwater level monitoring. Groundwater quality monitoring would include the field and laboratory parameters identified in **Table 12-8**.

Table 12-8 Groundwater quality monitoring – parameters

Field Chemistry Parameters	Laboratory Chemistry Parameters
pH, Temperature, Electrical Conductivity and Total Dissolved Solids	Ammonia as N, Nitrite, Nitrate, Total Nitrogen as N, Total Phosphorous as P, Arsenic, Cadmium, Chromium, Copper, Nickel, Lead, Zinc, Mercury, Major Cations (Calcium, Magnesium, Sodium and Potassium), Major Anions (Chloride, Sulfate and Alkalinity), Iron, Aluminium, Silver, Antimony, Molybdenum, Selenium, Total Petroleum Hydrocarbons (TPH) and benzene, toluene, ethylbenzene, and xylene (BTEX)

Groundwater level monitoring would be undertaken for six to twelve months prior to construction. It should be noted that with the use of automated groundwater level data recorders, groundwater levels can be monitored continuously. Groundwater quality monitoring would be undertaken on a quarterly basis for six to twelve months prior to construction phase of the Project. Groundwater level and quality monitoring would be undertaken on a quarterly basis during construction and at 6 monthly intervals during the operations phase.

An annual review of the collected data would identify any impacts and whether ongoing monitoring is required. Should any groundwater level or quality deviations from seasonal baseline data be observed, the nature of the impact would be assessed and mitigation measures implemented, where necessary.

During operation, groundwater inflows to the Project would be monitored for quality to determine and manage the requisite treatment, prior to release. The water quality values and objectives of EPP (Water) would apply to any release.

Settlement

To minimise risks associated with settlement, it will be important to adhere to suitable engineering practices and ensure that effective management and monitoring methods are implemented and reviewed from the onset of construction. Appropriate mitigation measures would be identified and implemented during the detailed design process. All buildings and structures within the areas where surface settlements and possible damage are predicted, such as Albert Street, would have a building condition survey completed. Surveys and other displacement monitoring would be used to monitor the effects of settlement, if any. Potential impacts and mitigation measures for settlement are examined in **Chapter 7 Topography, Geology, Geomorphology and Soils**.

12.3.6 Residual effects

The residual effects on groundwater during construction are predicted to be low for the short-term duration of the works. The residual effects on groundwater during the operation phase are also predicted to be low over the long-term.

Construction

During construction, the risk of adverse impacts on GDEs is considered to be of low significance and would be mitigated by the proposed construction methods. The risk of disturbing potential ASS is also considered to be of low significance. Should ASS be encountered, well-established protocols exist for the management of construction activities.

Groundwater monitoring as part of the draft outline EMP would be used to inform the detailed design and would be maintained during construction to address issues relating to groundwater drawdown and water quality.

Operation

With the adopted Project design, the impact on the groundwater regime is predicted to be of low significance. The extent of groundwater drawdown across the study area would be minimised by the proposed design for the main tunnels and the underground stations. Groundwater inflows and quality would be monitored during operation to assess and manage appropriate treatments, prior to release to the environment.

12.4 Summary

The groundwater resource in the study area is variable and influenced by the Brisbane River and the local drainage system, as much as it is by the geological conditions. In some locations, there is likely to be a hydraulic connection between the river and the local streams and shallow aquifers. Such connections would be via alluvial beds and fractured or jointed rock formations close to the surface. The unconformity between some rock formations, such as Brisbane Tuff and Neranleigh-Fernvale adjacent to the Brisbane River at Kangaroo Point and Woolloongabba, presents a complexity to the groundwater conditions along the study corridor.

For much of its route, the Project would pass through dense rock with limited potential to transmit groundwater to the Project voids (<1 L/second inflows, which is a long term steady state inflow rate over the life of the Project). As the main tunnels approach the surface, the potential increases to intercept fractured or jointed rock and alluvial beds with varying degrees of groundwater permeability.

Any construction involving the excavation of rock underground has the potential to draw groundwater to the void. Where the void is below the water table, then a potential for groundwater drawdown is created. In contrast, Project surface works would occur above the water table and therefore are unlikely to impact on groundwater resources.

With the Project, the potential for groundwater drawdown is created by the main tunnels, the cross-passages and the underground stations. A range of secondary effects, or impacts, could be created by the movement or drawdown of groundwater.

This investigation has found that the potential for groundwater drawdown is greatest at the underground stations in the CBD, ie Albert Street and Roma Street, at the Gabba Station and at the ventilation and emergency access building proposed at Fairfield. The areal extent of such drawdown has been mapped and presented in this Chapter and the associated *Technical Report No. 4 – Groundwater Assessment*.

The effect of this drawdown could include the mobilisation of contaminants already present in the shallow aquifers as a consequence of earlier human activity such as land use and construction. The potential for this effect has been linked to previous land uses and is described in **Chapter 8 Land Contamination.**

Other effects could include impacts on GDEs and the oxidation of potential ASS. This investigation, combined with the ecological studies undertaken, indicates that GDEs are present along the Brisbane River in the vicinity of the Botanic Gardens and the Kangaroo Point cliffs. The risk of adverse impacts on these ecosystems is considered to be low and would be mitigated by the proposed construction method. The risk of disturbing potential ASS as a consequence of the Project is considered to be negligible.

The risk of groundwater drawdown due to the main tunnels is mitigated by the proposal to implement a construction method using pre-cast concrete segmented lining with gaskets, in other words, a reinforced, waterproof lining. This inflow is sufficiently small enough to be considered to represent a ‘dry’ tunnel.

With the cross-passages, construction would entail the application of cast-insitu concrete lining over a waterproof membrane, again acting as an effective mitigation to groundwater inflow. While this method is an effective mitigation, the inflow rate in the cross-passages would be higher than for the main tunnels, particularly in those locations where they occur in permeable material, such as alluvium and jointed or fractured rock formations. Generally however, cross passages are expected to be in impermeable rock.

For the underground stations and the ventilation and emergency access building, the proposed construction method utilises cut-off walls or sheets to intercept and contain groundwater in the shallow aquifers. This approach is considered to be effective and practicable for the circumstances of each structure.

The predicted inflow of groundwater for all the underground components of the Project is estimated at <1 L/second.

A network of monitoring bores has been established as part of the geotechnical investigations for the Project. A review would be undertaken of available bore construction records and target aquifers to determine the suitability of the monitoring bores installed during the geotechnical investigations. There may be a requirement to install additional bores for future investigations. Groundwater monitoring prior to the construction phase of the Project would be undertaken in the groundwater monitoring network to establish baseline groundwater conditions. The baseline groundwater data would serve as guideline levels to identify potential impacts during the construction and operation phases of the Project.