BaT project

Chapter 9
Hydrology

Contents

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9. Hydrology

9.1 Introduction

The purpose of this chapter is to assess potential impacts of the Project relevant to water quality and quantity. It provides an overview of the surface water and groundwater conditions and assesses the potential for impacts on water resources, flooding characteristics and water quality values. Strategies to manage potential impacts are also recommended, where required.

This chapter addresses the following sections of the Terms of Reference (ToR):

- Water quality – section 10.16 to 10.22
- Water resources – section 11.13 to 11.15
- Flooding – section 10.28 and 10.29.

9.1.1 Methodology

This assessment considers the area of potential interaction between the Project, surface waterways (and other water bodies), floodplains and aquifers. In some locations, this extends beyond the study corridor as defined in **Chapter 1 – Introduction**.

Specifically this chapter assesses the potential impacts to the following waterways, water bodies and aquifers:

- Moreton Bay
- Lower Brisbane River
- Breakfast/ Enoggera Creek
- Norman Creek
- alluvial (primary porosity) aquifer systems overlying bedrock aquifers
- fractured rock (secondary porosity) aquifer systems
- other water bodies located within:
  - Victoria Park
  - Roma Street Parkland
  - City Botanic Gardens.

For further detail of the locations of these features in relation to the Project, refer to **Figure 9-1**.

LEGEND

- Existing rail station
- Existing rail line
- Watercourse
- Catchments
- Study corridor

Project Infrastructure

- Underground station
- Dutton Park Station (upgraded)

Alignment

- Above ground
- Underground

BUS AND TRAIN PROJECT
ENVIRONMENTAL IMPACT STATEMENT

FIGURE 9-1

Catchments and waterways

N

0 0.75 1.5
Kilometres
1:55,000 (at A4)
Projection: GDA 1994 MGA56

Aerial Photo: Brisbane City Council 2012

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Surface water quality and flooding

The assessment of potential flooding impacts to the Project, and the potential for the Project to change the existing flood characteristics, involved the following:

- reviewing Queensland Government and Brisbane City Council policies relevant to flooding and the Project
- identification of the existing flood regime in and around the study corridor by:
  - reviewing previous studies undertaken for each of the potentially affected waterways
  - reviewing available State and local government flood mapping for each of the potentially affected waterways
  - analysing the general flood behaviour and flood history of rivers, creeks and overland flow paths
  - assessing the likelihood of flooding in the study corridor under existing condition.
- assessing the potential impact of the Project through consideration of the existing flood characteristics and the elements of the Project that would potentially affect surface flooding
- development of mitigation strategies, as appropriate.

For the purpose of this assessment, it was determined that access to the above-mentioned data sources would be sufficient for appropriately assessing the flood impacts for this Project and for addressing the ToR. As such, no flood modelling was specifically undertaken for the reference design as part of this assessment.

The assessment of the impacts of the Project on surface water quality involved:

- reviewing legislation and policy with regard to surface water regulations and approvals
- assessing the existing environment, including:
  - identification and mapping of potentially affected waterways and catchments
  - definition of applicable environmental values and Water Quality Objectives (WQOs)
  - description of existing water quality for potentially affected waterways and catchments
- assessing the potential impacts and developing appropriate management measures.

The reference design has considered the flood risks of the study corridor with an aim to minimise the risks of flood damage to the Project to as low as reasonably practicable.

The target flood immunity for the tunnel portals and stations is protection from the 1 in 10,000 Annual Exceedance Probability (AEP) regional flooding event (riverine and creek events). Allowance is also made for protection from localised flooding in the 1 in 100 AEP event (overland flow events).

Groundwater

The assessment of groundwater 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 Queensland Department of Environment and Heritage Protection (DEHP) reports and records.

A review of available groundwater information relevant to the Project included:

- Department of Natural Resources and Mines (DNRM) groundwater facility and licensing databases (GWDB) (2014)
- preliminary groundwater and geotechnical investigations undertaken for the Cross River Rail project, including:
  - hydrogeology and groundwater issues reports prepared for the Department of Transport and Main Roads (TMR) (AGE, 2004 and 2006)
  - preliminary draft geotechnical investigations (AECOM, 2010)
- groundwater and geotechnical investigations undertaken for other projects within or near to the study corridor, 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 Tunnel (NSBT) and Airport Link projects (AGE Consultants, 2004 and 2006)
  - Northern Link Project (SKM-Connell Wagner Joint Venture, 2008a)
  - Eastern Busway Project (SKM, 2009)
- geotechnical and contaminated land assessments undertaken (or commissioned) in or around the corridor by Brisbane City Council's City Design (2000)
- available geotechnical data from TMR archives and Brisbane City Council archives
- published geographical information system datasets, including digital terrain model, topography, geology and aerial photography
- Queensland Geological Survey's published 1:100,000 Brisbane geology map sheet.

A conceptual hydrogeological model was developed using the available groundwater information, as a means of describing the existing hydrogeology in the study corridor. 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.

The assessment of groundwater drawdown is based on preliminary data obtained during geotechnical assessments undertaken for the Project. A review of this data determined that it was sufficient for the purpose of informing groundwater modelling of scenarios which are one, five and ten years following tunnel construction.

This preliminary data will be supplemented by detailed hydrogeological data made available upon completion of the geotechnical assessments being undertaken at the time of writing (refer to **Chapter 6 – Soils and topography**). This additional data, when available, will be used to verify conclusions drawn in this assessment.

Specifically, the model was aimed at quantifying the following potential impacts associated with tunnel and station inflows:

- depressed groundwater levels at the underground stations and ventilation outlet locations, affecting existing groundwater users or Groundwater Dependent Ecosystems (GDEs)
- drawdown in groundwater levels affecting areas of acid sulphate soils (ASS), particularly along the 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.

Subsequently, measures are proposed to manage the groundwater impacts resulting from the Project.

Model calibration has been made possible by matching model predicted groundwater levels to the potentiometric surface profile which has been generated from observed groundwater levels at discharge sites. Parameter estimation (PEST – Watermark Numerical Computing, 2005) was used to help optimise the calibration of the model along the study corridor.

9.1.2 Legislative and policy framework

Commonwealth government

Nationally, waterways are principally managed in accordance with the 'Australian and New Zealand Guidelines for Fresh and Marine Water Quality' (ANZECC & ARMCANZ, 2000b) and the 'National Water Quality Management Strategy' (ANZECC & ARMCANZ, 2000a). These provide guidance and strategic direction for assessing and managing water quality and for the sustainable use of water resources.

The *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) also provides for the protection and management of important natural and cultural places, including the Moreton Bay Ramsar site.

State government

The *Water Act 2000* (Water Act) provides for the sustainable management of water and other resources. The Water Act defines and describes watercourses and seeks to advance the sustainable management of water, including protection of the biological quality and health of natural ecosystems. One of the primary objectives of the Water Act is to maintain or improve the quality of naturally occurring waters and to protect them from degradation.

Under the *Environmental Protection Act 1994*, the Environmental Protection (Water) Policy 2009 (EPP (Water)) and the 'Queensland Water Quality Guidelines 2009' (DEHP, 2009) target the protection and enhancement of water quality. The EPP (Water) provides water quality guidelines and objectives for the protection of environmental values, and provides a framework for decision making related to Queensland waterways. The policy also identifies a framework for monitoring and reporting on the condition of waterways.

The Queensland *Coastal Protection and Management Act 1995* (Coastal Act) provides a comprehensive framework for the protection, conservation, rehabilitation and coordinated management of coastal resources and values, as well as tools for its implementation. The Coastal Act is designed to be used in conjunction with other legislation to enhance knowledge of coastal resources and the effect of human activities on the coastal zone.

The Queensland Water Quality Guidelines 2009 provide water quality triggers for each region and water body type across Queensland. The guidelines define levels of aquatic ecosystem condition and describe how water quality trigger values should be applied in the protection of these environments. The guidelines also include objectives for the management of urban stormwater.

Although the Project does not require approval under the State Planning Policy (SPP) 2014, it has been considered in this assessment, where relevant. The SPP identifies matters of State interest that require consideration for particular development and in plan making. State interests of relevance to the Project relating to hydrology include ‘water quality’ and ‘natural hazards, risk and resilience’.

Within the Brisbane City Council local government area (LGA), flood hazard areas and provisions required by the SPP are included in the Brisbane City Plan 2014 (City Plan). Further information on the SPP is provided in **Chapter 5 – Land use and tenure**.

Local government

At a local level, waterways are managed through a range of strategies, guidelines and policies. While the Project is exempt from assessment against the City Plan, it has been considered in the development of this assessment, where relevant.

The City Plan includes a number of codes that guide management of surface water. Those relevant to the Project include:

- stormwater management code
- waste water management (on-site effluent) code
- flood overlay code
- waterway corridors overlay code.

The codes support Brisbane City Council’s Subdivision and Development Guidelines and Environmental Best Management Practice for Waterways and Wetlands (Brisbane City Council, 2012). These outline key issues and measures to effectively manage water quality and flooding impacts associated with development activities.

9.2 Existing environment

9.2.1 Flooding

Existing waterways and sources of flood risk within the study corridor were identified based on Brisbane City Council’s Flood Awareness Mapping (Brisbane City Council, 2014). This mapping identifies flood risk based on four types of flooding source: overland flow, creek, river and storm tide flooding.

The Project surface works are not located within a storm tide flood risk zone, and as such, storm tide flood risk was not identified as a potential impact to the Project.

Four levels of flood risk are mapped with each risk level linked to an associated AEP, which is the probability of the area being flooded within any single year. **Table 9-1** presents these definitions.

Table 9-1 Flood Awareness Mapping risk level and associated AEP

Flood Awareness Map risk area	AEP
High risk area	1 in 20
Medium risk area	1 in 100
Low risk area	1 in 500
Very low risk area	1 in 2000

River flooding

The Brisbane River intersects the study corridor near the Brisbane Central Business District (CBD). The Brisbane River catchment upstream of the Brisbane CBD covers an area of approximately 13,560km^2 and includes both the Somerset Dam and Wivenhoe Dam.

Flood risk for the study corridor and surrounds due to the Brisbane River is presented in **Figure 9-2**, **Figure 9-3** and **Figure 9-4**. These figures are based on Brisbane City Council's Flood Awareness Mapping. The Brisbane River experienced large floods in 1974 and 2011 as well as a number of larger floods in the late 19th Century. Flood extents for the 1974 and 2011 events are presented in **Figure 9-5**.

The Brisbane River Catchment Flood Study is being undertaken in partnership between the Queensland Government and Brisbane City Council, led by the Department of State Development, Infrastructure and Planning (DSDIP). Completion and publication of this study is scheduled for late 2015, with an interim Hydrology Report expected to be released in late 2014. Once complete, this study will update and supersede any prior estimates of flood levels within the Brisbane River.

In the interim, Brisbane City Council's Flood Awareness Mapping represents the best available information on Brisbane River flood risks within the study corridor. This mapping is available for flood events up to and including the 1 in 2000 AEP event.

Estimates of the Probable Maximum Flood (PMF) event for the Brisbane River will become available with publication of the Brisbane River Catchment Flood Study. A nominal AEP of 1 in 74,000 has been assigned to the Brisbane River PMF based on guidance in the Australian Rainfall and Runoff national guideline (1999). Peak flood levels for the PMF event in the Brisbane River are likely to be in the order of 5 to 15m higher than the 1 in 2,000 AEP event.

Creek flooding

Creek flood risk for the study corridor and surrounding area is presented in **Figure 9-6**, **Figure 9-7**, and **Figure 9-8** based on Brisbane City Council's Flood Awareness Mapping. Norman Creek and Breakfast/ Enoggera Creek are the only creeks identified as influencing the study corridor. Brisbane City Council's Flood Awareness Mapping represents the best available information on creek flood risk within the study corridor.

Norman Creek is a tributary of the Brisbane River with its confluence in East Brisbane where Lytton Road becomes Wynnum Road. Tributaries of Norman Creek reach into Woolloongabba. A new flood study for Norman Creek is being conducted by Brisbane City Council.

Breakfast/ Enoggera Creek is a tributary of the Brisbane River. It extends almost 39km from the Brisbane Forest Park east to the Brisbane River at Newstead. Flood studies were previously conducted for Breakfast Creek by Brisbane City Council City Design in 1999 and 2007

Overland flow paths

Overland flow paths are drainage lines that convey water that are not part of a creek, river or waterway. These are usually dry except in rainfall events. They are typically activated in short duration, high intensity rainfall events.

Numerous overland flow paths exist in the study corridor and some potentially interact with the Project.

Flood risk for the study corridor due to overland flooding is presented in **Figure 9-9**, **Figure 9-10** and **Figure 9-11** based on Brisbane City Council's Flood Awareness Mapping. Brisbane City Council's Flood Awareness Mapping represents the best available information on overland flow flood risk within the study corridor.

9.2.2 Water quality

This section provides a description of surface water values within the study corridor and surrounding areas that may be affected by the construction and operation of the Project.

Catchments and surface water features

The Project has the potential to impact the following surface water features, as shown in **Figure 9-1**:

- Moreton Bay
- waterways such as the Brisbane River, Breakfast Creek, Norman Creek
- water bodies such as York's Hollow lake, Roma Street Parkland lake, City Botanic Gardens ponds.

Moreton Bay

Moreton Bay is the receiving environment for 14 major rivers from six drainage basins including the Brisbane River, which is the largest contributing catchment. Moreton Bay covers an area of 1,523km^2, but has a contributing catchment area of approximately 22,700km^2 (DoE, 2011). It is bordered to the east by Moreton Island and the south-east by North Stradbroke Island. The mouth of the Brisbane River is located near Bramble Bay (north of the outlet) and Waterloo Bay (south of the outlet) within Moreton Bay. These waters are classified as enclosed coastal and lower estuary waters. The central and eastern zones of Moreton Bay are classified as open coastal waters and are well flushed (EHMP, 2013a).

Moreton Bay was listed under the Ramsar Convention as an internationally important wetland in 1993, and provides habitat to several threatened species.

Brisbane River

The Brisbane River is split into three catchment zones, the Upper, Mid and Lower Brisbane River (DERM, 2010a). The Lower Brisbane River receives runoff from all disturbed areas of the Project during construction and operation. The Lower Brisbane River has a catchment area of 1,195km^2 and includes the tributaries of Breakfast/ Enoggera Creek and Norman Creek. The Lower Brisbane River also receives flows from the Upper and Mid Brisbane River Catchments, Bremer Catchment and Oxley Catchment. The total catchment area for the Brisbane River Basin is approximately 13,560km^2.

The Lower Brisbane River is classified as middle estuary in the areas intersecting with the Project (DERM, 2010a). Mid-estuarine waters receive a moderate amount of water movement from freshwater inflows and tidal exchange. Freshwater inflows are generated from catchment runoff.

The Lower Brisbane River Catchment is a highly modified, urbanised catchment. The dominant land uses include urban and rural residential land with some native bush and grazing land in upland areas. Extensive clearing of riparian vegetation has occurred and the majority of water discharging into the Brisbane River is through stormwater infrastructure in urban zones (EHMP, 2013b).

Figure 9-2, **Figure 9-3** and **Figure 9-4** show the flood levels of the Brisbane River within the study corridor for a range of events from very low risk, rare events (1 in 2,000 year Average Recurrence Interval (ARI)) to very high risk, more frequent events (1 in 20 year ARI).

Breakfast/ Enoggera Creek

The northern portion of the study corridor flows in to York's Hollow, which overflows into the Breakfast Creek catchment. Breakfast Creek is the lower, estuarine portion of the Enoggera Creek catchment, which meets the Lower Brisbane River at Newstead. Breakfast Creek receives freshwater inflows from its catchment and tidal exchanges from the Lower Brisbane River. The Enoggera Creek catchment covers an area of approximately 89km^2 and includes tributaries from Ithaca and Fish creeks.

The upper regions of the catchment are largely undisturbed and consist of natural vegetation. This portion of the catchment is impounded by Enoggera Reservoir. Downstream of the reservoir, the land use is primarily urban residential and includes the Brisbane suburbs of The Gap, Ashgrove, Bardon, Red Hill, Enoggera, Paddington, Newmarket, Wilston, Windsor, Herston, Spring Hill, Fortitude Valley, Albion, Lutwyche, Clayfield, Bowen Hills and Newstead (Brisbane City Council, 2013a).

A flood study for Breakfast/ Enoggera Creek is, at the time of writing, being undertaken and will include hydrological modelling (discharges and flows) and hydraulic modelling (flood levels and extents). This flood study will supersede any previous flood studies.

Norman Creek

The southern portion of the study corridor lies within the Norman Creek catchment. Norman Creek is a tributary of the Lower Brisbane River, which discharges into the Brisbane River at the border of East Brisbane and Norman Park. The catchment area for Norman Creek is approximately 30km^2 and the dominant land use is urban (residential). The lower reaches of Norman Creek through to Stones Corner are tidal. In this region, the banks are dominated by regenerating mangroves and some mature trees.

Suburbs which drain to Norman Creek, primarily through stormwater infrastructure include East Brisbane, Woolloongabba, Coorparoo, Camp Hill, Greenslopes, Annerley, Holland Park, Tarragindi and Mount Gravatt. There are some remnant bushland areas in Wellers Hill, Mount Stevens and Tarragindi Recreational Reserve (Brisbane City Council, 2008).

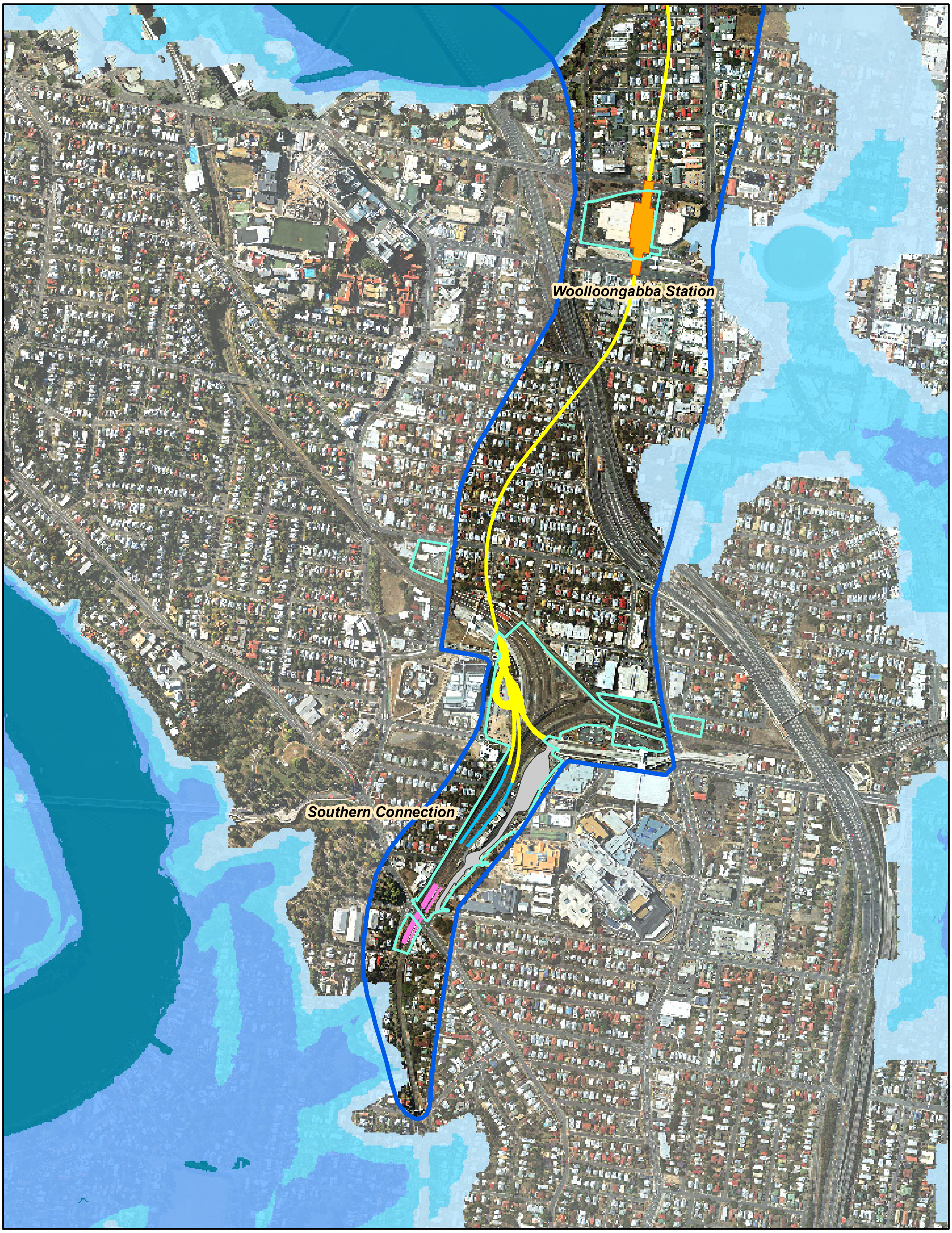
A flood study for Norman Creek is, at the time of writing, being undertaken and will include hydrological modelling (discharges and flows) and hydraulic modelling (flood levels and extents). This will supersede any previous flood studies.

Other water bodies

York's Hollow is a culturally significant wetland located at the eastern boundary of Victoria Park. The wetland was part of an original lagoon system and was remodelled as part of the Inner City Bypass (ICB) project. The wetland provides important habitat for waterbirds and fish. Overflow from the wetlands drains underground into the stormwater network and eventually discharges into Breakfast Creek.

The lake in Roma Street Parkland contains 11 megalitres of water and acts as a retention basin to improve the quality of stormwater runoff from the parkland. The lake is fed primarily through rainfall and runoff. Recycled water is used if rainfall is insufficient to achieve this level. Roma Street Parkland sits within the study corridor.

There are two ornamental ponds, within the City Botanic Gardens, which were constructed in the late 1950s. The ponds are located within the study corridor, above the underground alignment of the tunnel.



LEGEND

Riverine Flooding
- Very low flood risk
- Low flood risk
- Medium flood risk
- High flood risk

- Study corridor

Project Infrastructure
- Construction worksite
- Underground station
- Bus layover
- Dutton Park Station (upgraded)

Alignment
- Above ground
- Underground

Data Source: Brisbane City Council Flood Awareness Mapping
Aerial Photo: Brisbane City Council 2012

BUS AND TRAIN PROJECT
ENVIRONMENTAL IMPACT STATEMENT

Figure 9-2

Brisbane City Council Flood awareness mapping, river flooding - south

N

0 0.125 0.25
Kilometres
1:12,500 (at A4)
Projection: GDA 1994 MGA56

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LEGEND

Riverine Flooding
- Very low flood risk
- Low flood risk
- Medium flood risk
- High flood risk

Study corridor

Project Infrastructure
- Construction worksite
- Underground station

Alignment
- Underground

BUS AND TRAIN PROJECT
ENVIRONMENTAL IMPACT STATEMENT

Figure 9-3

Brisbane City Council Flood awareness mapping, river flooding - central

N

0 0.125 0.25
Kilometres
1:12,500 (at A4)
Projection: GDA 1994 MGA56

Data Source: Brisbane City Council Flood Awareness Mapping
Aerial Photo: Brisbane City Council 2012

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LEGEND

Riverine Flooding
- Very low flood risk
- Low flood risk
- Medium flood risk
- High flood risk

Study corridor

Project Infrastructure
- Construction worksite
- Underground station
- Bus layover

Alignment
- Above ground
- Underground

BUS AND TRAIN PROJECT
ENVIRONMENTAL IMPACT STATEMENT

Figure 9-4

Brisbane City Council Flood awareness mapping, river flooding - north

N

0 0.125 0.25
Kilometres
1:12,500 (at A4)
Projection: GDA 1994 MGA56

Data Source: Brisbane City Council Flood Awareness Mapping
Aerial Photo: Brisbane City Council 2012

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LEGEND

January 2011 flood extent
1974 flood extent
Study corridor

Project Infrastructure

Construction worksite
Underground station
Bus layover
Dutton Park Station (upgraded)

Alignment

Above ground
Underground

Data Sources:
1974 extent: Dept of Lands, Brisbane, Feb 1974
2011 extent: Dept of Natural Resources and Mines, 2011
Aerial Photo: Brisbane City Council 2012

BUS AND TRAIN PROJECT
ENVIRONMENTAL IMPACT STATEMENT

Figure 9-5

Historic Brisbane River floods

N

0 0.25 0.5
Kilometres
1:25,000 (at A4)
Projection: GDA 1994 MGA56

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LEGEND

Creek Flooding
- Very low flood risk
- Low flood risk
- Medium flood risk
- High flood risk

- Study corridor

Project Infrastructure
- Construction worksite
- Underground station
- Bus layover
- Dutton Park Station (upgraded)

Alignment
- Above ground
- Underground

Data Source: Brisbane City Council Flood Awareness Mapping
Aerial Photo: Brisbane City Council 2012

BUS AND TRAIN PROJECT
ENVIRONMENTAL IMPACT STATEMENT

Figure 9-6

Brisbane City Council Flood awareness mapping, creek flooding - south

N

0 0.125 0.25
Kilometres
1:12,500 (at A4)
Projection: GDA 1994 MGA56

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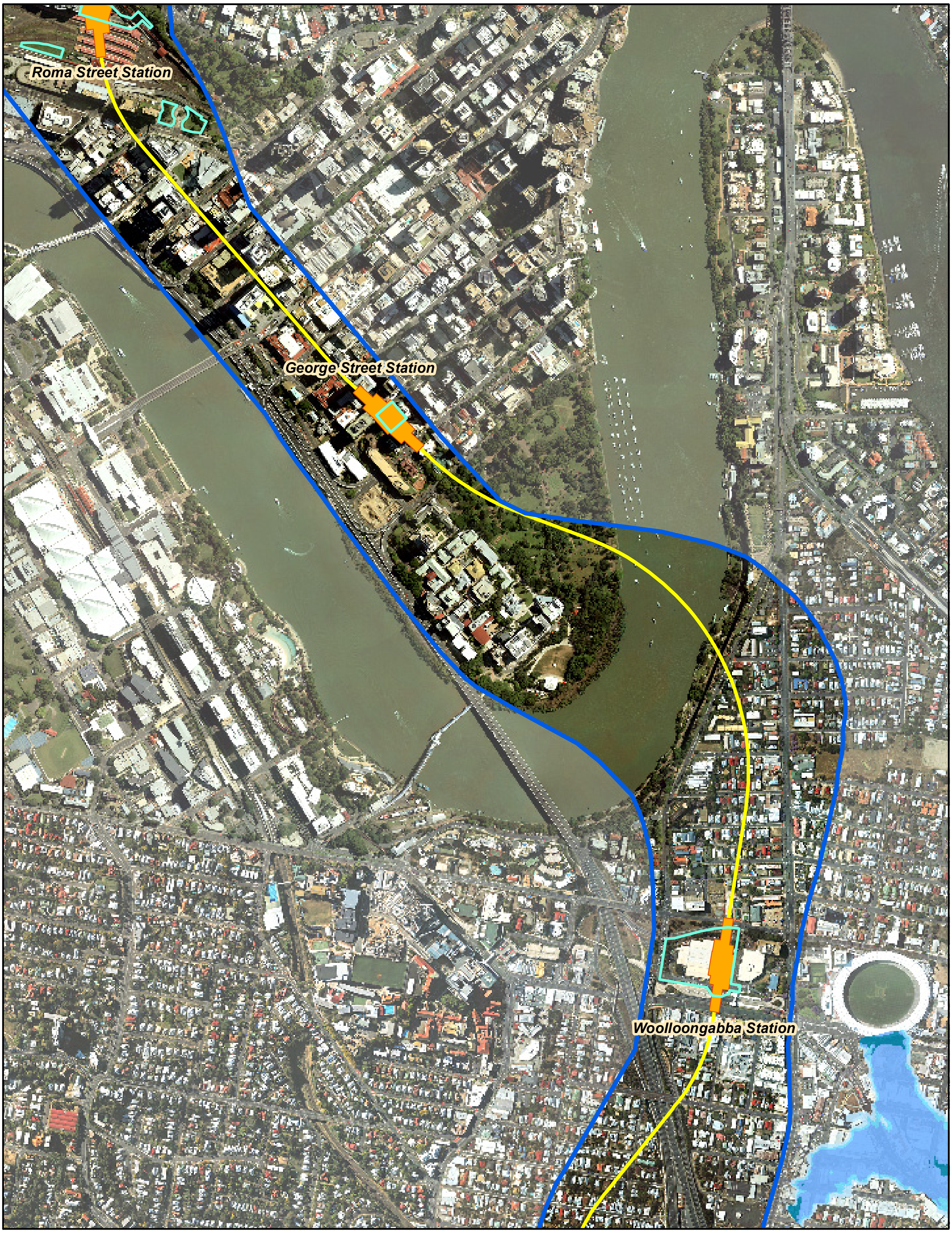

LEGEND

Creek Flooding
- Very low flood risk
- Low flood risk
- Medium flood risk
- High flood risk

Study corridor

Project Infrastructure
- Construction worksite
- Underground station

Alignment
- Underground

BUS AND TRAIN PROJECT
ENVIRONMENTAL IMPACT STATEMENT

Figure 9-7

Brisbane City Council Flood awareness mapping, creek flooding - central

N

0 0.125 0.25
Kilometres
1:12,500 (at A4)
Projection: GDA 1994 MGA56

Data Source: Brisbane City Council Flood Awareness Mapping
Aerial Photo: Brisbane City Council 2012

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LEGEND

Creek Flooding
- Very low flood risk
- Low flood risk
- Medium flood risk
- High flood risk

Study corridor

Project Infrastructure
- Construction worksite
- Underground station
- Bus layover

Alignment
- Above ground
- Underground

BUS AND TRAIN PROJECT
ENVIRONMENTAL IMPACT STATEMENT

Figure 9-8

Brisbane City Council Flood awareness mapping, creek flooding - north

N

0 0.125 0.25
Kilometres
1:12,500 (at A4)
Projection: GDA 1994 MGA56

Data Source: Brisbane City Council Flood Awareness Mapping
Aerial Photo: Brisbane City Council 2012

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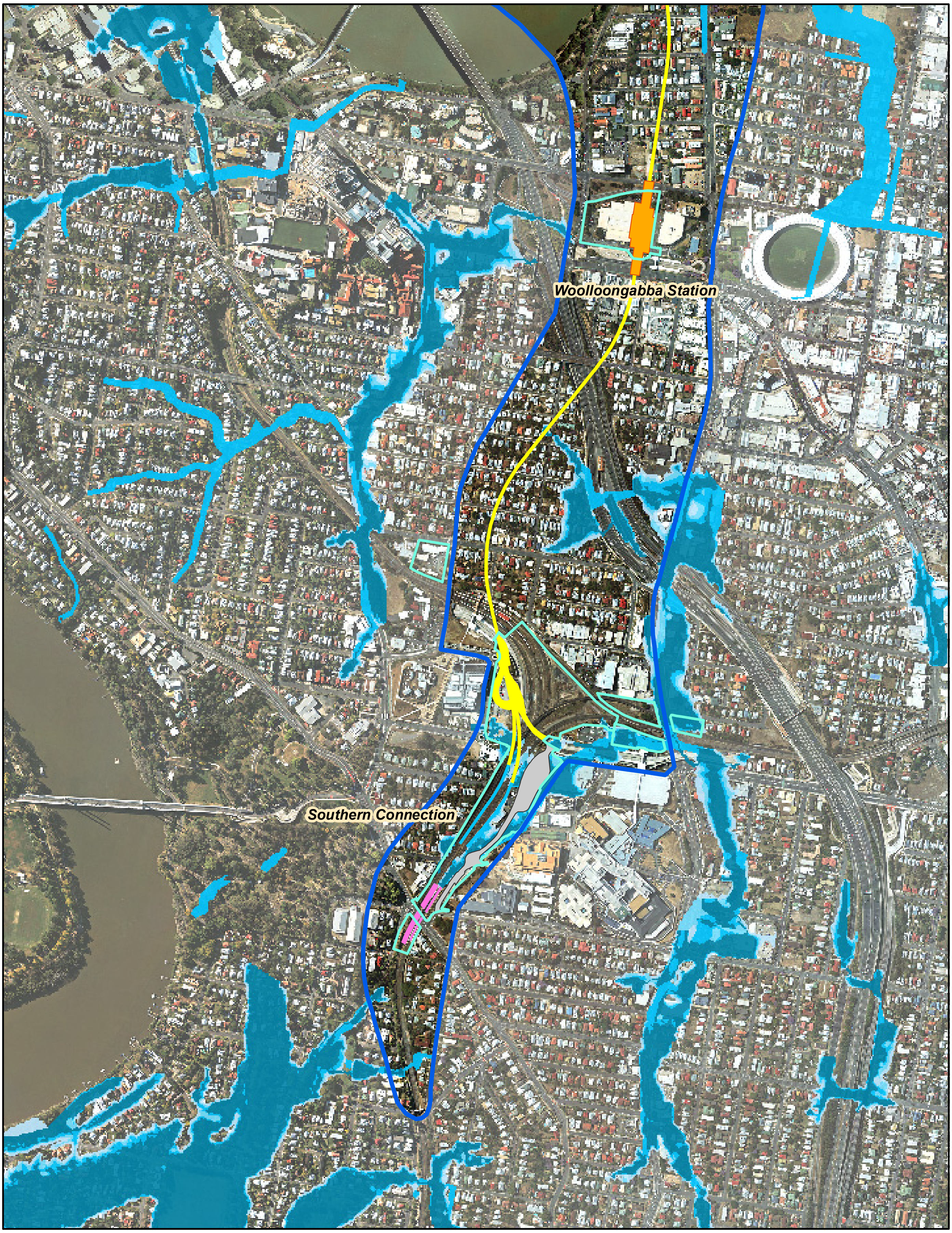

LEGEND

Overland Flooding
- Very low flood risk
- Low flood risk
- Medium flood risk
- High flood risk

Study corridor

Project Infrastructure
- Construction worksite
- Underground station
- Bus layover
- Dutton Park Station (upgraded)

Alignment
- Above ground
- Underground

Data Source: Brisbane City Council Flood Awareness Mapping
Aerial Photo: Brisbane City Council 2012

BUS AND TRAIN PROJECT
ENVIRONMENTAL IMPACT STATEMENT

Figure 9-9

Brisbane City Council Flood awareness mapping, overland flooding - south

N

0 0.125 0.25
Kilometres
1:12,500 (at A4)
Projection: GDA 1994 MGA56

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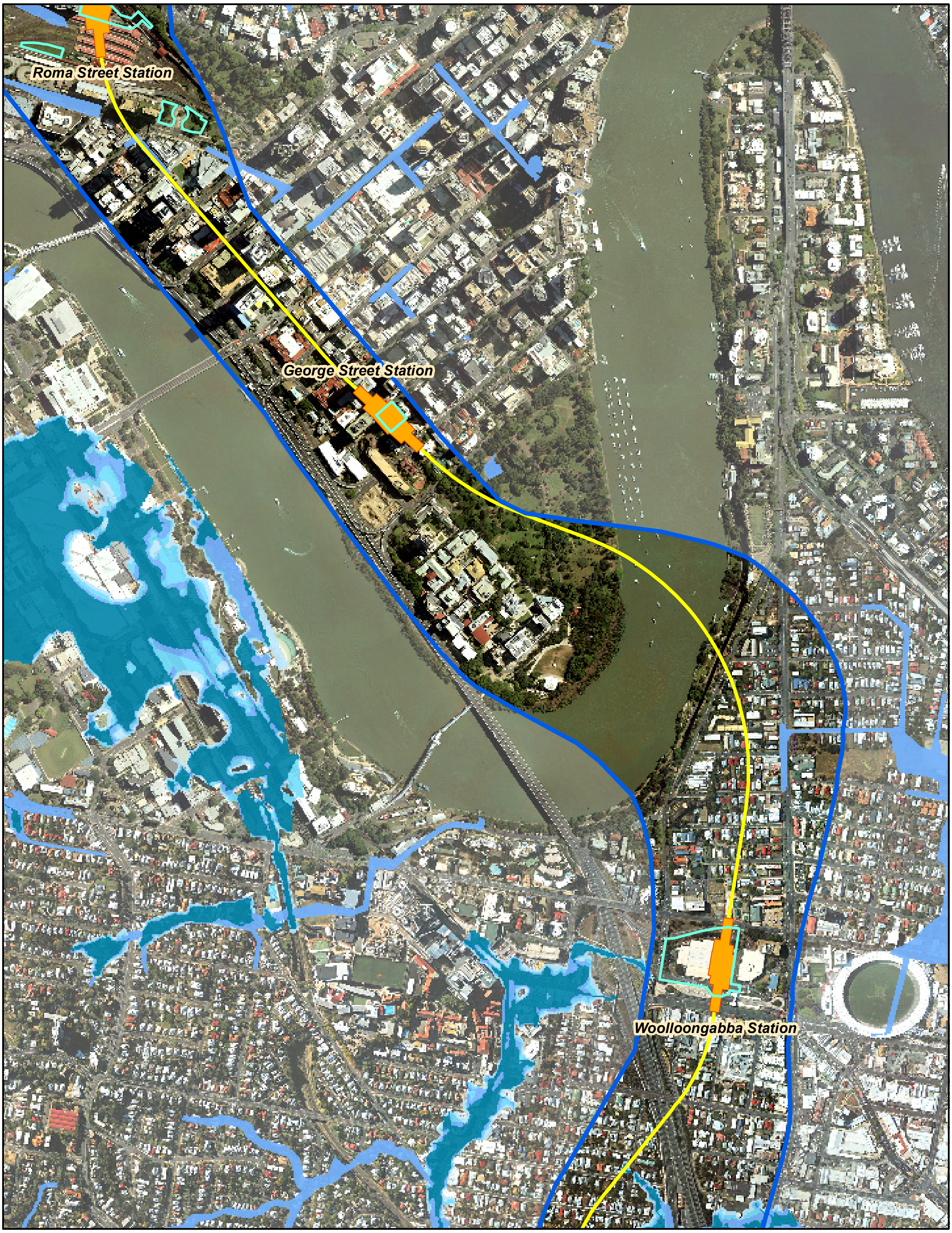

LEGEND

Overland Flooding
- Very low flood risk
- Low flood risk
- Medium flood risk
- High flood risk

- Study corridor

Project Infrastructure
- Construction worksite
- Underground station

Alignment
- Underground

BUS AND TRAIN PROJECT
ENVIRONMENTAL IMPACT STATEMENT

Figure 9-10

Brisbane City Council Flood awareness mapping, overland flooding - central

N

0 0.125 0.25
Kilometres
1:12,500 (at A4)
Projection: GDA 1994 MGA56

Data Source: Brisbane City Council Flood Awareness Mapping
Aerial Photo: Brisbane City Council 2012

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LEGEND

Overland Flooding
- Very low flood risk
- Low flood risk
- Medium flood risk
- High flood risk

- Study corridor

Project Infrastructure
- Construction worksite
- Underground station
- Bus layover

Alignment
- Above ground
- Underground

BUS AND TRAIN PROJECT
ENVIRONMENTAL IMPACT STATEMENT

Figure 9-11

Brisbane City Council Flood awareness mapping, overland flooding - north

N

0 0.125 0.25
Kilometres
1:12,500 (at A4)
Projection: GDA 1994 MGA56

Data Source: Brisbane City Council Flood Awareness Mapping
Aerial Photo: Brisbane City Council 2012

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Environmental values

Environmental values are defined as the quality or physical characteristics of the environment that are conducive to ecological health, public amenity or public safety. These environmental values should be protected from the impacts of habitat alteration, waste releases, contaminated runoff and changes to flow regimes. Protecting and enhancing environmental values helps to ensure healthy aquatic ecosystems and waterways, which are safe for human use (DERM, 2010a).

The environmental values for the Brisbane River, Breakfast Creek and Norman Creek are listed in **Figure 9-2**.

Table 9-2 Environmental values for surface water features

Waterway		Environmental values									
		Aquatic ecosystem	Seagrass	Irrigation	Human Consumer	Stock water	Primary recreation	Secondary recreation	Visual recreation	Cultural and spiritual values	Industrial uses
Brisbane River	Freshwater creeks and drains	✓						✓	✓	✓	
	Tidal creeks/ drains, estuarine	✓						✓	✓	✓	
Breakfast Creek	Estuarine	✓			✓		✓	✓	✓	✓	
Norman Creek	Freshwater	✓						✓	✓	✓	
	Estuarine	✓						✓	✓	✓	

Source: DERM, 2010a

Water Quality Objectives

The WQOs are specific water quality targets, established under the EPP (Water), that are used as indicators to assess the management and achievements of protecting and enhancing environmental values of waterways. WQOs are numerical concentration limits or descriptive statements that are agreed between stakeholders or set by local jurisdictions. Specific WQOs are applicable to each environmental value of waterways. Where WQOs differ between applicable environmental values of a waterway, the most stringent criteria is applicable.

The most stringent WQOs applicable to Breakfast Creek, Brisbane River and Norman Creek are listed in **Table 9-3**.

Table 9-3 WQOs for surface waters

Indicator	Mid-estuary, Brisbane River, Norman Creek	Lowland freshwater All other waters
pH	7.0 to 8.4	6.5 to 8.0
Dissolved oxygen	85 to 105% saturation	90 to 110%
Oxidised nitrogen	<10µg/L	<60µg/L
Organic nitrogen	<280µg/L	<420µg/L
Ammonia nitrogen	<10µg/L	<20µg/L
Total nitrogen	<300µg/L	<500µg/L
Total phosphorus	<25µg/L	<50µg/L
Filterable reactive phosphorus	<6µg/L	<20µg/L
Chlorophyll a	<4µg/L	<5µg/L
Turbidity	<8NTU	<50NTU
Secchi depth	>1m	n/a
Conductivity	n/a	<600µS/cm
Suspended solids	<20mg/L	<6mg/L
Aluminium pH > 6.5**	<0.5µg/L(1)	<55µg/L
Aluminium pH < 6.5	ID	<0.8µg/L(1)
Iron**	ID	ID
Arsenic (AsIII)**	<2.3µg/L(1)	<24µg/L(2)
Arsenic (AsV)**	<4.5µg/L (1)	<13µg/L(2)
Cadmium**(C)	<0.7µg/L(A)	<0.2µg/L
Chromium (CrIII)(C)	<10µg/L(3)	<3.3µg/L(3)
Chromium (CrVI)	<4.4µg/L	<1µg/L
Copper**(C)	<1.3µg/L	<1.4µg/L
Lead**(C)	<4.4µg/L	<3.4µg/L
Nickel**(C)	<7µg/L	<11µg/L
Zinc**(C)	<15µg/L(B)	<8µg/L(B)
Mercury (inorganic)**	<0.1µg/L	<0.06µg/L
Chlorine**	<3µg/L(1)	<3µg/L
Naphthalene	<50µg/L(B)	<16µg/L
Anthracene	<0.01µg/L(3)	<0.01µg/L(3)
Phenanthrene	<0.6µg/L(3)	<0.6µg/L(3)
Fluroanthene	<1µg/L(3)	<1µg/L(3)
Benzo(a)pyrene	<0.1µg/L(3)	<0.1µg/L(3)
Benzene	<500µg/L(B)	<950µg/L
Toluene	<180µg/L(1)	<180µg/L(1)
Ethylbenzene	<5µg/L(1)	<80µg/L(1)
Ortho-xylene	<350µg/L	<350µg/L

Indicator	Mid-estuary, Brisbane River, Norman Creek	Lowland freshwater All other waters
Meta-xylene	<75µg/L$^{(1)}$	<75µg/L$^{(1)}$
Para-xylene	<200µg/L	<200µg/L

Notes:
Indicator values were sourced mainly from the EPP (Water) 2009 Environmental Values and WQOs for the Brisbane River Estuary (Basin No.143) (DERM 2010a). However, indicators marked with (**) were sourced from the ANZECC Water Quality Guidelines 2000. If a particular parameter is not given in the above table, reference should be made to the EPP (Water) 2009 and the ANZECC Water Quality Guidelines 2000.
n/a = not applicable for this indicator and water type.
ID = insufficient data available to derive a reliable goal value.
(A) = chemicals for which bioaccumulation and secondary poisoning effects should be considered.
(B) = Figure may not protect key test species from chronic toxicity (ANZECC & ARMCANZ 2000, Section 3.4, Table 4.3.1).
(C) Cadmium, CrIII, Copper, Lead, Nickel and Zinc as HMTV (Hardness Modified Trigger Values), applies to freshwater only). The values have been calculated using a hardness of 30 mg/L $CaCO_3$, see Tables 3.4.3 and 3.4.4 of ANZECC Vol 1.
Indicators marked with (*) were sourced from the Queensland Water Quality Guidelines. To comply with these WQOs, the median value of the water quality data set should lie within the concentration range, or below the maximum concentration (DERM 2009b).
(1) Low reliability trigger value for 95 per cent protection, sourced from section 8.3.7 of the ANZECC 2000.
(2) High reliability trigger value for 95 per cent protection, sourced from section 8.3.7 of the ANZECC 2000.
(3) Moderate reliability trigger, sourced from Volume 2 p 1116 of the ANZECC 2000

Baseline surface water quality

Moreton Bay, Brisbane River

The Ecosystem Health Monitoring Program (EHMP) administered by Healthy Waterways[1] is a comprehensive water quality monitoring program which monitors and reports on the health of catchments and waterways. The EHMP uses a broad range of biological, physical and chemical indicators to evaluate ecosystem health and provides an overall report card grade for each catchment or waterway annually.

An explanation of the report card grading system is provided in **Table 9-4**. The current and previous report card grades for the Lower Brisbane River catchment, Brisbane River Estuary, Bramble Bay and Waterloo Bay are provided in **Table 9-5**. These catchments and waterways are illustrated on **Figure 9-1**.

Table 9-4 Report card grade explanations

Grade	Explanation
A	Excellent – conditions meet all set ecosystem health values; all key processes are functional and all critical habitats are in near pristine condition.
B	Good – conditions meet all set ecosystem health values in most of the reporting region; most key processes are functional and most critical habitats are intact.
C	Fair – conditions meet some of the set ecosystem health values in most of the reporting region; some key processes are functional but some critical habitats are impacted.
D	Poor – conditions are unlikely to meet set ecosystem health values in most of the reporting region; many key processes are not functional and many critical habitats are impacted.
F	Fail – conditions do not meet set ecosystem health values; most key processes are not functional and most critical habitats are severely impacted.

1 Healthy Waterways is a not-for-profit, non-government, membership-based organisation working to protect and improve waterway health in South East Queensland.

Table 9-5 Catchment and waterway report card grades

Place	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Lower Brisbane River catchment	nd	D-	D	F	F	D-	F	F	F	F	F	F	D+	D-
Brisbane River Estuary	D	D-	D-	D-	D-	D-	D-	D+	D+	D+	D	D	D+	D+
Bramble Bay	F	F	D	D	D	D+	D+	D+	C	F	D+	D-	D+	F
Waterloo Bay	C+	B-	B-	B	B	B-	B-	B+	A	D+	B	B+	A-	B

Source: Healthy Waterways, 2014

Notes: nd – no data

The results show the ecosystem health of the immediate receiving environment of the Project (the Lower Brisbane catchment and the Brisbane River Estuary) is 'poor'. This is primarily due to:

- poor results for nutrient cycling, aquatic macroinvertebrate and fish indictors in the catchment
- high turbidity, low dissolved oxygen, elevated levels of nutrients and poor riparian vegetation in the estuary.

Further downstream, in Moreton Bay, conditions vary between 'good' in Waterloo Bay and 'fail' in Bramble Bay. Waterloo Bay has deteriorated in ecosystem health due to decreased water clarity and coral cover, increased nitrogen levels and increased sewage indicators. The overall condition of Waterloo Bay is 'good'. Ecosystem health in Bramble Bay deteriorated significantly between 2012 and 2013 due to decreased water clarity, increased presence of algae and elevated nitrogen concentrations.

In general, the ecosystem health of Moreton Bay and the Lower Brisbane River declines after periods of heavy rainfall which occur primarily in the summer months. This decline is particularly prevalent following extreme events, such as tropical cyclones and tropical depressions. Increased runoff results in increased turbidity, sediment loads and nutrient loads. This results in algae blooms and decreased dissolved oxygen (EHMP, 2010).

Breakfast Creek and Norman Creek

A city-wide assessment of Brisbane creeks was undertaken between October 1999 and March 2000, which included Breakfast Creek and Norman Creek (DERM, 2000). Water quality was monitored in four separate dry-weather surveys. Water quality indicators were used to rate the overall condition of the waterways.

The study found that, in 1999 and 2000, the overall estuarine water quality in Norman Creek was 'poor' due to high nutrient levels. Similarly, the estuarine water quality in Breakfast Creek was found to be 'poor' with nutrient concentrations generally exceeding WQOs and dissolved oxygen below WQOs.

Since then, a separate study on Breakfast Creek has been conducted by Brisbane City Council (2013a). This study found the health of the waterway to have improved slightly, however, the overall health of the system was still considered 'moderate' in the estuarine zone. The 'moderate' condition is due to high nutrient levels and metal concentrations, most likely as a result of industry and urbanisation of the catchment.

9.2.3 Groundwater

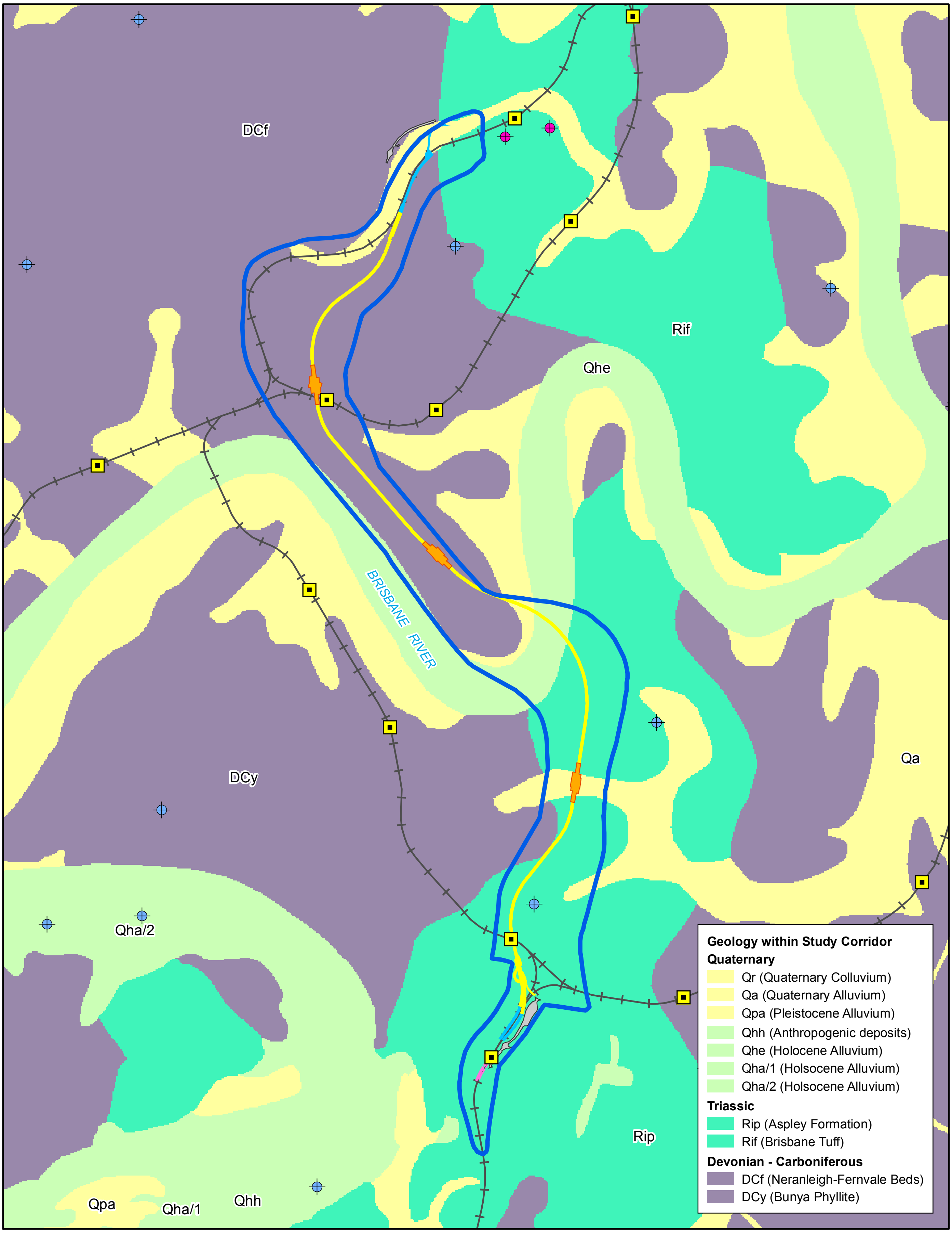
Aquifers

A review of the available geological data indicates that the hydrogeological regime of the study corridor and surrounding 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 and the Woogaroo Sub-Group
- alluvial (primary porosity) aquifer systems overlying bedrock aquifers.

While the specific thicknesses of aquifers are unknown, the hydrogeological characteristics of the various geological units within the study corridor are described in this section and indicated on **Figure 9-12**.

The groundwater resource in the study corridor 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 Brisbane 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 Beds adjacent to the Brisbane River at Kangaroo Point and Woolloongabba, presents a complexity to the groundwater conditions along the study corridor.



LEGEND

- Existing rail station
- Existing rail line
- Existing groundwater bores
- Extraction bores

- Study corridor

Project Infrastructure

- Underground station
- Bus layover
- Dutton Park Station (upgraded)

Alignment

- Above ground
- Underground

BUS AND TRAIN PROJECT
ENVIRONMENTAL IMPACT STATEMENT

FIGURE 9-12

Existing groundwater users and geology

N

0 0.5 1
Kilometres
1:30,000 (at A4)
Projection: GDA 1994 MGA56

Aerial Photo: Brisbane City Council 2012

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Naranleigh-Fernvale Beds

The Neranleigh-Fernvale Beds 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 corridor, the Neranleigh-Fernvale Beds outcrops to the north near the Brisbane CBD and Spring Hill areas, and in the south-east near the Woolloongabba area of the Brisbane River.

Groundwater occurrence in the Neranleigh-Fernvale Beds is typically limited to secondary porosity associated with localised zones of structural deformation. Fractures can occur at depths down to more than 60m mostly close to drainage lines. Due to the complex variety of rock types, groundwater characteristics vary considerably (Swann, 1997). Groundwater yields in the Neranleigh-Fernvale Beds are generally low and can range from 0 to 1L/s (Swann, 1997).

The bulk permeability of the Neranleigh-Fernvale Beds is likely to vary both spatially and with depth, as a function of geology and structural integrity. In general, the rocks of the Neranleigh-Fernvale Beds can be described as an aquifer of very low to low permeability with isolated areas of higher permeability (AGE, 2009).

Based on the available data, permeability for the Neranleigh-Fernvale Beds ranged from 0m/day to 0.59m/day (0 to 69 Lugeons), indicating very low to extremely high permeability. The average permeability for the Neranleigh-Fernvale Beds based on the above data is 0.12m/day. A review of the available data, however, shows that the majority of the data reports permeability of less than 0.01m/day which is indicative of low permeability. Higher permeability results are likely to be attributable to tests undertaken in isolated areas of higher permeability.

Hydraulic conductivities obtained from geotechnical investigations undertaken for the Clem Jones Tunnel (CLEM7) and S1 Sewer determined that 14 per cent of tests undertaken indicate potential for significant inflow. It is considered that these tests are associated with areas of localised dense fracturing rather than being indicative of broad areas of high permeability (AGE, 2009).

Transmissivity and storage values were obtained from pumping tests undertaken in the Neranleigh-Fernvale Beds for the Eastern Busway project. Based on this data, the average transmissivity and storage value for the Neranleigh-Fernvale Beds is $0.78m^2$/day and 0.009 respectively (Eastern Busway, 2009). The results of the testing undertaken for the Eastern Busway project provide a range of hydraulic conductivity values similar to those presented for previous studies.

Measured hydraulic conductivities for the Neranleigh-Fernvale Beds indicate a significant range of hydraulic conductivities (two orders of magnitude). The range in values is reflective of experience on previous tunnelling projects within the Neranleigh-Fernvale Beds whereby inflow rates can vary significantly.

The degree of confinement or unconfinement of the Neranleigh-Fernvale Beds is likely to vary given the discontinuous nature of zones of structural deformation (folding, faulting and fracturing). As part of the detailed design development, further hydrogeological investigations would aim to characterise the hydraulic interactions/ connectivity of adjacent and underlying units with the Neranleigh-Fernvale Beds.

Brisbane Tuff

The Brisbane Tuff outcrops near Fortitude Valley and Bowen Hills in the northern section of the study corridor and between Brisbane River and Park Road in the south. 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 1.5L/s. Data from previous investigations indicates variable permeable nature of the rock, with packer test results ranging from negligible water loss to instances where water losses were so great that no test could be completed (AGE, 2009). The average results range from less than 0.01m/day to 0.2m/day, which is indicative of very low to high permeability.

Measured hydraulic conductivities for the Brisbane Tuff indicate a significant range of hydraulic conductivities (two orders of magnitude). The range in values is reflective of experiences on previous tunnelling projects within the Brisbane Tuff whereby inflow rates can vary significantly. These results are consistent with the results presented for the Neranleigh-Fernvale Beds. Further hydrogeological investigations for detailed design would aim to characterise the hydraulic interactions/ connectivity of adjacent and underlying units with the Brisbane Tuff.

Aspley and Tingalpa Formation

The Aspley Formation and Tingalpa Formation have a similar geological and depositional history and will be considered as one in this assessment. Data from previous assessments undertaken for Airport Link and CLEM7 yielded average results ranging from less than 0.01m/day to 0.03m/day, indicating low to moderate permeability. The primary porosity of the Aspley and Tingalpa Formations is considered to be essentially zero, and the permeability of the rock will be governed by the number of fractures and the degree to which fracture zones are interconnected.

Assessment of the Aspley and Tingalpa Formation indicate a significant range of hydraulic conductivities (two orders of magnitude). The range in values is reflective of experiences on previous tunnelling projects within the Aspley and Tingalpa Formation whereby inflow rates can vary significantly spatially. These results are consistent with the results presented for the Brisbane Tuff and Neranleigh-Fernvale Beds.

It should also be noted that the median of the dataset, including zero values, is close to the lower bound estimate based upon the mean of the log values and the standard deviation. This skewness of the data is a result of the significant proportion of zero values (35 per cent) in the dataset, which are not included in the log statistical estimates. As part of the detailed design development, further hydrogeological investigations would aim to characterise the hydraulic interactions/ connectivity of adjacent and underlying units with the Aspley and Tingalpa Formation.

Quaternary Alluvium

The Quaternary Alluvium (less than two million years old) is the youngest unit in the study corridor and comprises sediments associated with watercourses. The four main areas of alluvium have been identified as the Brisbane River, Norman Creek, York’s Hollow Creek and Enoggera Creek (AGE, 2009). Groundwater potential in the alluvial aquifers is inherently 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.

Along the Brisbane River and its floodplain (and in the major tributaries and some lesser tributaries), the alluvium consists of both older (Pleistocene age) and younger (Holocene age) deposits. The Pleistocene deposits, commonly referred to as ‘old’ or ‘older’ alluvium, are typically river, and sometimes estuarine, deposits and overlie the bedrock.

The older alluvium generally consists of medium dense to dense sands and gravels, and over-consolidated stiff to very stiff clays. In the main Brisbane River channel, gravel horizons are often found immediately above the bedrock.

The Holocene or ‘recent’ alluvium often overlies the older sequence, having been deposited under estuarine conditions in the periods of higher sea level since the last ice age. Typically these deposits consist of normally to slightly over-consolidated silts and clays, often with organics and shells, and loose to medium dense sands and sometimes gravels.

Aquifers of the Brisbane River will largely be unconsolidated alluvium (semi-consolidated material is known) containing varying proportions of porous and permeable sands and gravels (EHA, 2006).

Locally, moderate groundwater yields may exist. 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.

Previous investigations undertaken in the vicinity of the study corridor (ie S1 Sewer, Inner Northern Busway, Eastern Busway) indicate that average hydraulic conductivity data for the alluvium ranges from 0.15m/ day to 86.4m/ day. This is indicative of high to extremely high permeability. Transmissivity, based on the above averages, in the alluvium ranges from 1.3m^2/ day to 8.6m^2/ day. Average storage coefficient for the alluvium ranges from 0.003 to 0.017.

Estimates for the alluvium indicate a significant range of hydraulic conductivities (two orders of magnitude). The range in values is lower than what would be expected for typical alluvial systems. It is noted the dataset population is limited and this may only be reflective of a small area. As part of the detailed design development, further hydrogeological investigations would aim to characterise the hydraulic interactions/ connectivity of adjacent and underlying units with the Quaternary Alluvium.

Fill material

Anthropogenic fill materials occur throughout the study corridor and are predominantly associated with areas of urban development. The nature, consistency, depth and extent will vary greatly across the study corridor. Significant depths are apparent where intensive development on re-shaping of landforms has taken place (eg pre-development drainage lines where extensive valley infill has occurred) (AECOM, 2010b).

Fill of this nature would be expected at the Woolloongabba GoPrint site (AECOM, 2010b). Previous assessments in the study corridor and surrounding 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 extent and are typically ephemeral in nature. As such, these features have not been considered further in this assessment.

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). Most of the waterways in the study corridor are tidal, such as Norman Creek, Breakfast Creek, Oxley Creek and Brisbane River.

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 corridor, 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; although specific areas where this is likely to occur 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, basement dewatering represents an additional, potential source of discharge for the surrounding aquifers. However, specific areas where this is occurring are unknown.

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 5km radius of the study corridor (DERM, 2010b). Of these, 331 are existing and 71 are abandoned and destroyed facilities.

Searches of the DNRM GWDB and Water Allocation Register were undertaken to identify volumetric allocations applied to individual bores. Results indicate that none of the groundwater facilities identified in the study corridor have volumetric allocation limits applied to them.

There are 35 existing groundwater facilities within a 1km radius of the study corridor. A summary of these is provided in **Table 9-6**.

Table 9-6 Groundwater facilities within a 1km radius of the study corridor

Section of study corridor	Number of bores	Range of total depth of bore	Geology	Range of yield
Northern section – north of Roma Street Station	17	8 to 80m	Aspley Formation, Quaternary Alluvium, Neranleigh-Fernvale Beds	0.06 to 1.88L/s
Central section – Roma Street Station to Woolloongabba Station	5	12 to 36m	Aspley Formation, Brisbane Tuff, Quaternary Alluvium, Neranleigh-Fernvale Beds	0.03 to 0.38L/s
Southern section – south of Woolloongabba Station	13	5.1 to 48m	Aspley/ Tingalpa Formation, Quaternary Alluvium, Woogaroo Sub-group	0.05 to 4.4L/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 2L/s (EHA, 2006).

Although not located in the study corridor, these bores give an indication of the typical yields experienced in the aquifer units located in the study corridor.

Extraction of groundwater from these bores during construction for dust suppression and other construction activities is not envisaged for the Project.

Groundwater levels

Broad trends in groundwater levels for the hydrogeological units can be inferred from geotechnical and groundwater drilling undertaken for previous projects. Groundwater levels in the study corridor are variable and are generally 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 9-7**.

Table 9-7 Groundwater levels within and around the study corridor

Project	Year	Approximate location relative to study corridor	Geological unit	Groundwater level or range (m BGL*)
CLEM7	2004	500m east of study corridor. Intersects study corridor around Herston and Woolloongabba	Quaternary Alluvium	1.02 to 5.33
			Brisbane Tuff	0.25 to 24.5
			Neranleigh–Fernvale Beds	4.01
			Open tidal hole	2.93 to 6.13
Legacy Way	2008	Intersects northern portion of study corridor near Red Hill. Less than 1km from Roma Street Station	Quaternary Alluvium	0.52 to 1.80
			Bunya Phyllite	0 to 20.70
			Neranleigh–Fernvale Beds	5.8 to 20.7
Airport Link	2006	500m north east of study corridor from Herston through to Wooloowin	Quaternary Alluvium	1.66 to 8.22
			Brisbane Tuff	-0.03 to 10.94
			Tingalpa Formation	1.59 to 9.81
			Aspley Formation	5.33
			Neranleigh–Fernvale Beds	10.93
Inner Northern Busway	2000	Intersects study corridor in Brisbane CBD from Queen Street to Roma Street	Quaternary Alluvium	2.8 to 6.5
			Bunya Phyllite	13.5
			Neranleigh–Fernvale Beds	13.1
Eastern Busway	2009	Less than 500m east of Dutton Park within the study corridor	Quaternary Alluvium	1.07 to 3.55
			Neranleigh–Fernvale Beds	-0.06 to 3.54
			Brisbane Tuff	2.82

Project	Year	Approximate location relative to study corridor	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 to 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 areas of soft compressible soils, lowering of groundwater levels via dewatering has the potential to result in ground settlement. For detailed description of ground settlement as a result of the Project, refer to **Chapter 6 – Soils and topography**.

The available hydrogeological data has been compiled to provide a preliminary indication of depth to water table for the study corridor using derived secondary variables from a Digital Terrain Model. 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.

Mapping of the depth to water table is provided in **Figure 9-13**. A shallow groundwater table (less than 5m BGL) is generally encountered along and in association with drainage lines in the study corridor. The data available indicates a significant range in groundwater levels in the study corridor. The inferred groundwater levels in the alluvial aquifer range from 0.52 to 8.22m BGL. Groundwater levels in the Aspley and Tingalpa Formation ranges from 1.59 to 9.81m BGL. The groundwater levels in the Brisbane Tuff ranges from -0.03 to 24.5m BGL. The Bunya Phyllite groundwater levels range from 0 to 20.70m BGL. Groundwater levels in the Neranleigh-Fernvale Beds vary from -0.06 to 20.7m BGL. Given the lack of long term groundwater level monitoring data available for this Project, seasonal trends in groundwater levels are unknown.

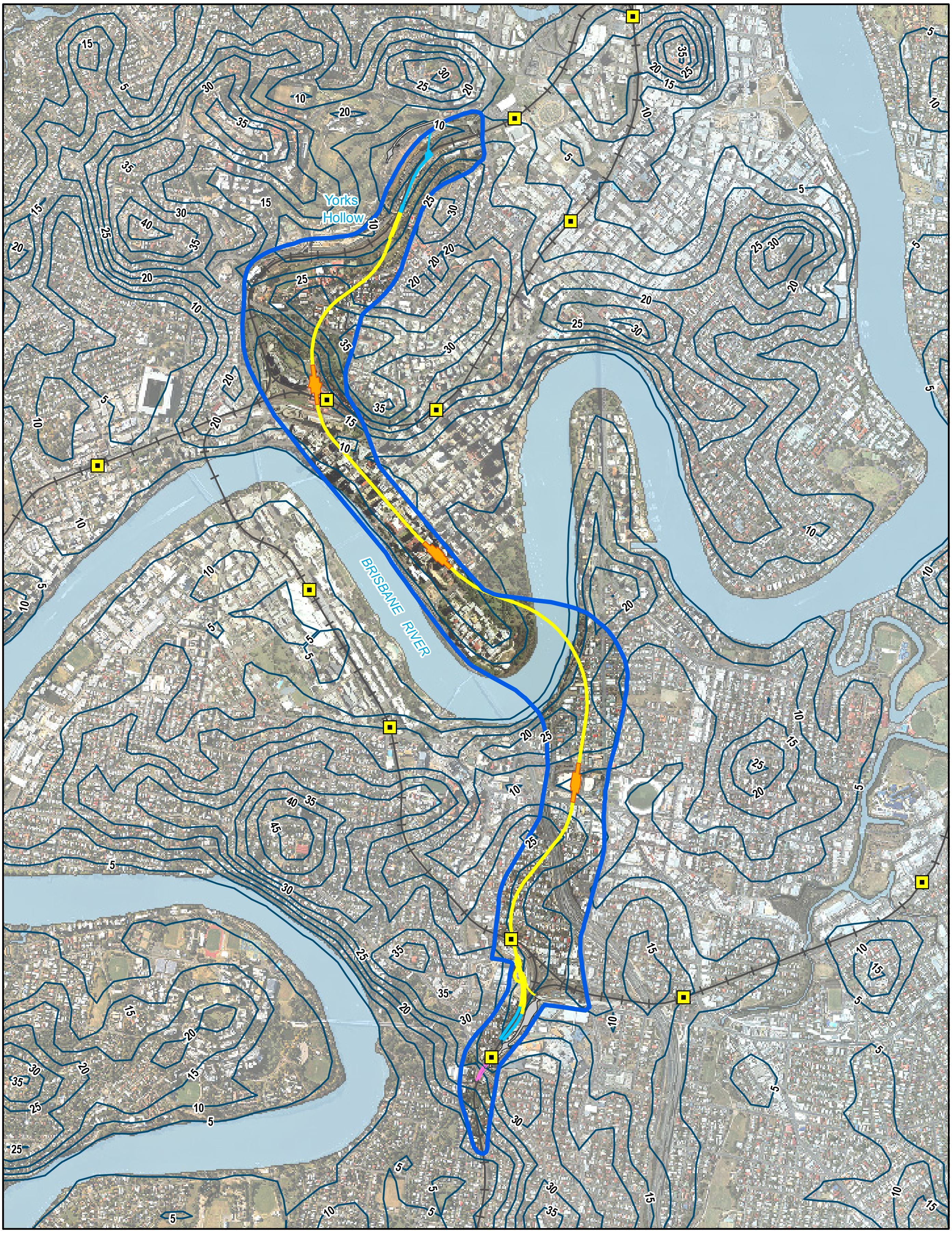
A long-section has been developed from the available information showing the likely water table profile along the study corridor in relation to topography. This long-section is shown in **Figure 9-14**.

Groundwater flow

A groundwater elevation contour map has been developed based on the available groundwater data previously described and provides an indication of groundwater flow direction (refer to **Figure 9-13**). 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 and fractured rock.

The groundwater monitoring program, described in **section 9.4.3** will provide site-specific hydrogeological data to characterise groundwater flow at drained locations including underground stations and cut and cover sections.



LEGEND

- Existing rail station
- Existing rail line
- Depth to water table
- Watercourse
- Study corridor

Project Infrastructure

- Underground station
- Bus layover
- Dutton Park Station (upgraded)

Alignment

- Above ground
- Underground

BUS AND TRAIN PROJECT
ENVIRONMENTAL IMPACT STATEMENT

FIGURE 9-13

Depth to water table

N

0 0.5 1
Kilometres
1:30,000 (at A4)
Projection: GDA 1994 MGA56

Aerial Photo: Brisbane City Council 2012

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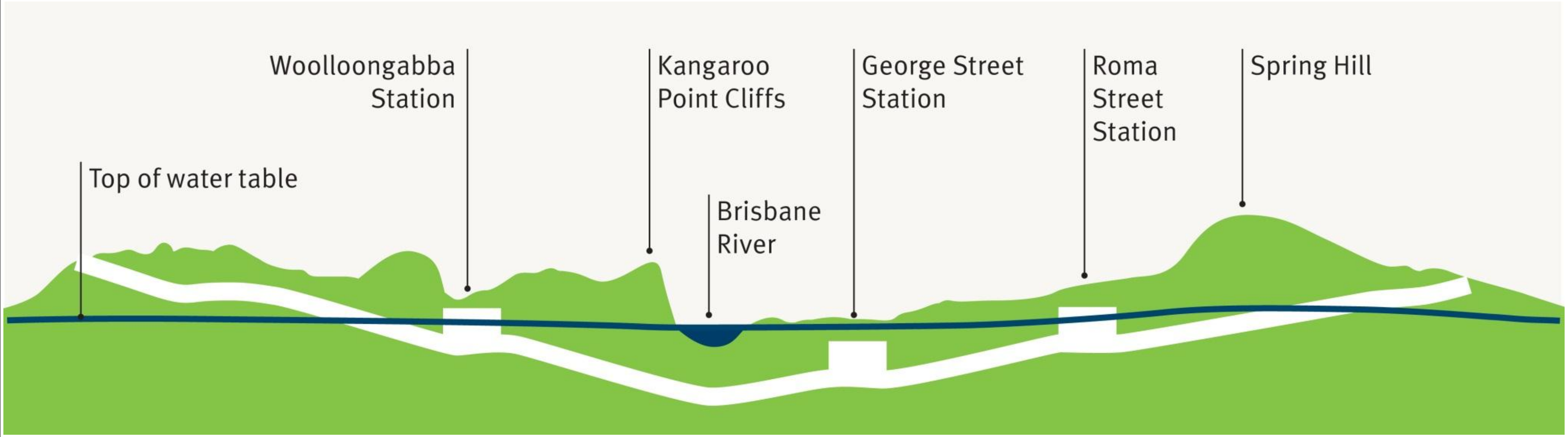


BUS AND TRAIN PROJECT
ENVIRONMENTAL IMPACT STATEMENT

FIGURE 9-14

Water table profile along the study corridor

Surface water – groundwater interaction

The dominant hydrological feature in the study corridor and the surrounding 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 corridor, these rivers and creeks are tidal in nature. Drainage from the study corridor is either directly to the Brisbane River, or into one of the three the main waterway catchments which ultimately drain to the Brisbane River (AGE 2004, 2006).

Surface water to 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 streambed 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 Brisbane River.

The groundwater monitoring program to be undertaken during detailed design will provide site specific hydrogeological data to characterise surface water-groundwater interaction at the worksites (refer to **section 9.4.3**).

Groundwater quality

Water quality data obtained for boreholes located within the vicinity of the study corridor is available from existing groundwater facilities recorded in the DNRM GWDB, and from the Eastern Busway and CLEM7 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 9-8**.

Table 9-8 Groundwater quality data within the Brisbane area

Aquifer	No. of monitoring bores	pH (range)	Total dissolved solids mg/L (range)
Airport Link			
Quaternary Alluvial	6	5.89 to 7.90	540 to 3,819
Brisbane Tuff	5	4.34 to 7.14	293 to 1,717
Neranleigh-Fernvale Beds	1	6.49 to 7.98	334 to 368
Tingalpa Formation	4	5.91 to 7.89	161 to 1,042
S1 Sewer tunnel			
Neranleigh-Fernvale Beds	1	6.7	3,540
CLEM7			
Quaternary Alluvium	4	5.4 to 6.8	570 to 3,200
Brisbane Tuff	4	6.4 to 6.9	860 to 3,200
Neranleigh-Fernvale Beds	2	6.7 to 7.3	15,000 to 22,000
Legacy Way			
Quaternary Alluvium	-	6.52 to 7.27	1,494 to 2,508
Bunya Phyllite	-	4.6 to 7.7	300 to 5,000
Neranleigh-Fernvale Beds	-	6.7	300 to 30,000
Eastern Busway			
Quaternary Alluvium	3	6.79 to 8.03	1,762 to 6,821

Aquifer	No. of monitoring bores	pH (range)	Total dissolved solids mg/L (range)
Brisbane Tuff	1	6.18	1,983
Neranleigh-Fernvale Beds	3	5.87 to 7.07	2,909 to 7,732
DNRM GWDB			
Not specified	17	4.5 to 8.4	33 to 9,896

Acid sulphate soils

The occurrence of ASS and Potential Acid Sulphate Soils (PASS) is reported in **Chapter 6 – Soil and topography**. Areas where PASS may exist includes Breakfast/ Enoggera Creek, Norman Creek, Oxley Creek and Brisbane River. Considering the existing land use and highly developed nature of the study corridor, in some areas a level of groundwater acidification is likely to have occurred. It is also likely in some areas ASS has been excavated and replaced with clean fill material for new developments.

Groundwater dependent ecosystems

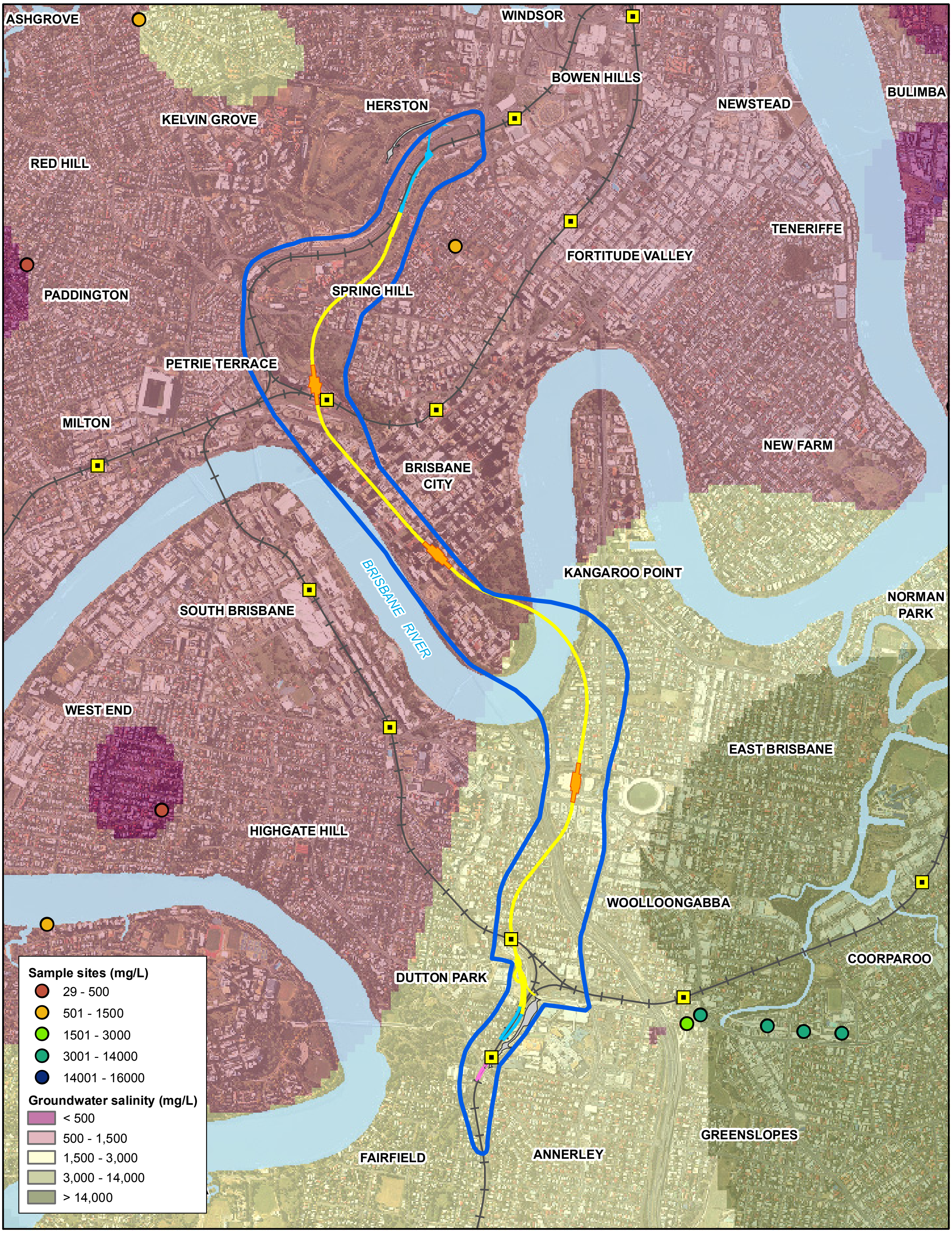
GDEs are ecosystems which have their species composition and their natural ecological processes determined by groundwater (ANZECC and ARMCANZ 2000). **Chapter 8 – Ecology** provides an overview of the sensitive terrestrial and aquatic ecosystems within the study corridor. The key findings indicate that:

- 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 York's Hollow, City Botanic Gardens and Roma Street Parkland 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. Considering that the majority of drainage lines within the study corridor are mostly saline to brackish and tidal in nature, it is anticipated that groundwater in these areas also has a saline nature (refer to **Figure 9-15**). 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 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.



LEGEND

- Existing rail station
- Existing rail line
- Watercourse
- Study corridor

Project Infrastructure

- Underground station
- Bus layover
- Dutton Park Station (upgraded)

Alignment

- Above ground
- Underground

BUS AND TRAIN PROJECT
ENVIRONMENTAL IMPACT STATEMENT

FIGURE 9-15

Groundwater salinity

N

0 0.5 1
Kilometres
1:30,000 (at A4)
Projection: GDA 1994 MGA56

Aerial Photo: Brisbane City Council 2012

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Groundwater – environmental values

Environmental values are defined as the quality or physical characteristics of the environment that are conducive to ecological health, public amenity or public safety. These environmental values should be protected from the impacts of habitat alteration, waste releases, contaminated runoff and changes to flow regimes. Protecting and enhancing environmental values helps to ensure healthy aquatic ecosystems and waterways, which are safe for human use (DERM, 2010a).

The environmental values for the Brisbane River, Breakfast Creek and Norman Creek are listed in **Table 9-2**.

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 corridor, any aquatic ecosystems that may exist within or around the study corridor are considered to be salt tolerant, and thus are unlikely to be impacted by the Project.

Drinking water

Comparison of the existing groundwater quality to the Australian drinking water guidelines 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 limited due to the generally low potential yields.

Irrigation

Based on the available water quality data, groundwater sourced from the study corridor would generally be too saline for general irrigation use as outlined in the Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC & ARMCANZ, 2000b). 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.

9.3 Impact assessment

9.3.1 Flooding

This section provides a summary of the flood protection elements of the reference design and an assessment of potential impacts on flood behaviour from the construction and operation of the Project. Flooding is a surface issue and, as such, impacts on flooding from the Project are limited to permanent surface infrastructure (eg stations and tunnel portals) and temporary infrastructure associated with construction activities (eg construction worksites).

Dutton Park

The Project includes a tunnel portal north of Annerley Road. **Figure 9-2** demonstrates that the portal location is elevated well above the Brisbane River. Brisbane City Council's Flood Awareness Mapping indicates the flood risk is less than very low.

The proposed surface works for the Project are outside the floodplain of the Brisbane River and beyond the areas defined within the City Plan's Brisbane River for creek/ waterway flood planning areas. The tunnel portal will not impact on riverine flood behaviour for all flood events up to very rare flood events.

The portal area is located within an overland flow flood planning area of the City Plan. Overland flooding occurs along the existing rail lines north of Annerley Road, before meeting a path flowing along Ipswich Road which leads to a tributary of Norman Creek. Some areas of overland flow are classified as having high overland flow flood risk (refer to **Figure 9-9**). Suitable design of the on-site stormwater network would be achieved in detailed design to ensure that the risks of overland flow entering the tunnel portal are minimised to an appropriate level.

Woolloongabba

Flood waters from the Brisbane River push back up Norman Creek and its tributaries, affecting the area near the Brisbane Cricket Ground (Gabba Stadium) in rare flood events (events less frequent than the 1 in 500 AEP). **Figure 9-3** demonstrates that the proposed Woolloongabba Station is elevated well above Brisbane River flood levels for nearly all flood probabilities.
Brisbane City Council's Flood Awareness Mapping indicates the flood risk is less than very low.

Figure 9-7 presents mapped flood risk from creek flooding for the Woolloongabba Station. Flood extents for Norman Creek flooding are smaller than Brisbane River flood extents. A new flood study for Norman Creek is being conducted by Brisbane City Council. Preliminary findings suggest the Woolloongabba Station is outside the flood extent of the PMF for Norman Creek flooding.

Woolloongabba Station is outside the areas designated within the City Plan's Brisbane River and beyond creek/ waterway flood planning areas, and is not expected to affect Brisbane River or Norman Creek flood behaviour for all flood events up to very rare flood events.

George Street

George Street Station is situated on a ridge elevated well above Brisbane River flood levels for nearly all flood probabilities. Brisbane City Council's Flood Awareness Mapping designates the flood risk is less than very low, with only William Street exposed to very low risk flooding (refer to **Figure 9-3**).

George Street Station is outside all the City Plan flood planning areas and is not expected to affect flood behaviour for all flood events up to very rare flood events.

Overland flow paths are not identified within the George Street area as a source of flood risk. Suitable design of the on-site stormwater network would be undertaken during detailed design to ensure overland flows are not impacted by the Project and that the risks of overland entering the tunnel portal are minimised to an appropriate level.

Roma Street

The Project includes a station beneath the existing Roma Street Station. River flooding does not affect the Roma Street area according to Brisbane City Council's Flood Awareness Mapping (refer to **Figure 9-4**). Roma Street Station is outside the City Plan's Brisbane River and creek/ waterway flood planning areas, and is not expected to affect flood behaviour.

Roma Street Station is located within the City Plan overland flow flood planning area. An overland flow path identified as having medium flood risk, which correlates to a 1 in 100 AEP event, flows from the north-western corner of the existing Roma Street railway station away from the study corridor and along the railway towards the ICB (refer to **Figure 9-11**).

Suitable design of the on-site stormwater network, during detailed design, would be required to ensure that overland flows are not impacted by the Project and that overland flow does not affect the Project and that the risks of overland entering the tunnel portal are minimised to an appropriate level.

Spring Hill (Victoria Park)

The Project includes a tunnel portal on the southern side of the Exhibition Line, on elevated terrain. Brisbane City Council's Flood Awareness Mapping indicates no creek or river flooding affects this area (refer to **Figure 9-4** and **Figure 9-8**). The tunnel portal surface works associated with the Project are is located outside the City Plan's Brisbane River and creek/ waterway flood planning areas. The Project is not expected to affect flood behaviour for all flood events up to very rare flood events.

Surface works associated with the busway are located within the City Plan's overland flow flood planning area in Herston (Victoria Park). An overland flow path originating near Kelvin Grove Road flows towards and alongside the ICB within Victoria Park, before joining several other overland flow paths in Fortitude Valley and meeting the Brisbane River south of the Breakfast Creek confluence. Areas of the flow path within Victoria Park are described as having a high flood risk (1 in 20 AEP event) (refer to **Figure 9-11**). Suitable design of the on-site stormwater network would be undertaken during detailed design to ensure overland flows are not impacted by the Project or impact upon the Project and that the risks of overland entering the tunnel portal are minimised to an appropriate level.

Construction worksites

During temporary construction worksites would be located at:

- Southern Connection
- Woolloongabba Station
- George Street Station
- Roma Street Station
- Northern Connection.

The proposed construction worksites are located outside of areas identified as having riverine, creek or storm surge flood risk by the Brisbane City Council's Flood Awareness Mapping. As such, the Project is not expected to have any discernible impact on river or creek flood behaviour or levels.

The Northern Connection and Southern Connection construction worksites are identified by Brisbane City Council's Flood Awareness Mapping to be affected by overland flooding.
The Woolloongabba Station construction worksite may potentially be affected by overland flow, with overland flow mapping under review in this area.

Construction worksites would be arranged such that they do not cause or contribute to afflux for a 1 in 5 AEP or greater flood event on the floodplain of any waterways or in overland flow paths. Additionally, sites would be designed to prevent flood waters being re-directed over other private property.

Protection measures would ensure construction worksites are protected from inundation by localised flood waters, including overland flows, up to a 1 in 20 AEP flood event. Where this condition is not met within existing site features, mitigation measures would include the construction of bunds or raising ground levels to protect worksites from flooding, thereby ensuring equipment, materials and storage areas are stored above the predicted flood levels.

Chapter 18 – Draft Outline EMP describes measures to minimise impacts on the existing flood regime of waterways, measures to minimise potential flooding risks during construction and flood monitoring during construction.

Climate change considerations

Potential climate change impacts may influence flooding in Brisbane including potential changes to rainfall and sea level rise. Estimates of sea level rise for Brisbane in 2100 have been reported as 0.5 to 1m (Queensland Office of Climate Change and Environmental Protection Agency, 2008).

A detailed assessment of climate change in regard to flooding is not made as part of this EIS. Risks associated with extremes of climate have been assessed and are presented in **Chapter 16 – Hazard and risk**. However, considering that all Project portals and stations are well outside of the City Plan's Brisbane River and creek/ waterway flood planning areas, increases to flooding due to climate change are unlikely to significantly change the flood risks to the Project or the potential for the Project to result in flooding impacts.

9.3.2 Water quality

The following section discusses the potential impacts on surface water quality as a result of construction and operation of the Project.

Sedimentation

Sedimentation occurs when suspended sediment particles from soil erosion settle in waterways following rainfall events. Erosion and sedimentation is a naturally occurring catchment process. However, factors such as vegetation clearing, earthworks and spoil stockpiling may increase concentrations of sediments to levels which may be detrimental to the environment.

Sedimentation has the potential to occur in waterways within the study corridor as a result of the construction of the Project due to:

- vegetation clearing
- demolition of existing infrastructure (if required)
- earthworks associated with track work, road/ footpath realignments, tunnel activities and haulage roads
- spoil removal, haulage and placement (beyond the study corridor).

Without adequate sediment and erosion control measures, there is potential for the Project to result in increased discharges of sediment into the receiving environment, including Brisbane River, Breakfast Creek, Norman Creek and Moreton Bay. However, the impacts are dependent on the physical and chemical characteristics of the sediment and nature of the preceding rainfall event.

Elevated background turbidity resulting from the sedimentation of the Brisbane River are also factors considered when assessing impacts. Potential impacts may include:

- impacts to aquatic ecosystem environmental values through:
  - reduction in water clarity and light penetration due to suspended particles (increased turbidity) impacting aquatic organisms including aquatic plant health
  - increased nutrient concentrations resulting in algal blooms and reduced dissolved oxygen for aquatic organisms
  - smothering of substrate, impacting on benthic organisms and aquatic plant health
  - reduction in seagrass habitat in Moreton Bay
- reduced recreational, visual, and cultural and spiritual values
- increased flood risk due to siltation of existing stormwater infrastructure.

The area encompassed by the construction worksites (approximately $0.23km^2$) is 0.02 per cent of the catchment area for the Lower Brisbane River catchment, and <0.01 per cent of the catchment for the Brisbane River Basin (including Upper and Mid Brisbane River catchments). The total proportion of catchment area that may contribute to sedimentation runoff will be significantly less as it is limited to the surface works during construction.

Based on the minimal disturbed catchment area, the assimilative capacity of the Lower Brisbane River, and given effective control measures are properly installed and managed, the residual impact of sedimentation would be negligible.

There are many well established management techniques to minimise erosion and prevent the discharge of sediment laden runoff. Details of these can be found in the Road Drainage Manual (TMR, 2002). Specific control measures and mitigation strategies covering discharge of sediments would be determined during detailed design and incorporated in the Erosion and Sediment Control Plan (ESCP). The ESCP is a requirement under the TMR Technical Standard – MRTS51 Environmental Management (MRTS51) and would form part of the Construction Environmental Management Plan (EMP) for the Project.

Monitoring, auditing and reporting of the ESCP implementation would occur in accordance with requirements stated in MRTS51. This includes:

- regular inspections of erosion and sediment controls (weekly and 24 hours after rainfall) recorded using the Site Inspection Checklist
- defects are to be rectified within seven days of detection
- monitoring details and Site Inspection Checklist to be reported monthly
- regular auditing of ESCP to be undertaken by suitably qualified and experienced personnel.

While erosion and sediment control measures may have reduced efficiency during periods of heavy flooding and tropical cyclones, the Project's potential impact on sedimentation is anticipated to be minimal given the assimilative capacity of the Lower Brisbane River during flooding.

Potential impacts associated with ASS and Contamination are addressed in **Chapter 6 – Soils and topography**.

Litter, toxicants and accidental spillages

Potential sources of pollutants that may enter waterways within the study corridor during the construction and operational phases include:

- litter, such as cans, paper, food, cigarette butts, plastic and glass
- nutrients
- heavy metals
- oils and hydrocarbons
- bacteria and viruses
- chemicals and other hazardous substances.

Where not appropriately managed, pollutants would primarily be transported to receiving waterways in stormwater runoff following rainfall events. Potential impacts on receiving waterways are dependent on the source, nature and extent of pollutants, and may result in a reduction in aquatic ecosystem health and reduced recreational, visual recreation and cultural/ spiritual environmental values.

The management of construction phase impacts is also dependent on the source, nature and extent of the pollutant. Detailed mitigation measures would form part of the EMP and would be in accordance with the MRTS51, which includes specific requirements for the management of accidental discharge of contaminants (chemicals and fuels).

Implementation of construction phase water management controls described in **section 9.4.2**, such as erosion and sediment controls, appropriate storage, bunding and spill kits, would prevent litter and spills from entering nearby surface waters. During the operation phase, water will be captured by a drainage system at each of the stations and portals, transferred to a central treatment plant and discharged as trade water to Queensland Urban Utilities' sewer network.

Based on the application of appropriate mitigation measures, the assimilative capacity of the Lower Brisbane River, the residual impact of litter, toxicants and accidental spillages would be considered negligible.

Construction water use

During construction of the Project, there are various demands for water which will be sourced from municipal potable water supplies and potentially, from recycled groundwater inflow treated at on-site water treatment plants. The water demands during construction may include for dust suppression, compaction, vehicle and wheel wash down, production of various construction materials such as grout, firefighting supply and human consumption. As noted in **section 9.2.3**, groundwater would not be extracted actively from nearby bores for use during construction of the Project.

The benefit of using recycled groundwater is a reduction on the demand of the potable supply network. The use of recycled water may have potential impacts to the receiving environment should discharge occur, through uncontrolled releases and/ or contaminated runoff. The impact of this discharge is dependent on the type and extent of discharge, and may include impacts to aquatic health through the release of chemicals, hydrocarbons, sediment, and highly saline water. The potential impact of a release of water used during construction will be managed by treating any recycled water to an acceptable standard prior to use.

9.3.3 Groundwater

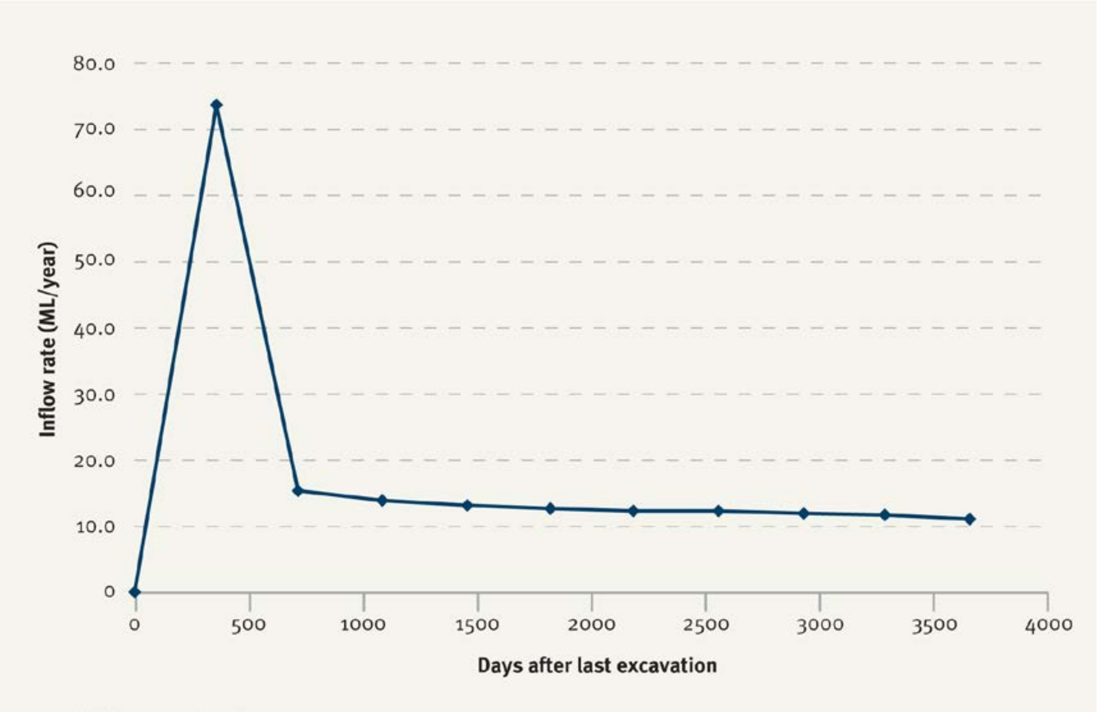
Groundwater modelling of potential impacts was undertaken for the construction and operation phases of the Project. The construction phase was simulated only for excavation areas and not the tunnelling, as the method of construction using the tunnel boring machine (TBM) would result in inflows that are no greater than those expected during normal tunnel operation. The TBM driven tunnel would be lined with pre-cast segmental concrete linings and gaskets to create a waterproof seal, reducing groundwater inflows to less than 1L/s.

Estimated groundwater inflow

The groundwater models were used to estimate groundwater inflow into the drained tunnel and station areas during construction and operation. **Figure 9-16** presents the model results.

The rate of groundwater inflow into the drained sections of the tunnel (ie station caverns and cut and cover sections) is shown to decrease over time after an initial high peak in the first year (refer to **Figure 9-16)**. The average groundwater inflow post-construction is approximately 11ML/ year. This is significantly less than inflows estimated for the CLEM7 and Legacy Way projects.

Figure 9-16 Estimated daily groundwater inflows into the entire tunnel system



Source: EIS Groundwater model

Groundwater flow

For the operational phase of the Project, groundwater heads for each of the modelled scenarios have been predicted for the first 10 years, or 3,650 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 3,650 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 may occur from the alluvial aquifer to the fractured rock aquifer and ultimately to the tunnel.

River leakage prediction

Drainage of groundwater into the tunnel has the potential to cause leakage of water from the Brisbane River into the groundwater system. Drawdown associated with drained sections (station caverns and tunnel cut and cover sections) of the Project is predicted to alter the hydraulic gradient and flow regime of groundwater resulting in the localised inflow of saline water. However, based on the model results, changes in base flow and/ or increases in leakage from the Brisbane River are expected to be minimal and below detection levels.

Groundwater drawdown

Groundwater drawdown occurs around the drained sections of the tunnel, including the portals and the station locations. Groundwater drawdown may occur within small areas of the City Botanic Gardens (towards Alice Street) and along the banks of the Brisbane River near Kangaroo Point.

The extent of groundwater drawdown has been predicted (refer **Figure 9-17**, **Figure 9-18** and **Figure 9-19**) for one, five and ten year periods following tunnel construction.

The modelling suggests that some of the drawdown areas would occur below alluvium. 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. Refinements to the modelling, including characterising and assessing drawdown propagation based upon additional site knowledge would be undertaken to inform detailed design.

Existing groundwater quality in the study corridor is generally brackish to saline in quality and is tidally influenced by the Brisbane River. As a result of drainage of groundwater into the tunnel over time, there is the potential for movement of this brackish zone inland towards the tunnel. Discharge of saline water to the tunnel has the potential to impact upon the integrity of the tunnel through the corrosion of concrete drains or potential precipitation (scaling) of calcium carbonate contributing to the clogging of concrete drainage systems. This potential issue would be addressed during detailed design (through methods such as increased concrete cover) and the Project's ongoing operational inspection and maintenance program.

The predicted groundwater drawdown for the drained sections of the Project is discussed in the following sections.

Woolloongabba Station

At Woolloongabba Station, drawdown of 1 to 5m extends approximately 160m horizontally from the tunnel following one year of tunnel operation and increases up to 341m from the tunnel following ten years of tunnel operation.

Drawdown of 5 to 10m extends approximately 116m horizontally from the tunnel following the first year of tunnel operation (refer to **Figure 9-17**). This drawdown increases up to 150m from the tunnel, after 10 years of tunnel operation (refer to **Figure 9-19**). Localised areas of 10 to 20m drawdown within the immediate vicinity of the Woolloongabba Station are predicted following five years of tunnel operation (refer to **Figure 9-18**).

The implications on settlement in areas of drawdown are discussed in **Chapter 6 – Soils and topography**.

George Street Station

At George Street Station, groundwater drawdown of 1 to 5m extends approximately 200m horizontally from the station following one year of operation (refer to **Figure 9-17**) and increases up to 250m from the station following 10 years of operation (refer to **Figure 9-19**).

Drawdown of 5 to 10m extends approximately 80m horizontally from the tunnel following the first year of tunnel operation (refer to **Figure 9-17**). The extent increases up to 170m from the tunnel after 10 years of operation (refer to **Figure 9-19**). Localised areas of 10 to 20m drawdown within the immediate vicinity of the George Street Station are predicted following five years of tunnel operation (refer to **Figure 9-18**).

Roma Street Station

At Roma Street Station, drawdown of 1 to 5m extends approximately 275m from the tunnel following one year of tunnel operation (refer **Figure 9-17**) and increases up to 370m from the tunnel following ten years of tunnel operation (refer to **Figure 9-19**).

Drawdown of 5 to 10m extends approximately 150m from the tunnel following the first year of tunnel operation (refer to **Figure 9-17**). The extent of groundwater drawdown remains at 150m from the tunnel, after 10 years of operation (refer to **Figure 9-19**). Localised areas of 10 to 20m drawdown within the immediate vicinity of the Roma Street station are predicted following five years of tunnel operation (refer to **Figure 9-18**).

Settlement

Potential impacts and mitigation measures for settlement are examined in **Chapter 6 – Soils and topography**.

Evaluation of significance

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 in the 10 years post-construction for the reference design scenario. Monitoring of head in either bore should continue as part of the RNA Showgrounds 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.

Mobile groundwater contaminants within the tunnel capture zone, would eventually discharge into the drained northern and southern portal sections of 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 one, five and 10 years after tunnel construction in **Figure 9-17** to **Figure 9-19** 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 approximately 11 ML/ year, 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 6 – Soils and topography**.

Acid sulphate soils

Considering the existing land use and highly developed nature of the study corridor, groundwater acidification is likely to have occurred to some extent. However, the extent of groundwater drawdown associated with underground construction is unlikely to extend into areas of PASS. The potential to lower groundwater levels in these areas and expose PASS is therefore considered negligible. A detailed assessment of ASS in the study area, including measures to manage PASS, is provided in **Chapter 6 – Soils and topography**.

Groundwater dependent ecosystems

The level of groundwater dependency in the study corridor is considered to be relatively low with terrestrial vegetation, river base flow 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, within the lined tunnel, groundwater drawdown is predicted to be limited. **Chapter 8 – Ecology** provides an overview of the sensitive terrestrial and aquatic ecosystems within the study corridor.

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FIGURE 9-17

Modelled drawdown at 300 days (1 year)

Aerial Photo: Brisbane City Council 2012

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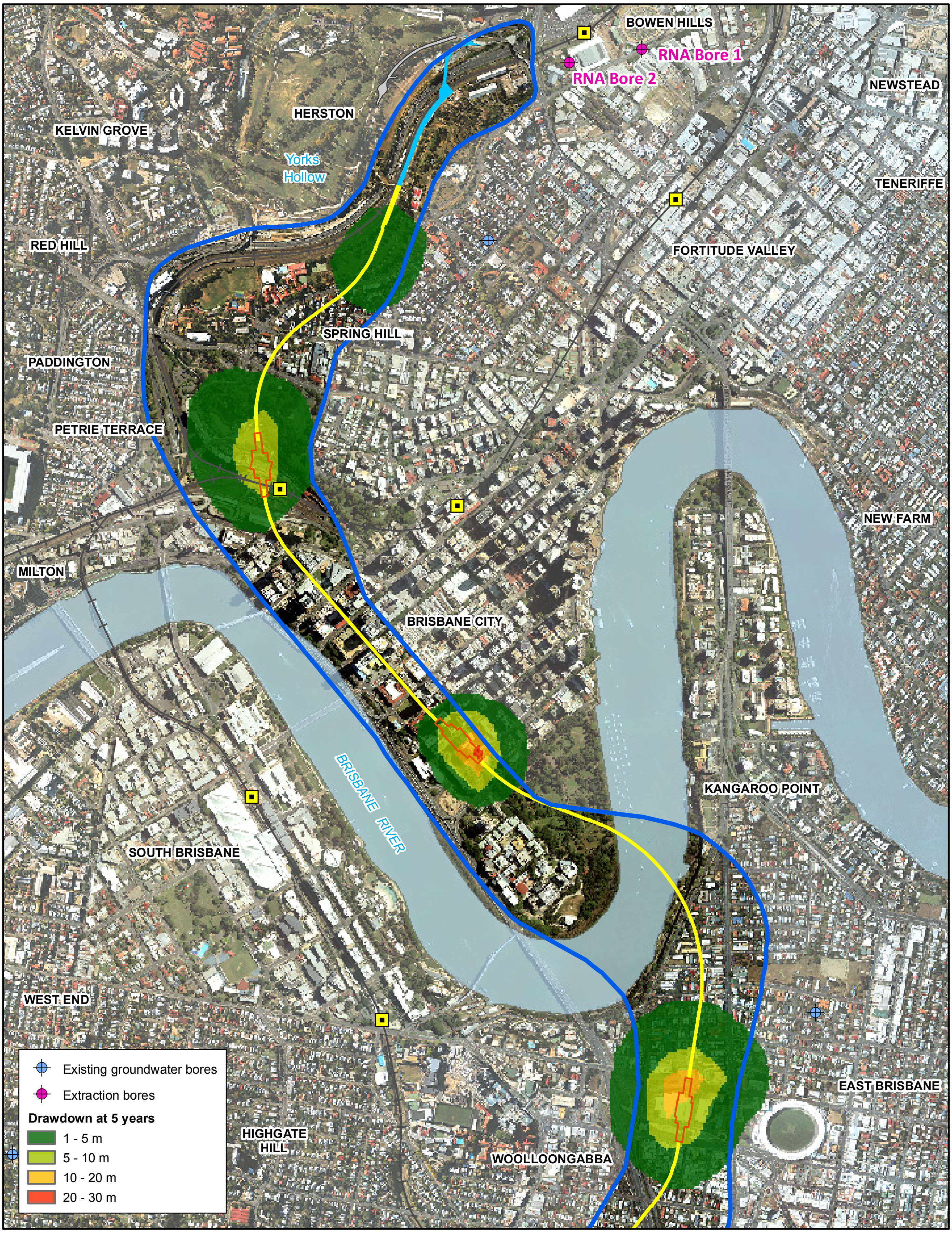

LEGEND

- Existing rail station
- Existing rail line
- Watercourse
- Study corridor

Project Infrastructure

- Underground station
- Bus layover

Alignment

- Above ground
- Underground

BUS AND TRAIN PROJECT
ENVIRONMENTAL IMPACT STATEMENT

FIGURE 9-18

Modelled drawdown at 1825 days (5 years)

N

0 0.25 0.5
Kilometres
1:18,500 (at A4)
Projection: GDA 1994 MGA56

Aerial Photo: Brisbane City Council 2012

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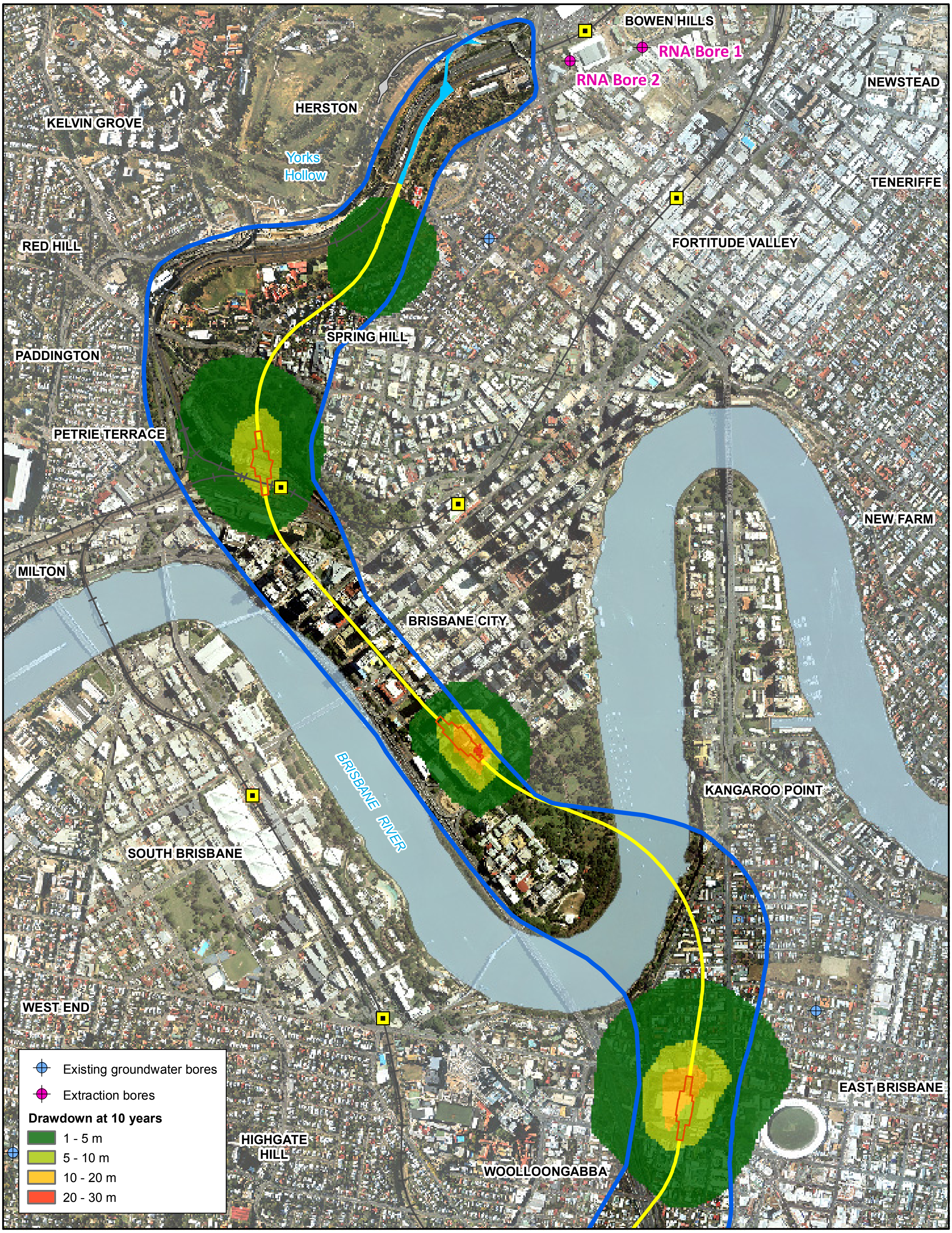

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LEGEND

- Existing rail station
- Existing rail line
- Watercourse
- Study corridor

Project Infrastructure

- Underground station
- Bus layover

Alignment

- Above ground
- Underground

BUS AND TRAIN PROJECT
ENVIRONMENTAL IMPACT STATEMENT

FIGURE 9-19

Modelled drawdown at 3650 days (10 years)

N

0 0.25 0.5
Kilometres
1:18,500 (at A4)
Projection: GDA 1994 MGA56

Aerial Photo: Brisbane City Council 2012

9.4 Impact management

9.4.1 Flooding

The risk of floods and storms and their potential to inundate the Project has been considered and addressed. Measures to provide an appropriate level of immunity have been included in the design, with the Project assigned a level of protection from the following events:

- 1 in 10,000 AEP regional events (eg river and creek flooding)
- 1 in 100 AEP local events (eg storms and localised, overland flow).

Design measures to achieve the desired immunity from floods and storms are described below.

Regional flood events

Immunity from regional floods during operation would be achieved through two primary measures; the elevation of infrastructure and barriers to prevent the ingress of water.

Where possible, above ground infrastructure would be located in areas of naturally elevated land and above the height of regional floods. The reference design would achieve this outcome at all five portals and at Woolloongabba Station. Supplementary measures would be required at the George Street and Roma Street stations, with these areas marginally lower than the 1 in 10,000 AEP river flood height. Temporary flood boards (approximately 1,200mm high) would be required, providing additional freeboard and the required immunity. These boards would be installed across the station entries manually and immediately prior to the potential for flooding.

Local flood events

Additional measures to manage storm water and localised, overland flow during operation would be required. These controls would ensure that disruptions to services during operation and maintenance costs are minimised. In summary, the principal controls would include;

- Southern Connection – an approximately 1m high retaining wall would be constructed to separate the bus layover area from the rail dive structures
- Northern Connection – an approximately 0.5m high retaining wall would be constructed alongside the rail dive structure
- stations – kerb and channel.

Localised relief drainage works and storm water network upgrades would also be undertaken where required.

Controls to manage storm water and localised, overland flow would also be required during construction. An overview of these measures is provided in **Table 9-9** and **Chapter 18 – Draft Outline EMP.**

Table 9-9 Proposed management measures

Impact	Project phase	Management measure
Flood protection of construction worksites	Construction	Implementation of suitable mitigation measures, such as the construction of bunds or raising ground levels, to: • prevent flooding of construction worksites in a 1 in 20 AEP event • prevent flooding of bulk storage facilities for hazardous substances in a 1 in 50 AEP event • allow continued access to the local road network from construction worksites during flood events up to 1 in 50 AEP events.
Flooding management during construction	Construction	Suitable design of construction worksites to not cause or contribute to afflux for a 1 in 5 AEP flood event or greater on the floodplain of any waterways or in overland flow paths. Construction activities, including any temporary works and spoil placement, prevents flood waters being re-directed over other private property.

Flood preparation and response

During operation, rainfall and rising water levels would be monitored by Queensland Rail and TransLink. Flood preparation and emergency response procedures would be enacted when the potential for floods arise. This would include the restriction or diversion of services until the flood waters abate. Prior to recommissioning, inspections and tests would be undertaken to ensure that all systems and services are functioning correctly.

9.4.2 Water quality

The potential impacts and management measures for the Project are listed in **Table 9-10**.

Table 9-10 Impact management measures

Impact	Project phase	Management measure
Interaction with surface waters	Construction and operation	Construction of portals and other tunnel/ station entrances to be located outside the 1 in 10,000 AEP event in regional flooding. Drainage water will be treated at one of the onsite water treatment plants located at each of the stations and portals before being discharged as trade water to Queensland Urban Utilities' sewer network.
Sedimentation of downstream waterways	Construction and operation	Prepare and implement an ESCP. Erosion control measures at surface worksites may include velocity reduction techniques (such as check dams, drop structures and modifications to flow path), chemical surface stabilisers, erosion control blankets, mulching, revegetation, stabilisation with geotextiles and surface roughening. Sediment control measures include buffer zones, grass filter strips, configuration of construction exits and the use of sediment fences, traps, basins and weirs.

Impact	Project phase	Management measure
Runoff from ASS	Construction and operation	Where identified, ASS will be managed in accordance with the Soil Management Guidelines in the Queensland Acid Sulphate Soil Technical Manual (2002, DNRM). Where required, management may include installation and inspection of ASS storage areas and runoff controls (treat if required), monitoring, auditing and reporting. Surface drainage measures give consideration to the avoidance or management of potential discharges from ASS into surface waters.
Runoff from contaminated soils	Construction and operation	Disturbance of contaminated soils is avoided or minimised, as far as practicable. Where contaminated soils are required to be disturbed, appropriate run-off controls are to be implemented ahead of works commencing to divert surface run-off around exposed soils.
Litter, toxicants and accidental spillages	Construction and operation	Prior to the commencement of construction, develop and implement storage and handling procedures for chemicals, litter and other hazardous materials to avoid the release of contaminants to waterways, stormwater drains or roadside gutters, including procedures for both managing uncontrolled releases to waters. Implement a combination of one or more control measures including oil and grit separators, gross pollutant traps, trash racks, screens, detention basins, sand filters, filter strips, buffer zones, grassed swales and water quality ponds. Specific measures are described in greater detail in **Chapter 18 – Draft Outline EMP.** During the construction and operation phases, water will be captured by a drainage system at each of the stations and portals, transferred to a central treatment plant and discharged as trade water to Queensland Urban Utilities' sewer network.
Runoff of construction water	Construction	Develop and implement construction water management measures, including: • provision of bunded chemical storage areas consistent with the requirements of *AS1940* – The storage and handling of flammable and combustible liquids • spill response kits • spill clean-up procedures • designated wash down areas for concrete deliveries • treatment of construction water and runoff controls, if necessary • progressively restore and rehabilitate sites affected by construction works.
Generation of wastewater by Project activities	Construction	Develop and implement measures for the collection, treatment, diversion and assessment of wastewater generated from construction activities via an approved system (on-site or off-site), including the provision of temporary water treatment facilities at the Northern Connection, Roma Street, George Street, Woolloongabba and Southern Connection construction worksites.

A comprehensive water quality monitoring plan and contingency plan would be detailed during detailed design and would form part of the overall EMP for the Project. This would be in accordance with requirements under the MRTS51and the following guidelines:

- EPP (Water)
- Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC, 2000)
- Queensland Water Quality Guidelines (DEHP, 2009)
- Monitoring and Sampling Manual 2009 (Version 2) (DEHP, 2013).

The WQOs for surface waters potentially impacted by the Project are shown in **Table 9-3**.

The water quality monitoring program is to be implemented prior to, during and subsequent to construction to monitor discharges from construction worksites to all identified receiving waters. The monitoring program will also assess water quality within receiving waters to evaluate compliance with the specified WQOs. The monitoring program will allow for the capture of adequate baseline data to establish seasonal WQOs for the Project with consideration for the receiving surface waters.

The water quality monitoring program will also include, but not be limited to:

- a description of potentially affected water bodies
- construction activities at each worksite and the potentially associated contaminants
- specific monitoring locations, including upstream and downstream surface waters at each construction worksite (eg Norman Creek, York's Hollow and Breakfast Creek).
- frequency of monitoring, including prior to discharge of any surface waters from each construction worksite at least weekly and immediately following a defined rainfall event.

During routine daily site inspections and immediately following any rainfall event causing runoff from the worksite, a visual assessment will be conducted of all waterways within and adjacent to worksites to determine the presence of litter, sediment, chemical plumes or other toxicants.

Immediately following a rainfall event causing runoff from the worksites, a visual inspection of all erosion and sediment control measures, bunding and water treatment facilities is to be conducted to assess any damage or maintenance requirements and to review effectiveness.

Where monitoring indicates an exceedance of the EPP (Water) or Queensland Water Quality Guidelines, or an uncontrolled release of contaminants, chemicals or fuels occurs:

- corrective actions and mitigation measures, including ceasing the release, are to be implemented immediately
- reporting of an event to DEHP within 24 hours of the proponent becoming aware of the release, where the event results in an uncontrolled release of contaminants to the environment
- conduct an investigation into the root cause of the exceedance or uncontrolled release. Additional mitigation measures, as appropriate, are to be implemented to address the non-conformance.

9.4.3 Groundwater

The key mitigation measures proposed will be incorporated into the methods of construction for the tunnel and the underground stations. Groundwater inflow will be mitigated by construction methodology as follows:

- TBM driven tunnel would be lined with pre-cast segmental concrete linings immediately after rock cutting. Gaskets would be included wherever these linings are used to create a waterproof lining
- all tunnel sections will be constructed by TBM and as a consequence, would be undrained
- station caverns and cut and cover locations will be drained.

Piles, followed by the application of shotcrete (or other suitable methods), would be used to reduce the inflow of groundwater into excavations during construction. Residual inflows would be captured by a drainage system, transferred to a central treatment plant and discharged as trade water to Queensland Urban Utilities' sewer network.

The tunnel would be considered to be 'dry' with groundwater inflow expected to be low, in the order of 11ML/ year. With the application of pre-cast concrete segments with gaskets as the preferred lining for the tunnel, the impacts of potential groundwater drawdown would be mitigated to the fullest extent practicable.

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 EMP (refer to **Chapter 18 – Draft Outline EMP**) and would include:

- prior to the commencement of construction, a water quality monitoring program must be established using the following guidelines:
  - EPP (Water)
  - Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC, 2000)
  - Queensland Water Quality Guidelines (DEHP, 2009)
  - Monitoring and Sampling Manual (Version 2) (DEHP, 2013)
- 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, through survey and consultation, 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
- outlining storage and handling procedures for fuels, chemicals and other hazardous materials, to avoid the release of contaminants to groundwater. This includes procedures to prevent or contain spills, and to ensure that accidental spills are cleaned-up and appropriately remediated to avoid contamination of groundwater seepage
- implementing appropriate practices and procedures for waste handling, storage and disposal, accidental spillages and use of concrete and grout to avoid contamination of groundwater.

It should be noted that the groundwater model is sensitive to initial groundwater levels and the conductance value that was applied to the Brisbane River. Further hydrogeological investigation, based on data obtained from further geotechnical survey (to inform detailed design), will be undertaken (including estimating river conductance) to verify the current groundwater drawdown calculations. Specific mitigation measures for groundwater drawdown will then be detailed in the final EMP for the Project.

Groundwater monitoring program

A monitoring program would be implemented to inform and support the construction and operation phases for managing and mitigating the groundwater effects of the Project. The groundwater monitoring program will be established with consideration of:

- EPP (Water)
- Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC, 2000)
- Queensland Water Quality Guidelines (DEHP, 2009)
- Monitoring and Sampling Manual (Version 2) (DEHP, 2013).

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 groundwater monitoring program is to include means of determining:

- water level drawdown as a result of the Project
- quality of groundwater being intercepted
- site specific parameters which will trigger further groundwater management
- assessment of actual and potential contaminant migration, including drainage from ASS
- an outline of contingency actions in the event adopted guideline levels are exceeded
- volume of groundwater to be treated and released to surface waters.

In turn, this information is expected to be sufficient to determine options for reducing the volume of groundwater to be treated and released by the Project. It would also inform selection of appropriate groundwater treatment methods to achieve compliance with adopted guideline levels for released waters.

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. Following this review, additional bores may be proposed to address any gaps identified in the existing groundwater monitoring network.

Groundwater quality monitoring would be undertaken on a quarterly basis during the 12 months prior to construction of the Project. This monitoring would be supplemented by data available from geotechnical drilling undertaken for the Project.

The collected baseline groundwater data would serve as guideline levels to identify potential impacts during the construction and operation phases. In the event a new ‘groundwater feature’ (eg areas of high groundwater flow/ yield) is identified along the Project alignment, further 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.

During and for 12 months following construction, groundwater level (for drawdown) and quality (for contamination) monitoring would be undertaken on a quarterly basis. 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.

Groundwater quality monitoring would include the field and laboratory parameters identified in **Table 9-11**.

Table 9-11 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, Sulphate and Alkalinity), Iron, Aluminium, Silver, Antimony, Molybdenum, Selenium, Total Petroleum Hydrocarbons (TPH) and benzene, toluene, ethylbenzene, and xylene (BTEX)

Scheduled groundwater monitoring events will be supported by routine daily site inspections to visually identify any potential for inundation of critical work areas or contaminant storage areas, or any increase of inflow rates with potential to exceed the capacity of groundwater containment and treatment measures. Daily site inspections are also to include inspection of machinery and equipment, and hazardous substance storage areas, to identify potential for leaks or spills.

During operation, groundwater inflows to the Project would be monitored for quality to determine and manage the requisite treatment, prior to release. The EPP (Water) and Queensland Water Quality Guidelines will apply to groundwater released to receiving waters.

9.5 Summary

9.5.1 Surface water

The Project infrastructure open to the surface, and with the potential for interaction with the floodplain, includes five tunnel portals and three stations, as well as worksites during the construction phase. Flood immunity has been incorporated into the Reference Design such that these areas would be appropriately protected from flooding and avoid flood impacts on third parties.

The tunnel portals, stations and worksites are situated outside of the City Plan’s Brisbane River and Creek/ waterway flood planning areas. Additionally, the portals and station locations were not affected by the Brisbane River floods of 2011 and 1974. As such, the Project is not expected to have any discernible impact on river or creek flood behaviour or levels.

The Project surface infrastructure at the Southern Connection, Roma Street Station and Northern Connection is located within the City Plan’s overland flow flood planning area. A review of the existing site terrain and Reference Design at each site has been undertaken. Based on this review the risk of partial tunnel inundation due to local overland flow, is considered to be low and within acceptable limits. Suitable design of the on-site stormwater network, during detailed design, will ensure that overland flows are not impacted by the Project and that overland flow does not affect the Project.

The Project would result in transport infrastructure with a lower level of flood risk than the existing bus and train networks in the study corridor.

The following potential impacts to surface water may occur as a result of the Project:

- interactions with surface waters
- sedimentation within downstream waterways
- runoff from potentially contaminated soils and ASS to downstream waterways
- introduction of litter, toxicants and accidental spillages to downstream waterways
- runoff of construction water to downstream waterways
- changes to overland flow paths.

The potential impacts may occur during the construction and operational phases of the Project, with the exception of runoff from construction water, which applies only during the construction phase. The impacts can be effectively mitigated by employing widely accepted management strategies.

The residual impact to surface water as a result of the Project is expected to be negligible.

Waterways, which receive direct runoff from the Project, include the Lower Brisbane River, Breakfast Creek and Norman Creek. Waterways that may be impacted further downstream include Moreton Bay (at Waterloo Bay and Bramble Bay). The condition of these waterways is generally ‘poor’ and largely impacted by urbanisation and industrial uses. The exception to this is Waterloo Bay, which is generally of ‘good’ ecosystem health.

9.5.2 Groundwater

Portions of the tunnel and station locations would require dewatering. Dewatering has the potential to result in groundwater drawdown. Based on results from groundwater modelling, groundwater drawdown in RNA Showground bores is not expected ten years post-construction and would have a negligible impact on pumping rates. Drawdown may impact on unregistered (unidentified) groundwater users within the zone of drawdown.

The extent of groundwater drawdown (greater than 1m) is not predicted to extend to the majority of the locations where GDEs may be present. However, groundwater drawdown may occur within small areas of the City Botanic Gardens (towards Alice Street) and along the banks of Brisbane River near Kangaroo Point. A slight decline (less than 0.1 per cent) in groundwater discharge is anticipated, however this is considered to be very small. It is considered 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 the saturated zone.

The existing beneficial use of groundwater within the study corridor is considered to be low. Existing groundwater quality in the study corridor is variable and can be brackish to saline in quality.

The contaminated sites investigation identified the presence of a number of sites with an existing or historical land use with the potential to cause land contamination. Groundwater is likely to be contaminated in these areas. Any mobile groundwater contaminants within the study corridor may ultimately discharge to the proposed tunnel. Groundwater inflow to the tunnel is expected to be low, in the order of 11ML/ year, any contaminant fluxes would also be correspondingly low.

Groundwater entering the tunnel will be treated prior to disposal. Construction of the tunnel will serve to intercept and treat any contaminated groundwater that would otherwise discharge to surface water systems. Treatment systems will need to be designed to handle the type of contaminants that may discharge into the tunnel. Therefore, capturing contaminated groundwater could have a positive impact on the aquifer and surface water systems.