Northern Link

7. Hydrology

Northern Link

Phase 2 – Detailed Feasibility Study

CHAPTER 7

HYDROLOGY

- September 2008

Contents

7. Hydrology

This chapter addresses Part B, Section 5.2 in the Terms of Reference relating to groundwater, surface water quality and flood potential. It describes the quantity, distribution, quality, use and importance of groundwater in the study corridor and, where relevant, in immediately adjacent areas. Environmental values of groundwater are described in terms of the Environmental Protection (Water) Policy, sustainability of water quality and quantity and physical integrity and fluvial processes of the groundwater resource. Potential impacts and areas of potential impact of the Project on any existing groundwater resources are assessed. Significance of the Project to groundwater depletion and recharge and any groundwater dependent ecosystems are identified. The potential for draw-down on known and potentially contaminated groundwater has been investigated. This assessment takes into account Section 5.1 of the EIS with reference to acid sulphate soils. Management options available to monitor and mitigate any potentially deleterious effects on groundwater resources are identified.

Watercourses in and adjacent to the study corridor are described in the context of their catchment areas. The quality of water in these waterways is assessed from past or existing monitoring programs. Potential impacts on the Environmental Values of the waterways are assessed and Water Quality Objectives are defined in line with existing local, state and national guidelines. Mitigation measures and/or management strategies are defined for identified potential negative impacts. Strategies for protecting water resource environmental values are defined and the effectiveness of mitigation measures is discussed with particular reference to sediment, acidity, salinity and other emissions of a hazardous or toxic nature to human health, flora or fauna. Methods of monitoring, auditing and management to achieve the objectives are outlined.

Hydraulic modelling of the Brisbane River and the local catchments of the study corridor is undertaken to assess the flood potential, particularly in the portal areas. This hydraulic modelling is used to assess potential impacts of the Project on regional flood levels, appropriate locations for construction sites and workshops and effects on adjoining properties. Potential impacts are identified and design revision or mitigation measures outlined to avoid or mitigate the potential impacts.

Detailed technical papers forming the base for this chapter are referred to throughout as Technical Paper No. 2 – Groundwater, Technical Paper No. 4 – Surface Water Quality and Technical Paper No. 8 – Flooding and drainage control, and are provided in Volume 3 of the EIS.

7.1 Existing Groundwater

7.1.1 Aquifers

Bunya Phyllite

This unit typically has negligible primary porosity and any groundwater is limited to localised structural defects such as joints, fractures, etc. Relatively 'clean' fractures (ie: those with void spaces along their extent) encountered at depth have the highest groundwater potential. However these are typically not interconnected or regionally extensive. Groundwater within the Bunya Phyllite is, therefore, likely to be semi-confined or confined (ie virtually zero hydraulic conductivity).

Depth to groundwater within the Bunya Phyllite varies spatially across the study area but is generally 3.9-7.5m below ground level. Hydraulic parameters for the Bunya Phyllite are inferred from a pumping test performed at the Botanical Gardens as part of the Brisbane Aquifer Project (Environmental Hydrology Associates, 2007). The average transmissivity value determined for the Bunya Phyllite was 9.5m^2/day (Environmental Hydrology Associates, 2006) with the horizontal hydraulic conductivity (k_h) estimated to be a very low 1.2m/day.

Hydraulic characteristics of the Bunya Phyllite vary over short distances. For example, a pilot bore drilled approximately 20m from the production bore produced very low groundwater yields of 0.1 l/s at 180m below ground level.

Neranleigh-Fernvale Beds

Groundwater in this unit is typically limited to secondary porosity (ie: fractures, joints or other structural voids) associated with localised zones of structural deformation. Bulk permeability is likely to vary both laterally and with depth as a function of geology and structural integrity. The in situ hydraulic conductivity of this formation is very low with hydraulic conductivities typically in the order of $<10^{-9}$ to 10^{-6} m/s.

Depth to groundwater within the Neranleigh-Fernvale beds is generally 3-4.5m below ground level. No long term hydrographs showing changes in groundwater level over time were available for the basement rock aquifers. However, groundwater levels are likely to respond rapidly to rainfall recharge on the flanks of ridges and where deep drainage from water supply infrastructure (ie: mains, stormwater) and drainage lines occur. Groundwater recharge is likely to be influenced by permeability, fracture connectivity and, in general, is probably slow and tortuous in most instances (except at rain events as mentioned in previous sentence).

Previous geotechnical investigations of the Neranleigh-Fernvale Beds (AGE 2004, 2006) indicate approximate permeability range from negligible (ie: $<10^{-9}$m/s) to 1.15×10^{-6} m/s with an average of 4.65×10^{-7} m/s.

Alluvial Aquifers

Quaternary alluvium is limited to isolated pockets along ephemeral drainage lines to the Brisbane River transverse to the proposed tunnel alignment. In general, these alluvial sediments form unconfined and perched aquifers overlying less permeable basement rocks, with groundwater occurrence primarily a function of matrix porosity.

No hydraulic testing has been undertaken within the alluvial sequences. However, test pitting investigations at the eastern extremity of the botanical gardens (in close proximity to the Botanical Gardens production bore) suggest that the alluvium, mainly gravels, is relatively transmissive. Groundwater levels recovered from bores and test pits constructed in alluvium are relatively shallow in the range 1.5-6m below ground level. Groundwater recharge to these areas is likely to be relatively rapid following rainfall events and is expected to gradually decline following cessation due to evapotranspiration.

7.1.2 Groundwater Movement

Groundwater movement within the basement rocks would occur predominantly along structural defects (faults, fractures, joints and foliation) with the rate of flow governed primarily by the frequency, length and aperture, connectivity and orientation (longitudinal, transverse or oblique) of fractures and joints (Cook, 2003). Within the surficial alluvium, groundwater movement would occur as a function of gravity drainage within intergranular pore space.

Limited monitoring data are available to define the relationship between alluvium along the proposed alignment and the underlying fractured basement rocks. Conceptually, it may be inferred that vertical leakage from the overlying alluvium to the basement rock aquifer occurs but is typically limited by the low permeability of the underlying unit.

In contrast, upward seepage from the basement rocks into overlying alluvium may occur based on the observation that heads within the Bunya Phyllite are at least locally artesian. This upward flow results from recharge entering the basement aquifers at locations which are at greater elevations than the measured heads and/or the storage of groundwater under pressure.

7.1.3 Groundwater Users

Survey of DNRW's groundwater database (GWDB) identified 12 registered groundwater bores within 5km of the study corridor, with five of these facilities classified as 'abandoned and destroyed'. No detailed water quality, hydraulic testing or groundwater yield data were available for any of the registered existing bores.

The very small number of groundwater facilities within 5km of the study corridor is not surprising given that the bedrock of the Brisbane area is typically associated with very poor groundwater prospects. Based on available data it is considered that groundwater occurrences for domestic or commercial purposes in the vicinity of the study corridor are largely opportunistic or limited and unreliable in any larger quantities.

No existing facilities were identified within the study corridor except for the borehole designated MC1-A in the Botanic Gardens. However, this bore is not yet being exploited.

7.1.4 Groundwater Quality

Available groundwater quality data are compared with established guidelines (ANZECC, 2000) to assess the suitability of groundwater for use. The guidelines considered were:

- water quality objectives to protect environmental values specified in the Environmental Protection (Water) Policy Environmental Values and Water Quality Objectives for Brisbane River Estuary Basin No. 143 (2007);
- Australian and New Zealand Guidelines for Fresh and Marine Water Quality (October, 2000), prepared by the Australian and New Zealand Environment and Conservation Council (ANZECC) and the Agriculture and Resource Management Council of Australia and New Zealand, (ARMCANZ); and
- Australian Drinking Water Guidelines, National Health and Medical Research Council/ Agricultural and Resource Management Council of Australia and New Zealand, 2004.

In general, quality of water within the Bunya Phyllite is spatially variable and considered poor with reference to drinking quality, as total dissolved solids (TDS) concentrations range from fresh (300mg/l) to brackish (5000mg/l). Similar trends were noted in the Neranleigh-Fernvale beds with TDS values ranging from 300 to 30,000mg/l (AGE, 2006). For reference purposes the Australian Drinking water guidelines recommend values between 500mg/l and 1000mg/l for potable use.

Groundwater within the localised alluvial aquifer near the lowest point in the Botanic Gardens was brackish with a TDS of 1,494-2,508mg/l and a pH ranging from slightly acidic to neutral (pH 6.52 and 7.27). An overview of groundwater quality data in the study corridor is presented in Volume 3 of the EIS *(Table 5 in Technical Report No. 4 – Groundwater)* along with relevant guidelines.

Environmental values for groundwater identified in Environmental Protection (Water) Policy under Section 7 include:

- Aquatic Ecosystems - groundwater is likely to be 'non pristine' due to anthropogenic development within the study corridor and associated recharge zones. Baseflow systems[1] are unlikely to exist within the

[1] Systems where groundwater discharge to riverine or marine environments could potentially support aquatic ecosystems

general area so the potential for aquatic ecosystems to be associated with the study corridor is considered negligible;

- Drinking Water - groundwater in the study corridor is generally unsuitable for potable use, due to elevated salinity levels;
- Irrigation - groundwater in the study corridor is considered too saline for irrigation use;
- Stock Water - stock water quality objectives suggest that groundwater from the study corridor may be suitable for stock water use. However, the salinity restricts the type of appropriate species and low reported yields are unlikely to provide sufficient groundwater for stock use (which is incompatible with existing land use); and
- Farm Use - the high salinity of groundwater (and existing land use in the area) is likely to restrict the suitability of groundwater for 'general' farm use.

Contamination

Historical activities with potential to result in groundwater contamination are assessed in Chapter 6 of the EIS and in *Technical Report No 3—Contaminated Land in Volume 3* of the EIS. Several of these sites are related to petroleum storage and these are considered to have the greatest potential to contribute to groundwater contamination. However, given the low permeability of the underlying strata the potential for contaminant mobilisation within groundwater is likely to be localised with long travel times.

Acid Sulphate Soils

Potential for the occurrence of acid sulphate soils (ASS) is presented in Chapter 6 of the EIS. There is no evidence to suggest marine sediments or processes have occurred within the study corridor and the potential for ASS materials to be encountered is negligible, particularly given the topographical elevation of most of the study corridor.

7.1.5 Groundwater Dependant Ecosystems

Groundwater Dependant Ecosystems (GDE) have their species composition and their natural ecological processes determined by groundwater (ANZECC, 2000). In general, groundwater dependency is likely to be low with terrestrial vegetation, river base flow systems and aquifer systems potentially utilising groundwater in the saturated zone only during drier periods when surface water flux is uncommon. The exception to this may be the wetland in Anzac Park. The wetland, despite being largely dry at present is likely to rely upon a combination of surface water flow and groundwater. Established park vegetation on residual soil or imported fill may 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.

7.2 Existing Surface Water

7.2.1 Surface Water Drainage and Catchments

The major existing waterways within the area of the Project are the Brisbane River, Breakfast/Enoggera Creek and Toowong Creek.

The main areas of interest at the western end of the study corridor are the headwaters and tributaries of Toowong Creek, the Mt Coot-tha Quarry and the drainage lines including artificial lagoons and lakes within the Mt Coot-tha Botanic Gardens and Anzac Park identified in **Figure 7-1A**.

LEGEND

- Sub-Catchment Boundary
- Study Area Corridor
- Stormwater Open Drain
- Stormwater Pipe Network
- Stormwater Drain
- Major Creek
- Minor Creek

0 200 400
metres

Scale 1: 10,000 (A4)

N

NORTHERN LINK
ENVIRONMENTAL IMPACT STATEMENT

Figure 7-1A

Surface Water - Overview

Northern Link

SKM Connell Wagner
JOINT VENTURE

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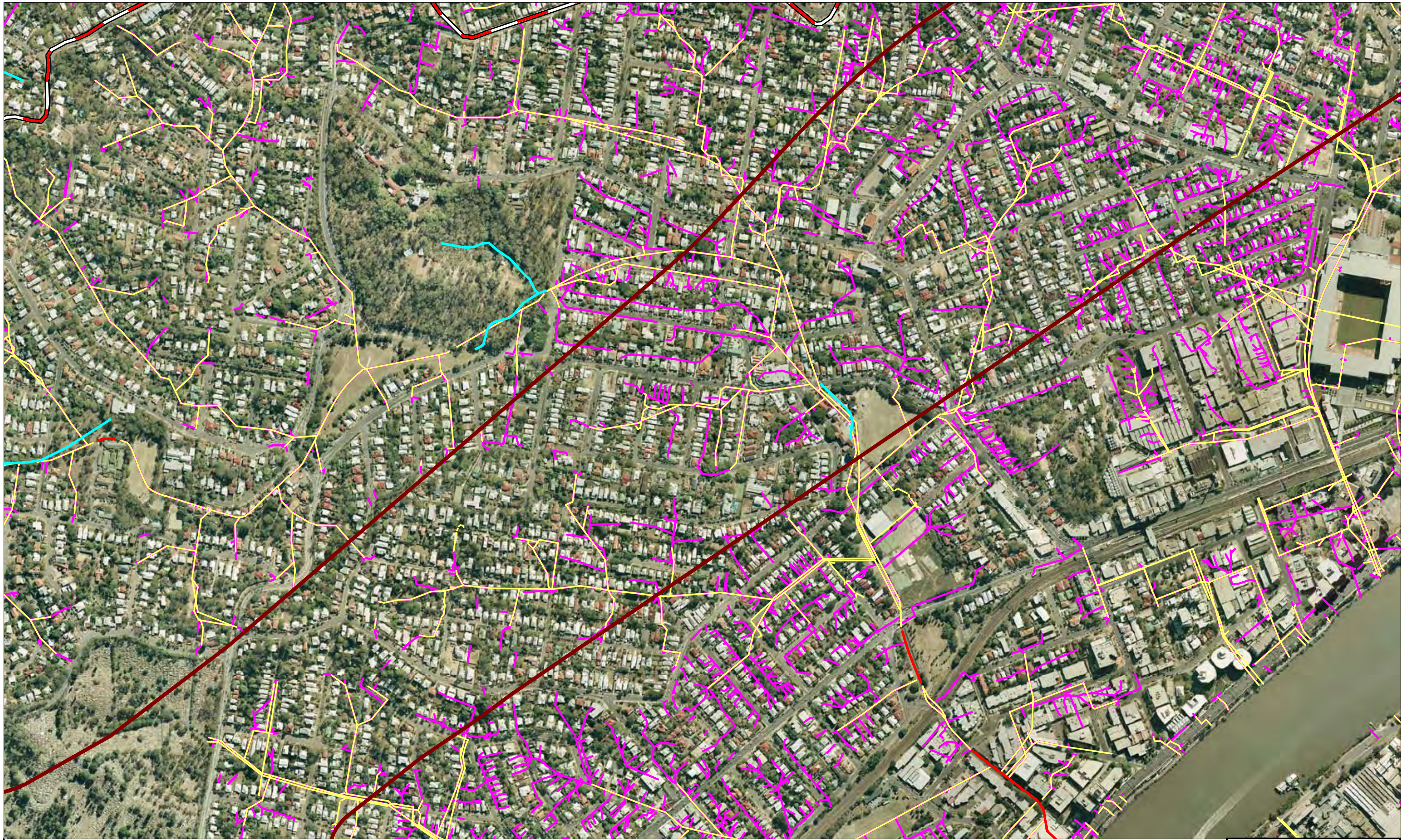
In the far western section of the study corridor, south of the Mt Coot-tha quarry, drainage flows through open gullies and channels within Brisbane Forest Park before passing under the Western Freeway via culverts leading to Toowong Creek which is a mixture of subsurface pipes and open surface channels forming an urban stormwater system that discharges ultimately into the Brisbane River west of Toowong Village.

The catchment to the north and east of the Toowong Creek catchment, encompassing most of the Botanic Gardens, and the valley north of the Mt Coot-tha Quarry up to Sir Samuel Griffith Drive passes under the Western Freeway, via two existing culverts west of the Mt-Coot-tha Road Roundabout. In the event of high rainfall or flooding events, an existing basin formed upstream of the roundabout acts to detain water and reduce significant surface water flows prior to the underground stormwater drains taking this flow under the Western freeway. These culverts join with an open watercourse along the northern edge of Anzac Park, which is further joined downstream by other culverts taking water from the southern slopes of the Toowong Cemetery under Mt Coot-tha Road. This watercourse through Anzac Park then enters an underground urban drainage system, which starts on the western side of the Bus Depot. This stormwater network collects surface water runoff from the local streets and urban areas and eventually discharges to the Brisbane River at Auchenflower adjacent to the Wesley Hospital.

Throughout most of the central section of the study corridor (**Figure 7-1B**), extensive networks of underground stormwater pipes convey runoff from impervious surfaces such as roads and roofs into the Brisbane River. These major alterations to the natural catchment hydrology have resulted in an increase in the volume, time of concentration and frequency of surface water runoff discharging to the receiving waters. The tidal influence of the Brisbane River extends at least as far as Milton Road.

The eastern end of the study corridor is within a small drainage that naturally entered the Brisbane River at Newstead but has been diverted into the Breakfast Creek/Enoggera Creek catchment. In this area the catchment is heavily urbanised, with a high degree of imperviousness and an extensive network of stormwater pipes (**Figure 7-1C**). This network has only limited capacity and significant overland flows occur under moderate to large rainfall events. The catchment for the Victoria Park drainage system extends from Red Hill, beginning west of Kelvin Grove Road, flowing through the Kelvin Grove Urban Village, Brisbane Grammar School playing fields and along the ICB. At the eastern end of the study corridor the significant features from a drainage and water quality perspective are the Victoria Park Drain at Herston and York's Hollow, a culturally significant wetland within Victoria Park. The York's Hollow wetland **(Figure 7-2)** was part of an original lagoon system, which was remodelled as part of the Inner City Bypass (ICB) project in 2000. This wetland provides an important habitat for waterbirds and acts as a fish refuge/breeding area.

- **Figure 7-2 York's Hollow, Victoria Park**



LEGEND

- Sub-Catchment Boundary
- Study Area Corridor
- Stormwater Open Drain
- Stormwater Pipe Network
- Stormwater Drain
- Major Creek
- Minor Creek

0 200 400

metres

Scale 1: 10,000 (A4)

N

NORTHERN LINK
ENVIRONMENTAL IMPACT STATEMENT

Figure 7-1B

Surface Water - Overview

Northern Link

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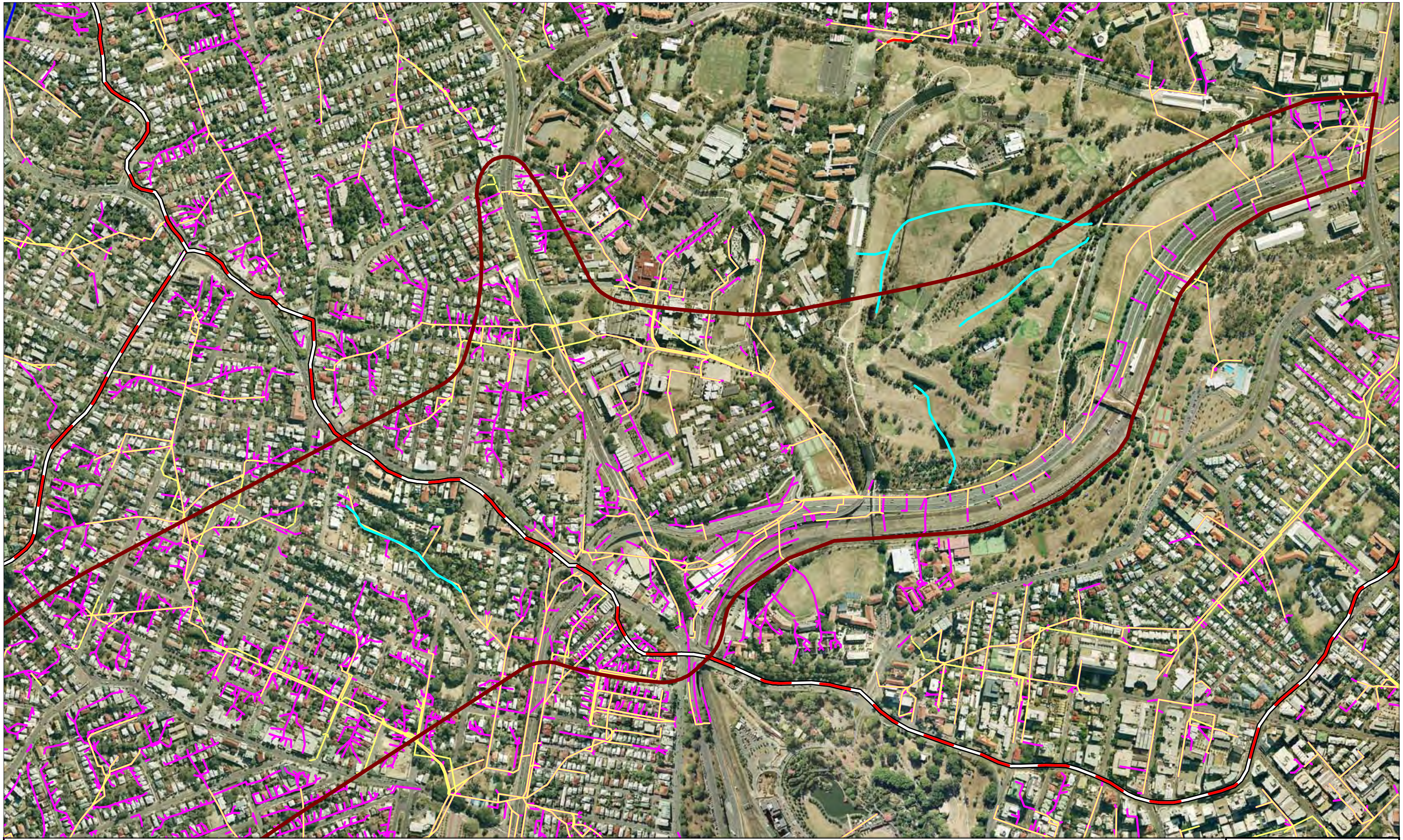

NORTHERN LINK
ENVIRONMENTAL IMPACT STATEMENT

Figure 7-1C

Surface Water - Overview

Northern Link

SKM Connell Wagner JOINT VENTURE

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7.2.2 Surface Water Quality

The two water quality monitoring programs undertaken to observe the condition and characteristics of the estuary and tributaries of the lower Brisbane catchment are summarised in **Table 7-1** below. The City-wide water quality monitoring sites are shown in **Figure 7-3**.

- **Table 7-1 Review of Regional Water Quality Monitoring Programs**

Monitoring	Conducted by	Date	Program
City-wide Assessment	EPA and Brisbane City Council	October 1999 - April 2000.	A City-wide assessment of water quality was undertaken of Brisbane's creeks providing the most extensive spatial assessment of water quality in the Brisbane area. Monitoring was conducted approximately six times a year at 0.2 m depth. Water quality within Toowong Creek was identified as poor
Healthy Waterways EHMP	Moreton Bay and Catchment Partnership. A regional program involving the EPA, DNRM, local councils and research organisations	2006 - 2007	The Ecosystem Health Monitoring Program (EHMP) is one of the most comprehensive marine, estuarine and freshwater monitoring programs in Australia. This monitoring program provides a regional assessment of the ambient ecosystem health for the 18 major catchments in SEQ. The water quality monitoring program is conducted on a regular basis with annual report cards produced reflecting the status of the water quality in each catchment. The EHMP Annual Report 2006-2007 identified that the tributaries of the Lower Brisbane River catchment remain in a poor condition in terms of their water quality. The Brisbane River Estuary has shown some improvement when compared to previous years, with an improvement in nitrogen and dissolved oxygen levels adjacent to the Oxley WWTP discharge.

The water quality objectives for Brisbane City Council, the EPP (Water) and the Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC, 2000) are provided in **Table 7-2**.

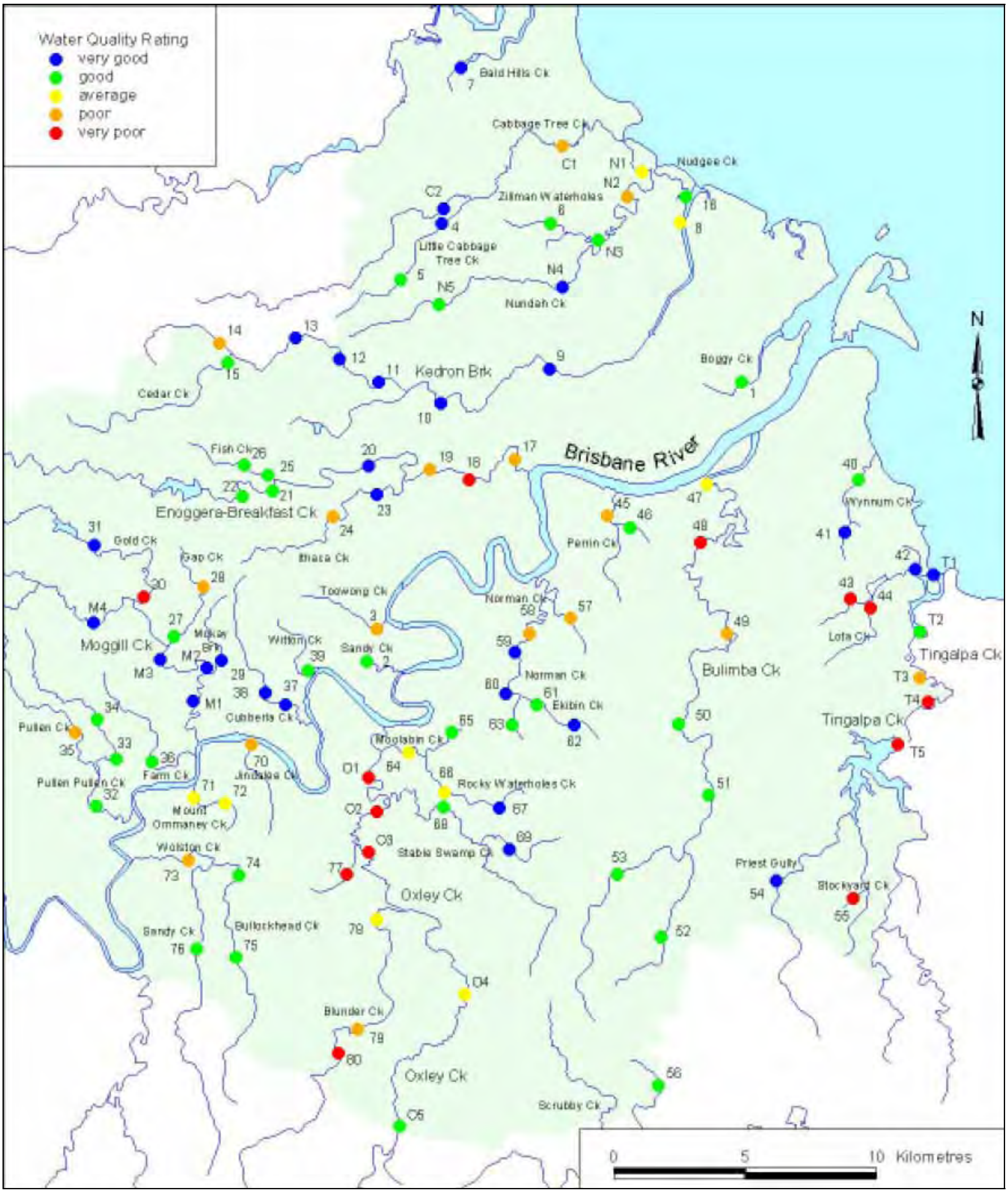
- **Table 7-2 Water Quality Objectives relevant to the area of the Project**

Water Quality Indicator		Brisbane City Council		EPP (Water)		ANZECC (2000)	
		Fresh water	Estuarine	Fresh water	Mid/upper Estuarine	Lowland River	Estuarine
Chlorophyll-a (µg/L)		8	10	8	10	5	4
TP (µg/L)		70	70	70	60	50	30
FRP (µg/L)		35	25	N/A	N/A	20	5
Organic N (µg/L)		500	380	N/A	N/A	N/A	N/A
Suspended Solids (mg/L)		15	30	15	30	N/A	N/A
TN (µg/L)		650	450	650	450	500	300
NO_x (µg/L)		130	25	N/A	N/A	40	15
NH_4(µg/L)		35	40	N/A	N/A	20	15
Turbidity (NTU)		20	20	20	20	6-50	0.5-1.0
DO % sat	**Lower**	80	80	80	80	85	80
	Upper	105	100	105	100	110	110
pH	**Lower**	6.5	6.5	6.5	6.5	6.5	7.0
	Upper	8.5	8.5	8.5	8.5	8.0	8.5

Table Notes:

N/A – Not Available
TN – Total Nitrogen
NO_x – Oxides of Nitrogen
DO – Dissolved Oxygen
µg/L – micrograms per litre
FRP – Filterable Reactive Phosphorus
TP – Total Phosphorus
NH_4 - Ammonium
DO % sat - Dissolved Oxygen percentage saturation

Figure 7-3 EPA water quality monitoring locations and water quality rating.



Source: Webb (2001) Citywide-assessment of water quality in Brisbane's creeks October 1999-April 2000

Existing water quality data obtained from the EPA monitoring program (Webb, 2001) for sites 3 and 17 shown on **Figure 7-3** are shown on **Table 7-3** below.

- **Table 7-3 Citywide assessment of water quality in Brisbane's creeks: Toowong Creek (Site No. 3) and Enoggera/Breakfast Creek (Site No. 17)**

Water Quality Parameters		Toowong Creek (Site No.3)	Breakfast/ Enoggera Creek (Site No. 17)
Dissolved oxygen (% sat)	% sat	70	73
pH		7.4	7.5
Conductivity	mS/cm	4.405	23.943
Temperature	°C	23.3	25
Chlorophyll-a	µg/L	1.2	2.4
Turbidity	NTU	19.5	19
Suspended solids	mg/L	10.5	25.5
Nitrogen (organic) as N	mg/L	0.350	0.340
Nitrogen (ammonia) as N	mg/L	0.059	0.079
Nitrogen (oxidised) as N	mg/L	0.535	0.43
Nitrogen (total) as N	mg/L	1.005	0.85
Phosphorus (dissolved reactive) as P	mg/L	0.092	0.125
Phosphorus (total) as P	mg/L	0.140	0.175
Faecal coliforms	CFU/100ml	1200	700

Source: (Webb, 2001) A city-wide assessment of water quality in Brisbane's creeks October 1999-April 2000

The values identified above for Toowong Creek (site 3) are evaluated against the water quality objectives in **Table 7-4** below.

- **Table 7-4 Toowong Creek – Comparison of Water Quality with the Water Quality Objectives**

Parameter	Site 3 compared with Brisbane City Council WQO	Site 3 compared with EPP (Water)	Site 3 compared with ANZECC (2000)
Oxygen % sat	Not Met	Not Met	Not Met
pH	Met	Met	Met
Chlorophyll-*a*	Met	Met	Met
Turbidity	Met	Met	Not Met
Nitrogen (ammonia) as N	Met	N/A	N/A
Nitrogen (oxidised)	Not Met	Not Met	Not Met
Nitrogen (total) as N	Not Met	Not Met	Not Met
Phosphorus (dissolved reactive) as P	Not Met	Not Met	Not Met
Phosphorus (total) as P	Not Met	Not Met	Not Met

The water quality of the estuarine reach of Toowong Creek at 'Site 3' was poor, with nutrient concentrations (especially oxidised nitrogen) exceeding all guidelines. The increase in nutrient levels in this area was attributed to tidal exchange from the Brisbane River (BCC, 2001). Dissolved oxygen concentrations failed to meet water quality objectives. Low chlorophyll-a concentrations indicate minimal algal productivity within the system.

Although Breakfast Creek/Enoggera Creek does not directly intersect the study corridor, a major detention basin within the Victoria Park area discharges via an underground brick arch drain into Enoggera Creek. As a result, construction activities at the eastern end of the project area, if not adequately mitigated, have the potential to increase the concentration of sediments, nutrients and contaminants (hydrocarbons and heavy metals) entering the lower reach of Enoggera Creek.

Water quality results for Enoggera Creek ('Site 17') from the City-wide monitoring assessment (Webb, 2001) were evaluated against the objectives indicated in **Table 7-2** in terms of compliance. Median values for the parameters measured at 'Site 17' are identified in **Table 7-5**.

- **Table 7-5 Enoggera Creek WQ Evaluation with the Water Quality Objectives**

Parameter	Site 17 (Median value) compared with Brisbane City Council WQO	Site 17 (median value) compared with EPP (Water)	Site 17 (median value) compared with ANZECC (2000)
Dissolved Oxygen % sat	Met	Met	Met
pH	Met	Met	Met
Chlorophyll-*a*	Met	Met	Met
Turbidity	Met	Met	Not Met
Suspended solids	Met	Met	Met
Nitrogen (organic) as N	Met	N/A	N/A
Nitrogen (ammonia) as N	Met	Met	Not Met
Nitrogen (oxidised)	Not Met	Not Met	Not Met
Nitrogen (total) as N	Not Met	Not Met	Not Met
Phosphorus (dissolved reactive) as P	Not Met	Not Met	Not Met
Phosphorus (total) as P	Not Met	Not Met	Not Met

The water quality of Enoggera Creek at 'Site 17' was poor. Overall nutrient concentrations of nitrogen (total and oxidised nitrogen) and phosphorus exceeded Brisbane City Council WQO's, QWQG's levels and ANZECC (2000) water quality guidelines. The increase in nutrient levels in this area was also attributed to tidal exchange from the adjacent Brisbane River estuary (BCC, 2001). Median values for dissolved oxygen, chlorophyll-a, suspended solids, and pH, all met the relevant water quality criteria. Turbidity at this site exceeded NZECC (2000) guidelines.

The Healthy Waterways EHMP monitoring programme has been conducted since 2000 and provides a comprehensive assessment of South East Queensland waterways. An annual report card indicates the condition of water resources within the SEQ region. The 2007 EHMP report card for the Lower Brisbane Estuary showed an improvement in water quality, with the grade improving from an F in 2006 to a D+ in 2007. The nitrogen and dissolved oxygen levels in the middle reaches of the estuary, adjacent to the Oxley Waste Water Treatment Plant discharge, were much improved. The freshwater streams and creek systems of the lower Brisbane catchment remained in a poor condition, with an overall grading of F (Healthy Waterways, 2007).

Data from EHMP monitoring sites (collected between November 2003 up to and including October 2007), relevant to the study corridor, were evaluated against BCC Water Quality Objectives in **Table 7-6** and against State and National guidelines in *Table 1-7 and Table 1-8 of Technical Report No. 5 - Surface Water in Volume* 3 of the EIS. The values for each sampling site and the median water quality values for each parameter are listed in Appendix B of the same *Technical Report No. 5 - Surface Water in Volume 3* of the EIS.

In general, nitrogen and phosphorus concentrations as well as turbidity levels did not comply with BCC, Water Queensland or ANZECC water quality guidelines at monitoring sites in the city reaches of the Brisbane River whereas chlorophyll-a concentrations and pH complied with these guidelines at the same monitoring sites.

Table 7-6 WQ Evaluation – EHMP data comparison with BCC Water Quality Objectives

		Brisbane River AMTD 21.7 km under Story Bridge (EHMP Site 703)			Brisbane River AMTD 26.1 km under Grey Street Bridge (EHMP Site 704)			Brisbane River AMTD 33.7 km (EHMP Site 705)		
	Unit	Season		Total	Season		Total	Season		Total
		Wet	Dry	Median	Wet	Dry	Median	Wet	Dry	Median
Dissolved oxygen	% sat	Met	Met	Met	Met	Met	Met	Not Met	Met	Met
pH		Met	Met	Met	Met	Met	Met	Met	Met	Met
Chlorophyll-a	µg/L	Met	Met	Met	Met	Met	Met	Met	Met	Met
Turbidity	NTU	Met	Met	Met	Met	Met	Met	Not Met	Met	Not Met
Nitrogen (organic) as N	mg/L	Met	Met	Met	Met	Met	Met	Met	Met	Met
Nitrogen as N (ammonia)	mg/L	Met	Met	Met	Met	Met	Met	Met	Met	Met
Nitrogen (oxidised) as N	mg/L	Not Met	Not Met	Not Met	Not Met	Not Met	Not Met	Not Met	Not Met	Not Met
Nitrogen (total) as N	mg/L	Not Met	Not Met	Not Met	Not Met	Not Met	Not Met	Not Met	Not Met	Not Met
Phosphorus (dissolved reactive) as P	mg/L	Not Met	Not Met	Not Met	Not Met	Not Met	Not Met	Not Met	Not Met	Not Met
Phosphorus (total) as P	mg/L	Not Met	Not Met	Not Met	Not Met	Not Met	Not Met	Not Met	Not Met	Not Met

Table Notes: Compliance based on comparison of the median value of the data set from November 2003 to October 2007. Shaded values indicate exceedance of guideline.

Environmental Values

The study corridor is located within Basin No. 143 (part), which includes all creeks of the Brisbane River estuary other than Oxley Creek (EPP (Water), 1997). Watercourses in the vicinity of the study corridor are defined by the EPP (Water) as being lowland freshwaters (in terms of the creeks and tributaries of the Brisbane River) and mid-estuary (in terms of the Brisbane River in this area). The EPP (Water) classifies this area as Level 2, which refers to an aquatic ecosystem which is slightly or moderately disturbed (EPA, 2007). The Environmental Values (EVs) for the watercourses in the area of the Project are identified in **Table 7-7** below.

Table 7-7 Environmental Values for watercourses in the area of the Project

Environmental Values	Brisbane River Estuary – estuarine and enclosed coastal	Brisbane River – tidal creeks and drains - estuarine (incl. Enoggera Creek and Toowong Creek)	Brisbane River – freshwater creeks and drains	Toowong Creek - freshwater	Other wetlands or lakes (ie Victoria Park wetland)
Aquatic Ecosystem	ρ	ρ	ρ	ρ	ρ
Human consumer	ρ				
Primary recreation (eg: swimming)	ρ				
Secondary recreation (eg: boating)	ρ	ρ	ρ		
Visual recreation	ρ	ρ	ρ	ρ	ρ
Drinking water					
Industrial use	ρ				
Cultural and spiritual values	ρ	ρ	ρ	ρ	ρ

Source: EPP(Water) (EPA 2007)

Table Note: ρ Identifies the Environmental Values of the watercourse

7.3 Flood Potential

The flood potential in and adjacent to the study corridor has been assessed, to understand how the project may alter the existing flooding regime of the area, to ensure that the Project design takes account of flooding risks and to identify how to avoid flood damage during the construction and life of the infrastructure.

Flood risk to property and infrastructure has been assessed for the 1 in 100 Average Exceedance Probability (AEP) flood event, a standard tool for assessment of flooding impacts due to development. In particular Brisbane City Council requires that no development causes an adverse impact on adjacent properties for flood events up to and including the 1 in 100 AEP flood event.

Flood immunity of the tunnel has been assessed for the 1 in 10,000 AEP flood event. Designs for the preceding road tunnels of the TransApex network required a 1% probability of receiving flood flow for each of the 100 years of design life. This approximately translates to a requirement for the tunnels to have 1 in 10,000 AEP flood immunity.

7.3.1 Regional Flooding

Regional flooding is dominated by the Brisbane River. Extreme floods in the Brisbane River may be of long duration, involve large volumes of water and present significant risk to the tunnel if the portals are overtopped. Another potential threat from regional flooding is from storm surge in the river. However, the topography of all portal areas is generally above 20m AHD and thus well clear of that threat. Earlier relevant studies of flooding in the Brisbane River (SKM, 1998, 2000, 2004a, 2004b) used a hydraulic model of the same basis, constructed in the modelling software *MIKE11*. This hydraulic model was provided by Brisbane City Council. The flood levels for various floods of different recurrence intervals are presented in **Table 7-8**.

- **Table 7-8 Existing Flooding Characteristic of Brisbane River***

AEP (1 in Y)	Critical Duration (hours)	Discharge (m^3/s)	Flood Level (mAHD)
10	30	2800	2.0
20	30	3400	2.4
50	72	4600	3.4
100	72	6000	4.5
2000	120	11700	9.2
PMF#		35900	23.3

Table Notes:

*MIKE11 Results (SKM, 2004a; 2004b);

MIKE11 Results (SKM, 1998)

The adopted Brisbane City Council one in 100 AEP flood level in the Brisbane River closest to the western connections is 4.5m AHD (SKM, 2004a). This level is well below the terrain in the study area at the western connection with the terrain of the Milton Road and Frederick Street intersection above 14m AHD. Therefore Brisbane River flooding would not impact on the Project in a one in 100 AEP event and the Project would not impact on flood levels developed by the Brisbane River in a one in 100 AEP flood event.

The one in 10,000 AEP flood event in the Brisbane River was assessed in the *Brisbane River Flood Study* (SKM, 1998). However, it was not reassessed following the recalibration and reassessment that was undertaken in 2004. A re-assessment of the one in 10,000 AEP event in the Brisbane River near the western connections of the Project was undertaken as part of this investigation and this was carried out in consultation with both Council and SEQWater.

Table 7-9 presents estimates of the one in 10,000 AEP flood for the purposes of the Project with an upper and lower bound as confidence levels of this estimate. Given the above sensitivities, a level of 14.9mAHD has been adopted for the Reference Project with a freeboard of 300mm. Further modelling, supported by Brisbane City Council and SEQWater would be required for detailed design.

- **Table 7-9 Flood Characteristic of Brisbane River for one in 10,000 AEP Event**

Scenario	Discharge (m^3/s)	Flood Level (mAHD)
Discarded Estimate	12,000	8.5
Lower Bound	17,500	12.6
Upper Bound	21,200	14.9

Table Note:

Estimates of discharges and levels are calculated for the purposes of the EIS. These levels are preliminary and indicative only and are not suitable for design purposes.

7.3.2 Western Connections

Existing flood risk in the study corridor around the western connections may be due to either local drainage via surface flow and small drains or regional flooding from the Brisbane River.

Local Drainage

Local flood risk is associated with small catchments draining Mt Coot-tha and the Toowong Cemetery. Drainage paths flow through open channels and gullies, to culverts under the Western Freeway and Milton Road and into an urban stormwater system to the Brisbane River. Large and extreme, short duration events in these local catchments result in small volumes of water but rapid water level rise and fall. Overtopping from local flooding still has the potential to be hazardous and damaging to the tunnels.

Figure 7-4 shows the local catchments and drainage paths relevant to the western connections. Hydrology of the Mt Coot-tha Quarry area (Catchments C2 and C3) is defined by quarry operations. C3 comprises the active pit and surrounding benches, is large enough to contain significant rainfall events without risk of overtopping and is, thus, not included in this assessment.

Catchment C2 has been altered such that it includes storage and the benching of the quarry walls. The benching prevents direct drainage down the faces of the excavation, slowing catchment response. Flow from C2 is captured in small sedimentation ponds and then flows through the Botanical Gardens (Catchment C1). C1 incorporates a partly urbanised upper catchment and the majority of the Botanical Gardens. Drainage from C1 and C4 flows through culverts under the Western Freeway but in larger events, they interact and flow is detained in the basin upstream of the Western Freeway.

The drainage path within the Toowong Cemetery (Catchment C8) is independent of other local catchments until it enters the stormwater network via a culvert under the Milton Road roundabout.

C7 is a small local catchment between the Mt Coot-tha Road Roundabout and C8. Runoff from this area flows through culverts under Milton Road and as it is not expected to impact on flood levels it has not been assessed in detail. C5, C6 and C9 are distant from the proposed western connection areas. They are not anticipated to impact on flooding and they have not been assessed in detail.

LEGEND

Study Area Corridor
Local Catchments
Local Drainage Structures
Drainage Direction

0 250 500
metres

Scale 1:12,000 (A4)

N

NORTHERN LINK
ENVIRONMENTAL IMPACT STATEMENT

Figure 7 - 4

Western Connection Local Catchments

Northern Link
SKM Connell Wagner JOINT VENTURE

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Hydrologic Modelling

The hydrology of the area was assessed with the *RAFTS* rainfall runoff model software which is used as a standard hydrologic tool throughout Queensland. The inputs to the *RAFTS* model including surface areas and characteristics of the surfaces of individual catchments, rainfall and runoff data, inferred runoff volumes as well as validation exercises of the model outputs are presented in *Technical Report No. 6 - Flooding in Volume 3* of the EIS.

No calibration data were available for the watercourses of the area and a search of Council records did not identify previous studies for the drainage lines. Peak discharges from the hydrological model were validated against the Rational Method as outlined in the Queensland Department of Main Roads *Road Drainage Design Manual* (DMR, 2002) for the one in 100 AEP event.

The validated model was used to determine design discharges and hydrographs for the one in 100 and one in 10,000 AEP events. A range of storm durations were considered and the critical duration storm determined to be the one hour storm for all catchments. **Table 7-10** summarises peak discharges predicted for each catchment in the one in 100 and one in 10,000 AEP events.

- **Table 7-10 Local Catchment Peak Discharges**

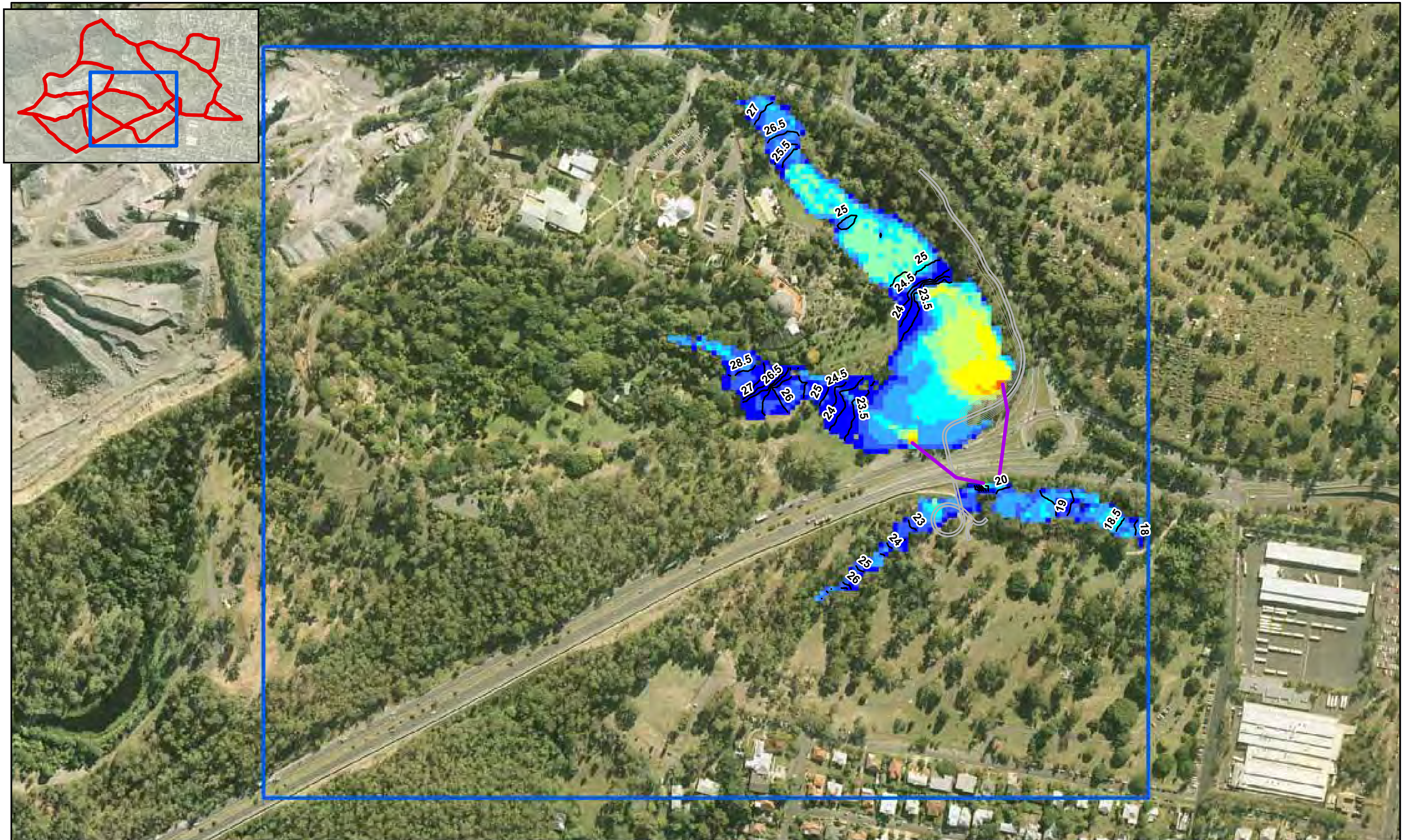
Catchment	Peak Design Discharge (m^3/s)	
	one in 100 AEP	*one in 10,000 AEP*
C1	25.0	43.2
C2	8.8	13.0
C3	-	-
C4	5.7	12.0
C5	3.8	7.4
C6	5.1	10.8
C7	0.9	1.3
C8	11.8	25.4
C9	4.6	8.9

Mt Coot-tha Drainage

A hydraulic model was developed to simulate drainage from Mt Coot-tha through the Botanical Gardens and under/over the Western Freeway. In large flow events, Catchments C1 and C4 interact in a natural depression immediately upstream of the Western Freeway.

The linked 1D-2D hydraulic model, *MIKEFLOOD*, was adopted to simulate both the two dimensional storage interaction upstream of the Western Freeway and the one dimensional flow through culverts under the Western Freeway. The layout of the model, the terrain data, the boundaries and other relevant inputs to the hydraulic modelling are presented in *Technical Report No. 6 - Flooding in Volume 3* of the EIS.

The results of the hydraulic model showed that the two catchments (C1 and C4) do interact in the one in 100 AEP flood event and that the flow would be contained within the culverts without overtopping the Western Freeway. The area upstream of the Western Freeway would act as a large detention storage allowing the culverts under the road to cope with the flow. The flood water would pond to a peak level of approximately 23.3 m AHD upstream of the Freeway. The peak modelled depth and water surface levels for the 1 in 100 AEP flood are presented in **Figure 7-5**.



LEGEND

- Model Area
- Local Drainage Structures
- Peak Flood Level (m AHD)
- Bikeway

Peak Flood Depth (m)

- 0.0 - 0.2
- 0.3 - 0.5
- 0.6 - 1.0
- 1.1 - 1.5
- 1.6 - 2.0
- 2.1 - 2.5
- 2.6 - 3.0
- 3.1 - 3.5
- 3.6 - 4.0
- 4.1 - 4.5

0 100 200
metres

Scale 1:5,000 (A4)

N

NORTHERN LINK
ENVIRONMENTAL IMPACT STATEMENT

Figure 7 - 5

Mt Coot-tha Existing Conditions: 1 in 100 year ARI Flood Extent

Northern Link
SKM Connell Wagner JOINT VENTURE

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Toowong Cemetery Drainage

A minor drainage line through Toowong Cemetery was assessed to understand flooding risk for a tunnel portal on or near Frederick Street north of Milton Road. This drainage through the cemetery, which is detailed in *Technical Report No. 6 - Flooding in Volume 3* of the EIS, is well defined and does not interact with neighbouring watercourses. A one-dimensional modelling approach using the *HEC-RAS* software developed by the United Stated Army Engineering Corps was constructed within a GIS environment using the software *HEC-GEORAS*. The inputs, other details and the results of the modelling exercise are provided in *Technical Report No. 6 - Flooding in Volume 3* of the EIS.

The modelled inundation extent for the one in 100 AEP flood event above the Milton Road roundabout shows that a one in 100 AEP flood would not overtop Frederick Street itself. However, the flood level immediately upstream of the Milton Road roundabout would be approximately 15.3m AHD and overtop the roundabout by 300mm.

7.3.3 Eastern Connections

The mainline tunnels connect directly to the Inner City Bypass and a further connection is made to Kelvin Grove Road opposite Musk Avenue. These connections are above 20m AHD, well away from the influence of the Brisbane River or any of the major creeks or waterways of the region in terms of potential for regional flooding. Therefore, the focus of the investigation at the eastern connections is on local drainage only.

Local Drainage

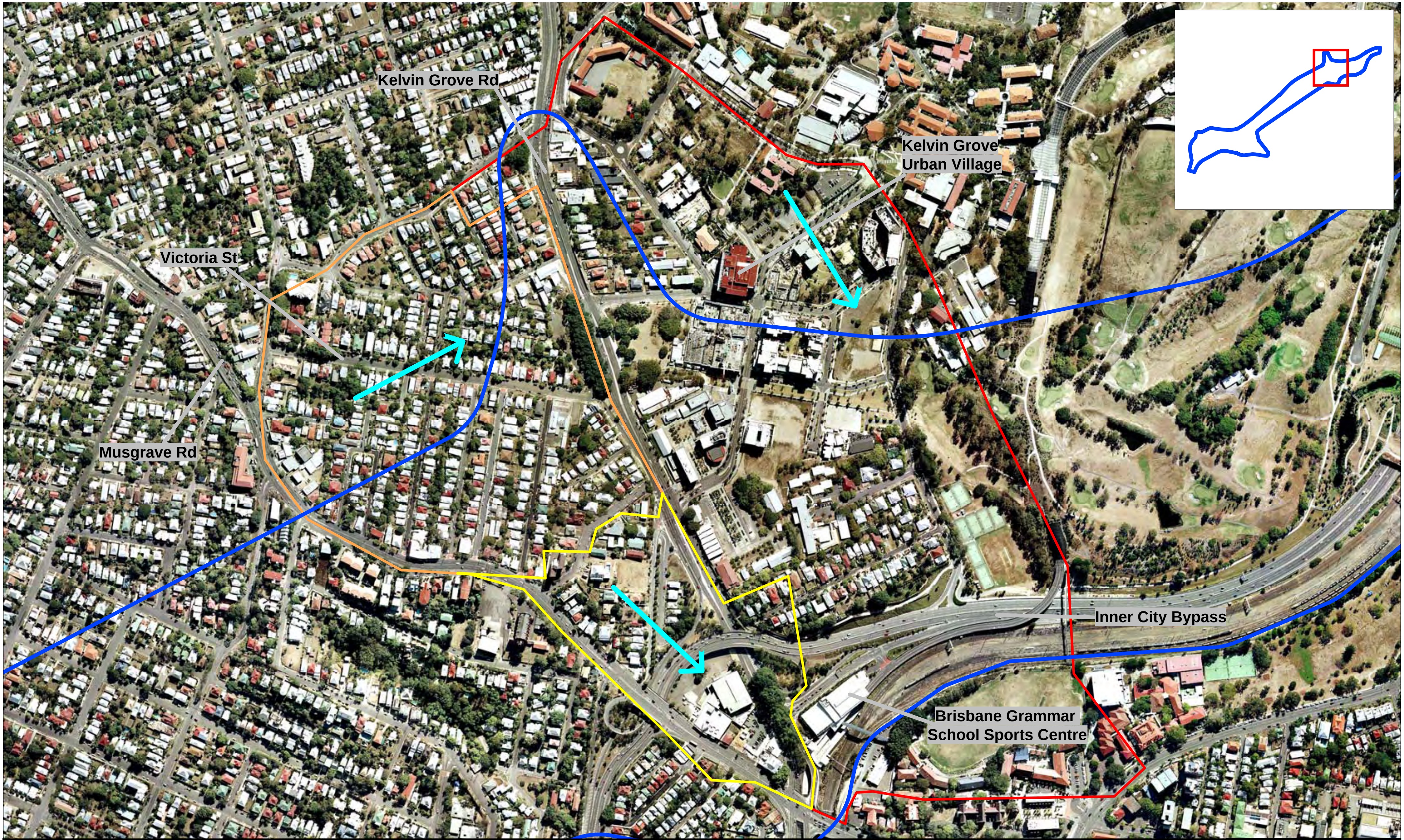
The Kelvin Grove and ICB connections lie within a single catchment with two subcatchments as shown on **Figure 7-6**. The catchment has an area of approximately 81.7ha and extends from the ICB connection in the east, to Musgrave Road in the west and approximately one kilometre north from the Normanby Underpass to the intersection of Kelvin Grove Road and L'Estrange Street.

The contributing catchment west of Kelvin Grove Road to the north of the Kelvin Grove Road connection has an area of approximately 21.9ha. The existing terrain forms a basin behind the Kelvin Grove Road embankment under which the drainage passes in pipework.

Within the more southerly subcatchment, an area of approximately 6.5ha is situated west of Kelvin Grove Road and south of the proposed Kelvin Grove Road connection. This existing catchment forms two detention areas, one formed by the Hale Street and Kelvin Grove Road intersection and the other at the Ithaca Street and Kelvin Grove Road intersection.

The ICB connection is near the lowest point of this entire catchment of 81.7ha. A further detention area adjacent to this connection is bounded by the existing ICB and Inner Northern Busway embankments and the natural hillside along Victoria Park Road and is used as school sporting fields.

The majority of the catchment consists of relatively steep, undulating terrain, with some outer areas having slopes above 10%. The catchment is heavily urbanised and essentially impervious. A detailed pipe network exists throughout the catchment. However this network has only limited capacity and significant overland flows occur under moderate to large rainfall events.



LEGEND

- Study Area Corridor
- Kelvin Grove Road Connection
- Public Transport Connection
- Inner City Bypass Connection
- Drainage Direction

0 140 280
metres

Scale 1: 7,000 (A4)

N

NORTHERN LINK
ENVIRONMENTAL IMPACT STATEMENT

Figure 7 - 6

Eastern Connection
Local Catchments

Northern Link
SKM Connell Wagner
JOINT VENTURE

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Hydrologic Modelling

The hydrologic (*RAFTS*) model developed for the Kelvin Grove Urban Village project was included in this analysis. The *RAFTS* model includes all three focus areas and was adapted as the basis of the hydraulic analysis for this investigation. The sources of data for the modelling, modifications to the earlier model and other considerations including validation are provided in *Technical Report No. 6 - Flooding in Volume 3* of the EIS.

Kelvin Grove Connection

The connection to Kelvin Grove Road is directly opposite the entrance to Musk Avenue on the dividing ridge between the two subcatchments shown in **Figure 7-6**. Accordingly, the tunnel portals for this connection are well clear of any flooding potential. However, road works to Kelvin Grove Road both north and south of the portals would include areas in drainage lines that have the potential to flood, particularly because earlier urban development has created several detention basins along these drainage lines.

Between Victoria Street and Blamey Street, opposite McCaskie Park, is storage upstream of Kelvin Grove Road and low lying land up into existing residential properties. Any alteration of the storage volume or the drainage under Kelvin Grove Road therefore has the potential to alter flood levels and impact flood immunity of upstream properties.

The existing catchment discharges under Kelvin Grove Road via pipes into an overland flow-path designed into the Kelvin Grove Urban Village development. Any reduction in storage volume therefore may increase discharges and hence peak water levels in this downstream system.

The hydrologic model predicted a peak discharge of 16.8m^3/s for a one in 100 AEP design event. A peak basin outflow of approximately 4m^3/s is predicted. This is all pipe flow with no overtopping of Kelvin Grove Road. **Figure 7-7** shows the predicted inundation in the 1 in 100 and the 1 in 10,000 AEP floods.

Under existing conditions for one in 10,000 AEP storm events, a peak discharge to the basin of 36.6m^3/s was predicted. A peak basin outflow of approximately 20m^3/s was predicted which includes pipe through flow and overtopping of Kelvin Grove Road by about 340mm. Modelling results are summarised in **Table 7-11**.

- **Table 7-11 RAFTS Model Predictions - Kelvin Grove Road Basin**

AEP	WSL (mAHD)	Minimum Road Level (mAHD)	Freeboard to Road (m)	Peak basin Outflow (m³/s)
One in 100	39.5	40.2	0.67	4
One in 10,000	40.5	40.2	Overtopped	20

South of the proposed Kelvin Grove Road portals are two detention areas. The one upstream of the ICB overpass (Hale Street Basin), discharges to the one adjacent to the Kelvin Grove Road (Ithaca Street Basin) through a 375mm diameter pipe, or via overland flow down Kelvin Grove Road. The lower basin discharges via a 900mm diameter pipe into the pipe drainage network.

One in 100 AEP and 10,000 AEP rainfall events were simulated in the hydrologic model. Model predictions are summarised in **Table 7-12** and **Table 7-13**. Predicted extents of inundation are shown in **Figure 7-8** for the Hale Street Basin.

LEGEND

- Study Area Corridor
- 100 Year KGR Inundation Area
- 10000 Year KGR Inundation Area

0 80 160
metres

Scale 1: 4,000 (A4)

N

NORTHERN LINK
ENVIRONMENTAL IMPACT STATEMENT

Figure 7 - 7

100 & 10000 Year Inundation
Kelvin Grove Road (Victoria Street)

Northern Link
SKM Connell Wagner
JOINT VENTURE

G:\MIPO\Northern Link\C_Subjects\700_Spatial Data\DetailedFeasibilityStudy\Mapinfo\130808_Hydraulics_KGR_Fig7-9

LEGEND

- Study Area Corridor
- 10000 Year Hale Street Basin
- 100 Year Hale Street Basin

0 80 160
metres

Scale 1: 4,000 (A4)

N

NORTHERN LINK
ENVIRONMENTAL IMPACT STATEMENT

Figure 7 - 8

**100 & 10000 Year Inundation
Hale Street Basin**

Northern Link
SKM Connell Wagner
JOINT VENTURE

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Table 7-12 RAFTS Model Predictions – Hale Street Basin

AEP	WSL (mAHD)	Weir Level (mAHD)	Depth over Weir (m)	Peak Outflow (m^3/s)
One in 100	39.6	41	-1.4	0.5
One in 10,000	41.0	41	0.02	20

Table 7-13 RAFTS Model Predictions – Ithaca Street Basin

AEP	WSL (mAHD)	Weir Level (mAHD)	Depth over Weir (m)	Peak Outflow (m^3/s)
One in 100	34.6	34.4	0.2	2.8
One in 10,000	34.77	34.4	0.4	6.0

Discharge from the upstream basin is primarily via the existing pipe drainage. Overtopping onto Kelvin Grove Road is not predicted to occur during one in 100 AEP conditions. During one in 10,000 AEP conditions, only minor overflow onto the pavement is predicted with the pavement overtopped by less than 50mm. Significant ponding is predicted at the Ithaca Street intersection under one in 100 AEP and one in 10,000 AEP conditions.

Any reduction to available storage volume in the existing basin areas through construction or operation would need to be offset by basin reconfiguration to achieve zero external hydraulic impacts.

ICB Connection Drainage

The Reference Design has a connection with the ICB near Victoria Park Road, adjacent to the existing ICB and Northern Busway flyover. The adjacent area on the corner of the ICB and Victoria Park Road and bounded on the east by the Inner Northern Busway is used as sports fields by the Brisbane Grammar School. Under large to extreme flood events it also functions as a detention basin that stores water before passing it down an existing drainage line adjacent to the ICB.

Outflow from the existing storage area is via a large drop-inlet structure. This structure discharges to an open channel that runs parallel to the ICB to Yorks Hollow. The existing drop inlet structure may also be affected by the works and has the potential to affect the outflow capacity of the basin. This could in-turn affect the performance of the basin in terms of upstream water levels and downstream discharges. Several piped drainage networks also discharge to the basin outlet structure. These piped drainage networks emanate from the two previously described connections' catchments.

Hydrologic model predictions for the detention basin are presented in **Table 7-14** and the predicted extents of inundation are shown in **Figure 7-9**. It is important to note that detailed drawings for the outlet structure have not been received at the time of writing this report. The analysis has been conducted using information estimated from site observations. Additional information is still being sought. If no further data is available, a detailed survey of the structure may be required to facilitate future stages of the investigation.

Table 7-14 RAFTS Model Predictions - ICB Connections

AEP	WSL (mAHD)	Invert Level of Drop Structure (mAHD)	Water Depth at Structure (m)	Peak basin Outflow (m^3/s)
One in 100	24.1	22.5	1.6	29
One in 10,000	25.1	22.5	2.6	60

LEGEND

- Study Area Corridor
- 10000 Year ICB Inundation Area
- 100 Year ICB Inundation Area

0 80 160

metres

Scale 1: 4,000 (A4)

N

NORTHERN LINK
ENVIRONMENTAL IMPACT STATEMENT

Figure 7 - 9

100 & 10000 Year Inundation Inner City Bypass

Northern Link

SKM Connell Wagner JOINT VENTURE

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The hydrologic modelling found that ponding would occur behind the drainage structure and therefore any filling required for the ramps to ICB may reduce flood storage volume available in the basin. This may in turn affect peak water levels in the basin. Whilst this is not expected to affect residential properties, such an impact could be considered to be a worsening of conditions at the sports fields and mitigation may be required depending on the design outcomes.

To achieve the 10,000 AEP flood immunity to the tunnels, protection to a level of 25.4m AHD would be required (including a 300mm freeboard allowance). This may be achieved using modified concrete crash barriers or noise barriers on the eastern side of the ramps.

The expanded ICB formation would require modification of the existing outlet structure (due to the reduced available width). Accordingly, augmentation via an additional outlet structure beneath the Inner Northern Busway embankment may be required. It would be important that such a measure does not adversely affect the foundations of the existing reinforced earth wall for the Inner Northern Busway.

7.4 Groundwater Impact Assessment and Mitigation

7.4.1 Modelling

The primary objective of this hydrogeologic assessment is to assess the groundwater level drawdown impacts in response to the construction and operation of the Northern Link tunnel.

The principal tool in making this assessment is a numerical model developed of the subsurface hydrogeological environment and dynamics to simulate the dewatering impact of the proposed Northern Link tunnel on the existing groundwater flow regime. Predictive numerical modelling was carried out to assess groundwater inflow volumes to the tunnels and to estimate local variations in drawdown as a consequence. Groundwater flow modelling has used the finite difference numerical model MODFLOW, developed by the United States Geological Survey. The operating interface that was used with MODFLOW was VISUAL MODFLOW (version 4.2).

In the model, groundwater is assumed to flow horizontally within model layers and vertically between layers. MODFLOW is incapable of modelling discrete fractures or fracture networks which requires much more sophisticated software and detailed spatial information of the fractures. Groundwater data are also generally sparse and it is unreasonable to expect a groundwater modelling software code to incorporate a level of complexity beyond that of the available data.

During this investigation, groundwater modelling was undertaken to develop and calibrate the groundwater flow model to a steady state condition. Following completion of the steady state calibration, the model was used to simulate transient groundwater flows into the Northern Link tunnel.

Further details of the design, calibration and hydraulic parameters used for the model are provided in *Technical Report No. 4- Groundwater in Volume 3* of the EIS.

7.4.2 Model Predictions

The calibrated potentiometric surface of Layer 1 (alluvium and weathered material) and Layer 2 (fractured rock) indicate a falling hydraulic gradient towards the Brisbane River. The water table intersects Layer 1 of the model where the water table is shallowest; otherwise the water table intersects Layer 2 of the model (fractured rock). The water table intersects Layer 1 of the model in areas that typically coincide with the occurrence of alluvium. However, there are significant areas of weathered rock in Layer 1 that are also intersected by the water table. These areas usually surround the alluvium material.

The predicted groundwater level drawdown as a consequence of tunnel construction and operation is illustrated for the alluvial/weathered material (Layer 1) and fractured rock aquifers (Layer 2) at quasi steady state conditions (inferred to be 50 years post-construction)[2] in **Figure 7-10** and **Figure 7-11**, respectively.

In general, one year following the construction of the Northern Link tunnel, the groundwater level within the alluvium and weathered material (Layer 1) can be expected to decline by up to 5m. The greatest drawdown is predicted to occur within the alluvium located in proximity to Fernberg Road (at the mid-point of the tunnel alignment), although as discussed below this is likely to be an over-estimate. A steep groundwater level drawdown cone is expected to develop in the fractured rock aquifer (Layer 2) and is approximately 100m wide on either side of the tunnel alignment following one year of construction. The groundwater level drawdown within Layer 1 is a consequence of the vertical movement of groundwater as steep vertical gradients develop between the alluvium and weathered material on one hand and the fractured rock aquifer on the other.

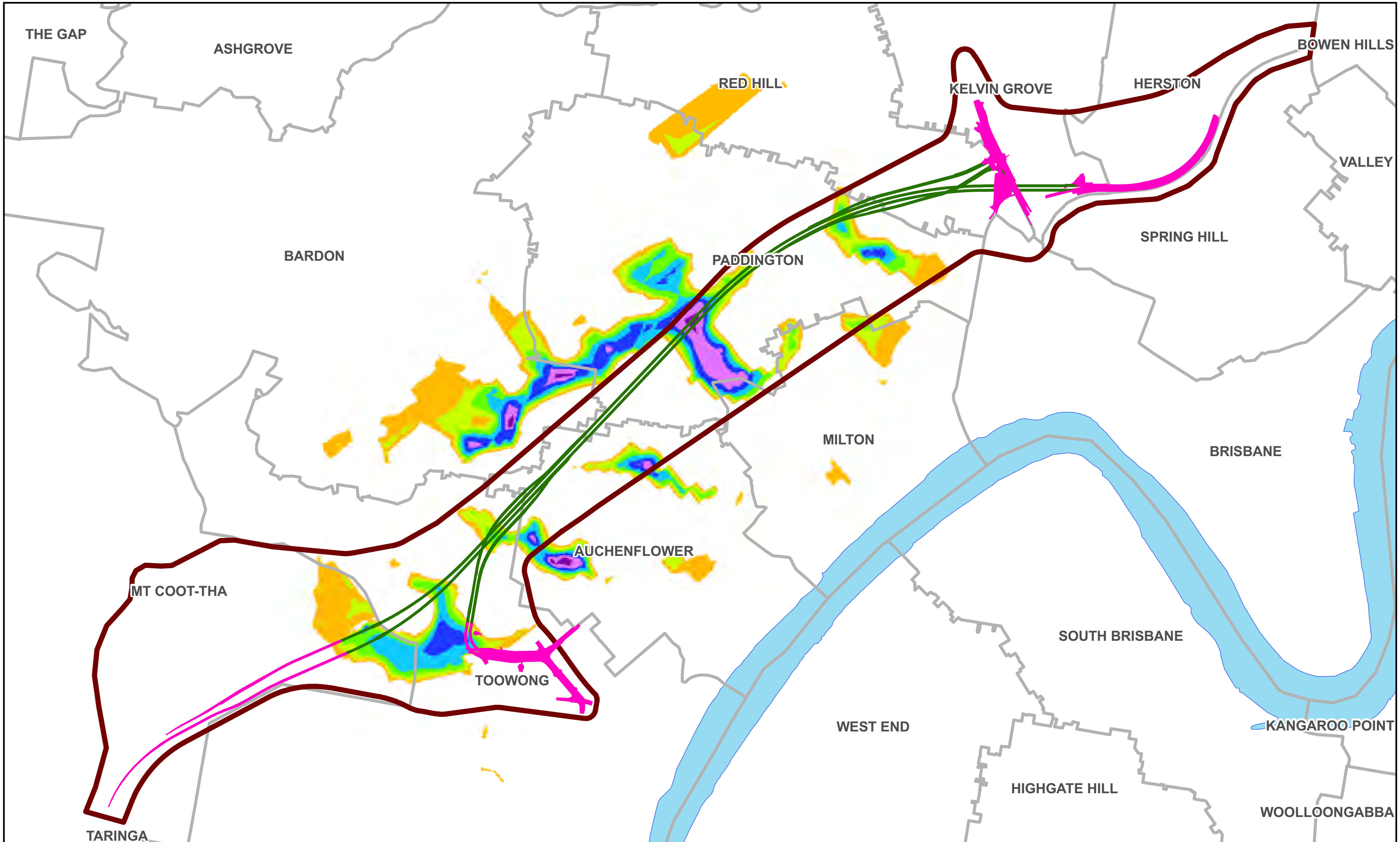
As indicated in these figures the model predicts that the alluvium/weathered material in proximity to the tunnel would dry out as a consequence of the steep vertical drawdowns between Layer 1 and Layer 2. This prediction is likely to be an overestimate of the groundwater level drawdown in the alluvial aquifer as the model assumes the absence of any confining element between the two layers. A level of confinement is expected (as evidenced by the artesian and upward hydraulic gradient recorded in NL2-19D), hence, the alluvium/weathered material is unlikely to dry out completely. Rather the alluvium is likely to harbour a perched shallow aquifer, interrupting the direct hydraulic connection between the two aquifers.

It is expected that quasi-steady state conditions would be reached in the aquifers following a period of 10 to 20 years post-construction. At this time, the groundwater level within the fractured rock aquifer is drawn down to the invert level of the tunnel and a steep lateral hydraulic gradient would occur with a width of approximately 800m either side of the tunnel. Drawdown is aligned about the Project axis and is greatest at the mid-point of the tunnel where a drawdown of up to 45m is predicted in the fractured rock aquifer.

The gradient of the potentiometric surface in the fractured rock aquifer is likely to remain towards the river due to a zone of slightly elevated groundwater between the tunnel and the Brisbane River (**Figure 7-11**). Based on the current level of data it is extremely difficult to reach a definitive conclusion regarding the post-construction movement of groundwater in the area between the tunnel and the river, but as shown in **Figure 7-11** the river is at or beyond the extreme edge of the potential drawdown cone. The potential for migration of saline water towards the Northern Link tunnel is discussed in further detail in Section 7.4.6.

---

[2] The modelling exhibited quasi-steady state conditions following a period of 10-20 years. Quasi steady state is a near approximation of steady state (or dynamic equilibrium) and is achieved in the model when the lateral extent and depth of the groundwater level drawdown essentially remains constant having reached a near state of equilibrium. A conservative approach has been adopted by illustrating quasi steady state in the model output following a period of 50 years post tunnel construction.



LEGEND

- Study Area Corridor
- Suburb Boundaries
- Brisbane River

Proposed Alignment

- Surface Works
- Tunnel Underground

Groundwater Model (50yrs)

- 1 - 2
- 2 - 3
- 3 - 4
- 4 - 5
- 5 - 6
- 6 - 7
- 7 - 8

0 500 1,000
metres

Scale 1:25,000 (A4)

N

NORTHERN LINK
ENVIRONMENTAL IMPACT STATEMENT

Figure 7 - 10

Modelled Groundwater Level Drawdown Post Construction (50yrs) - Layer 1

Northern Link

SKM Connell Wagner JOINT VENTURE

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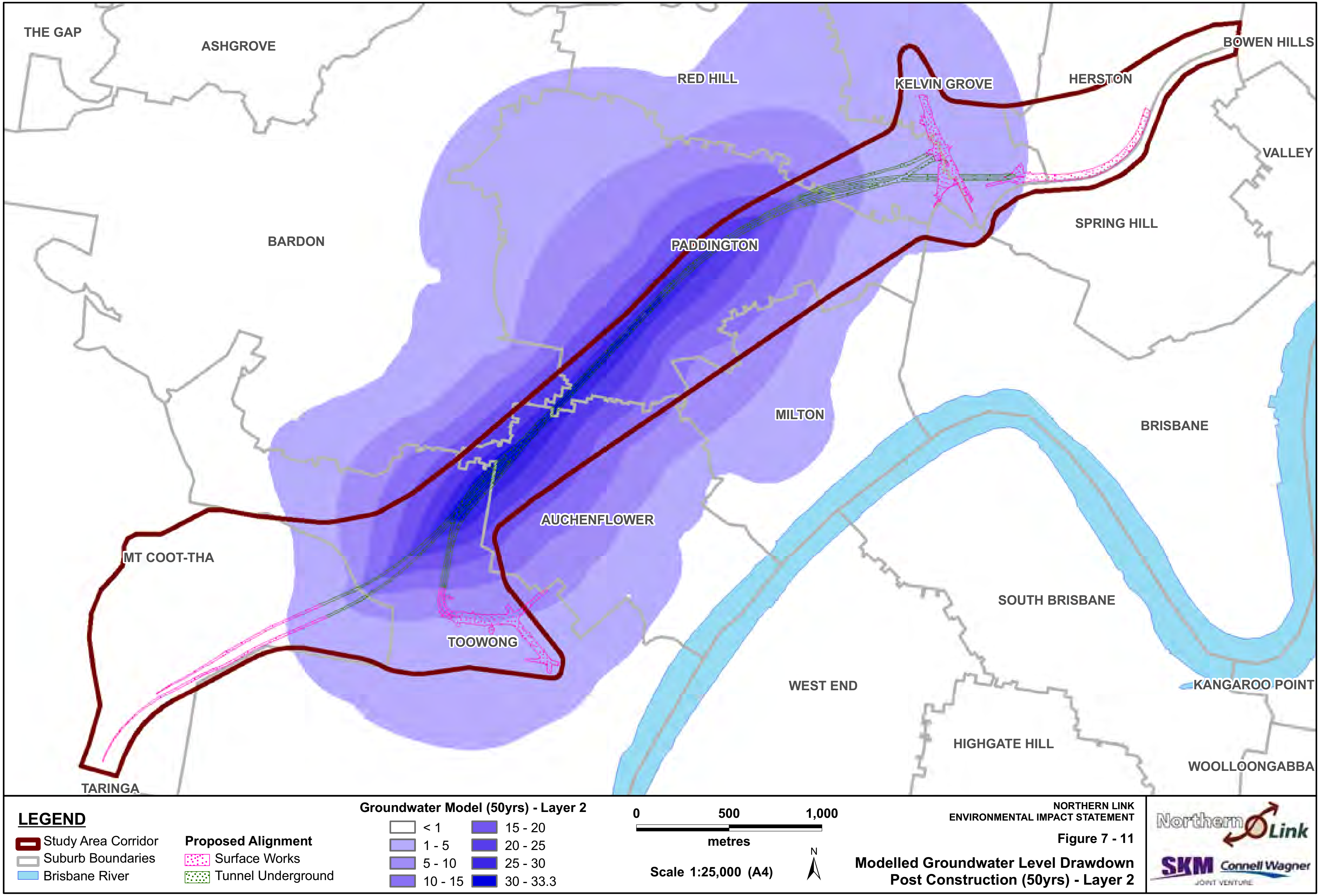

THE GAP
ASHGROVE
RED HILL
KELVIN GROVE
HERSTON
BOWEN HILLS
VALLEY
SPRING HILL
BARDON
PADDINGTON
MILTON
BRISBANE
AUCHENFLOWER
MT COOT-THA
TOOWONG
SOUTH BRISBANE
WEST END
KANGAROO POINT
HIGHGATE HILL
WOOLLOONGABBA
TARINGA
LEGEND
Study Area Corridor
Suburb Boundaries
Brisbane River
Proposed Alignment
Surface Works
Tunnel Underground
Groundwater Model (50yrs) - Layer 2
< 1
1 - 5
5 - 10
10 - 15
15 - 20
20 - 25
25 - 30
30 - 33.3
0
500
1,000
metres
Scale 1:25,000 (A4)
N
NORTHERN LINK
ENVIRONMENTAL IMPACT STATEMENT
Figure 7 - 11
Modelled Groundwater Level Drawdown
Post Construction (50yrs) - Layer 2
I:\QENV\Projects\QE07311\Spatial\Arc_MXD\Hydrogeology\080816_GW_Drawdown_Layer2_Fig7_13.mxd

7.4.3 Groundwater Depletion or Recharge

The results of the modelling discussed in the previous sections can be used to quantify any groundwater depletion and recharge as a consequence of the construction and operation of the tunnel. The following impacts to the groundwater and recharge regime may occur:

- total long-term groundwater inflow to the tunnels over their full length is likely to be in the order of 4L/s. This inflow rate was validated with the Heuer method as described in the Appendix to *Technical Report No. 4 – Groundwater in Volume 3* of the EIS. Construction inflow would be dependent upon the number, permeability and position of individual fractures intersected. The current prediction of long-term groundwater inflows of 4L/s along the length of the tunnel compares with the Airport Link tunnel (8L/s) and the Clem Jones Tunnel (CLEM7)[3] (5L/s);
- quasi-steady state conditions may be reached following a period of 10-20 years post-construction;
- steep vertical downward hydraulic gradients are expected between the upper alluvial aquifer and the fractured rock aquifer. Leakage of groundwater from the upper to the lower and ultimately to the tunnel may result. The alluvial aquifer is unlikely to dry out completely as it is likely to be perched above the bedrock without or with little direct hydraulic connection between the two aquifers;
- groundwater levels within the weathered Bunya Phyllite/Neranleigh-Fernvale Beds would be permanently lowered by up to 45m with the drawdown cone up to 800m either side of the tunnel corridor; and
- surface water inflow from the Brisbane River is unlikely to occur as a consequence of groundwater drawdown during construction and operation of the tunnel.

7.4.4 Settlement

Land disturbance as a result of the Project construction would largely be limited to the open trough structures and cut and cover tunnels. High rainfall events that coincide with the presence of open cut and cover areas or open troughs may temporarily flood workings and lead to a short period of localised increase in recharge to the aquifer system. In this instance the impacts would be considered minor, localised and of short duration.

With regards to potential settlement issues as a result of groundwater drawdown, the rocks along most of the tunnel alignment are very strong and competent. The rocks have been subject to high compaction forces and are highly over-consolidated. For this reason, settlement due to groundwater level lowering, along almost the entire tunnel route would be effectively negligible. The only possible exceptions are the occurrences of alluvium in proximity to the western portal cut and cover section and at the central section of the tunnel (close to Fernberg Road).

The alluvium at the Western Freeway cut and cover section, consists of up to 2m of compressible silty clays with SPT values between 1 and 9. A drained tunnel could potentially dewater this material and small absolute and differential settlement would occur. The Reference Project however proposes an undrained or sealed section of tunnel through this area of alluvium with no settlement impacts.

Groundwater level drawdown within the alluvial sediments in the central section of the tunnel (close to Fernberg Road) is unlikely to dry out the alluvium completely. While the model assumes there is no confining layer to separate the underlying fractured rock aquifer from the alluvium, a level of confinement is expected (as

[3] Formerly known as the North-South Bypass Tunnel (NSBT).

evidenced by the artesian and upward hydraulic gradient recorded in NL2-19D) with a perched shallow aquifer, interrupting the direct hydraulic connection between the two aquifers.

Bore logs in the vicinity of Fernberg Rd (NL1-3 and NL1-4) indicate 2-6m of alluvium. These medium to high plasticity CI silty clays have a recorded SPT value of 8-9. The water table depth is unknown. If it is assumed that the silty clays would be dried out (and as stated above this is likely to be an overestimation) a maximum settlement of 15-25mm may be possible. The rapidly varying thickness of the alluvium suggests that this could induce significant differential settlements. Accordingly, the nature of the confining layer between the fractured rock and alluvium needs further examination upon analysis of the Stage 3 Geotechnical Investigation results.

7.4.5 Potential Impact to Groundwater Dependent Ecosystems

Construction of cut and cover tunnels through the alluvial channel for the Western Freeway connection adjacent to the Anzac Park wetland is proposed as undrained (ie: watertight) which is analogous to inserting a sealed pipe through the alluvial aquifer. This construction method means that no groundwater will report to the tunnel but pass around the tunnel in much the same way as it does now. Construction of gravel drains over the lid of the cut and cover tunnels would facilitate the flow of groundwater in the alluvial aquifer during periods of high rainfall when the aquifer would be near saturation. In so far as the design of the tunnel would not deplete or impede groundwater movement in the alluvial aquifer it would not be expected to interfere with the wetland in Anzac Park.

Groundwater drawdown within the alluvium in the central section of the tunnel (close to Fernberg Road) may potentially impact upon any similar groundwater dependant ecosystems within this area. This remains unlikely however as the alluvial aquifer is most likely perched above the impermeable bedrock as discussed above in section 7.4.4. The nature of the alluvial aquifer in this area would be further investigated and assessed during pre-construction studies and detailed design.

7.4.6 Impact on Groundwater Quality and Contamination

A range of Environmental Management Register (EMR) listed land parcels (refer to Chapter 6, Figures 6-6A, B and C) are located within the zone of potential groundwater drawdown. Any mobile groundwater contaminants within this zone may be expected to ultimately discharge to the proposed tunnel. Contaminant travel times would be dependent upon the contaminant itself, the distance from the tunnel and the magnitude of the hydraulic gradient towards the tunnels. As groundwater inflows to the tunnel are expected to be low (in the order of 4L/s), contaminant fluxes are expected to be correspondingly low. All groundwater collected in the tunnel sumps would be pumped out and treated to appropriate standards before being disposed of to the stormwater drain system.

Potential may occur for migration of contaminated groundwater towards or through adjacent previously uncontaminated sites as a consequence of the altered hydraulic gradient. Existing water-table depths in the alluvium may be within typical root zone depths (<8m) of overlying vegetation. The groundwater level would lower as the tunnel is constructed and in turn, the potential environmental impact of any migrating contamination would be reduced.

The potential for inducement of saline water from the Brisbane River into the aquifer and the tunnel as a consequence of groundwater drawdown causing reversal of the hydraulic gradient between the aquifer and adjacent river system is unlikely. Discharge of saline water to the tunnel has the potential to impact upon the integrity of the tunnel by the corrosion of concrete drains or potential precipitation (scaling) of calcium carbonate contributing to the clogging of concrete drainage systems. However, **Figure 7-11** shows the river to be at or beyond the extreme edge of the potential drawdown area making the likelihood of river water migration through the aquifer extremely improbable.

The numerical modelling indicates that the drawdown cone is unlikely to intercept the Brisbane River in the long term. The prospect of saline water migrating and discharging to the tunnel is therefore considered improbable. Furthermore, in the event that a marginal reversal of the hydraulic gradient does occur, saline water would not be expected to intercept the tunnel for well over 200 years.

7.4.7 Potential for Acid Sulphate Soils

As discussed in Section 6.2.5 the potential for ASS materials to be encountered is considered negligible.

7.5 Surface Water Resources – Potential Impacts and Mitigation

7.5.1 Construction Water Impacts

The construction phase would require onsite water to be used for construction activities including:

- dust suppression;
- earth compaction;
- washdown of vehicles and roadheaders; and
- grout and shotcrete production.

Construction activities at the Western Freeway and Toowong worksites may potentially impact on several minor waterways including tributaries of Toowong Creek, the drainage line from Mt Coot-tha Botanic Gardens and Toowong Cemetery.

The key activities and potential impacts in this area, if not properly managed, include:

- vegetation clearing and establishment of access roads to the worksites leading to sediment-laden runoff;
- diversion of drainage channels and/or underground stormwater infrastructure resulting in a change to surface water hydrology;
- establishment of the Western Connection worksite, including launching of the tunnel boring machines (TBMs) and storage and use of other machinery and equipment, which could lead to a release of water contaminated with hydrocarbons, heavy metals and other chemicals;
- construction of embankments for the elevated road alignment and tunnelling works resulting in sedimentation and runoff, as well as release of contaminated water;
- removal of spoil by enclosed conveyor from the Western Connection worksite to Mt Coot-tha quarry could lead to sediment-laden runoff from spoil stockpiles (but would be contained within the quarry); and
- use or leakage of improperly treated recycled water for construction activities leading to elevated nutrient and faecal coliform concentrations in runoff.

Within the Breakfast Creek/Enoggera Creek catchment, an overland flowpath from the Kelvin Grove Urban Village via the Brisbane Grammar School Playing Fields is intersected near the ICB. This overland flowpath only conveys surface water following rainfall. A major detention basin within Victoria Park, adjacent to Bowen Bridge Road, discharges by underground drain to Enoggera Creek. Degraded surface water travelling via this drainage system during storm events would have a direct impact on downstream water quality.

The key activities and potential impacts in this area, if not properly managed, include:

- establishment of the Kelvin Grove Road worksite, including launching of the roadheaders and storage and use of other machinery and equipment, could lead to release of water contaminated with hydrocarbons, heavy metals and other chemicals;
- excavation of the cut and cover tunnel works and transition structures leading to sediment-laden runoff;
- construction of access ramps, transition structures and surface works for both the ICB and Kelvin Grove Road Connections, resulting in sedimentation and runoff, or release of contaminated water;
- diversion of existing drainage channels or underground stormwater infrastructure resulting in a change to surface water hydrology;
- temporary storage of spoil overnight at the ICB Connection worksite and removal by truck to an appropriate area for disposal, this could lead to sediment-laden runoff from spoil stockpiles; and
- storage and use of improperly treated recycled water for construction activities leading to elevated nutrient and faecal coliform concentrations in runoff.

Use of Recycled Water

If the option to source a portion of the construction water through sewer mining (as considered in Chapter 3) is taken up, it would include treating water onsite at the Western Freeway worksite in line with Queensland Water Recycling Guidelines (EPA, 2005). Treated water would then be stored onsite, as well as being trucked to the Toowong and Kelvin Grove worksites where it would also be stored in covered tanks for construction use. Reuse of water can benefit the surrounding environment by reducing the demand on potable water supply.

There would however remain a risk that untreated wastewater from such an option could be accidentally released, leading to degradation of the surrounding environment. Such an option for water use would be regulated through the approval process for an Environmentally Relevant Activity with specific management measures to identify and avoid risks of off-site impacts the an approved environmental management plan. This would include emergency response and spill containment procedures.

Operational Impacts

The likely areas that may impact upon surface water quality during operation are the four connection points of the road network to the tunnel; Western Freeway, Toowong, ICB and Kelvin Grove Connections. The tunnel would have a separate drainage collection system, which would collect tunnel washdown water, any stormwater ingress and any spillage such as chemicals, and petrochemicals. Water from the tunnel collection system would be removed by tanker and taken for offsite treatment or appropriate disposal.

Potential impacts from operation of the Project would include:

- stormwater runoff, contaminated with suspended sediments, heavy metals, oil, grease or other hydrocarbons;
- accidental spillage of pollutants from a collision or other incident;
- litter;
- increased stormwater runoff and alteration/impediment to its movement; and
- failure of the drainage collection system or inability to contain volumes of contaminated water greater than the design volume (ie: prolonged heavy rainfall conditions resulting in continuing ingress).

7.5.2 Sedimentation and Runoff

Construction

Sediment-laden runoff from construction activities is considered a particularly high risk to waterways and the drainage network, adjacent to or downstream of the construction area. Construction activities, if improperly managed, could result in erosion and transportation of sediment off site. These activities include:

- vegetation clearance;
- excavation and earthworks associated with utility diversion, cut and cover tunnel, embankments and bridges, haul roads; and
- stockpiling and transferring of spoil from tunnel construction.

Operation

The main impact to surface water quality during operation would be road runoff, which is likely to contain elevated levels of sediment, heavy metals, petroleum hydrocarbons and polycyclic aromatic hydrocarbons (PAH's). A road runoff study was undertaken by the Queensland Department of Main Roads in partnership with the Moreton Bay Waterways and Catchment Partnership (MBWCP) and provides an estimate of the relative impacts that road runoff may have on water quality and aquatic habitats in South East Queensland. A summary of the potential construction and operational phase impacts identified by the study is provided in **Table 7-15**.

Table 7-15 Potential sources of pollution and potential impacts during construction and operation phases

Pollutant	Source	Potential Impact
Sediment	Construction activities, such as excavation, earthworks, stockpiles	▪ The build up of sediments in waterways may alter stream hydraulics leading to potential increase in channel scour, riverbank erosion and changes to patterns of flooding
	Abrasion of road gravel and tar	▪ Increased turbidity in waterways that may reduce light penetration and lead to a reduction of aquatic plant growth and smothering of aquatic fauna (including fish eggs and larvae)
Heavy metals		▪ Elevated levels of heavy metals can be toxic to aquatic biota. Uptake may occur through passive uptake across gills or through ingestion of food, resulting in sublethal and lethal effects on aquatic organisms affecting growth, reproduction and behaviour ▪ Heavy metals can be accumulated in the tissues of aquatic organisms and may be bioaccumulated up the food chain, resulting in elevated concentration of contaminants with implications for marine biota, fisheries and aquaculture and human health
Zinc	Tyres	
Copper	Brake pads	
Other common metals	Corrosion	
PAHs, oils and grease and other hydrocarbon products	Exhaust and sump oil	▪ PAHs are known carcinogens and mutagens and can be bioaccumulated by aquatic organisms. High levels of PAHs have implications for aquatic organisms and human health ▪ Oils and grease are unsightly and can damage aquatic ecosystems ie reducing the diffusion of oxygen into the water column and smothering aquatic biota

7.5.3 Spillage or Accidental Release of Pollutants

Construction

During construction hazardous and chemical substances (such as hydrocarbons for fuel, asphalt plumes, cement slurry) may be used and contaminated water from washdown may be generated. These sources would become potential environmental pollutants if not properly managed through appropriate storage, bunding or treatment. Spillage or accidental release of pollutants may have the following impacts on surface water quality.

- Hydrocarbons, heavy metals and other chemicals can result in acute or chronic toxicity impacts to the aquatic biota present and may result in severe disruption to local ecosystem biodiversity.
- Oils and grease are unsightly and impact on in-stream biota and other fauna dependent on the waterway.
- Litter is unsightly, pollutes streams and can be physically harmful to aquatic organisms.
- High nutrient concentrations from the accidental release of untreated wastewater from sewer mining, or inappropriate use of recycled water, may result in algal blooms or dominance by aquatic weed species adapted to high nutrient environments. Accidental release of untreated wastewater also presents concerns from a human health perspective.

Operation

During operation, the main risk of release of pollutants to the surrounding environment is litter, or fuel or chemical spills occurring due to vehicle collision. Depending on the volume of the spill, there is potential to cause significant damage to the terrestrial environment and downstream waterways, as well as potential public health impacts. The potential environmental damage from a spill may be long term, particularly if groundwater contamination occurs, as the effects may persist for many years.

7.5.4 Surface Water Hydrology

Construction activities for the Project may involve localised changes to the hydrology of the area. While the study corridor does not directly intersect any major waterways, construction may involve permanent or temporary alterations to existing drainage channels and the stormwater network.

Alteration or impediment to stormwater flow may alter the physical dynamics of the receiving waterways, which in turn would have implications for its ecology. In most cases the impacts would only be short-term with temporary impediments including stockpiling of spoil, material storage, equipment and machinery. However, the constructed infrastructure may impede water movement during baseline flows and/or flooding events leading to pooling within waterways or channels, diversion of overland flow or changes to frequency of flows and quantity and quality of surface water runoff.

Pooling of water in drains and channels may provide breeding sites for mosquitoes, which are vectors of a number of diseases. Suitable breeding sites include fresh, brackish and polluted water in constructed drains, depressions, discarded tins and bottles.

7.5.5 Acid Sulphate Soils (ASS)

The potential for construction works to interfere with ASS is negligible but a range of potential impacts and nearest low risk areas are outlined in *Technical Report No. 5 – Surface Water in Volume 3* of the EIS.

7.5.6 Mitigation Measures — Surface Water

Construction Phase

An Erosion and Sediment Control Plan would be designed as part of the Environmental Management Plans and implemented to minimise any transport of sediment from the project construction areas into the surrounding waterways and drainage lines. During construction, potential impacts to water quality would be managed through the following measures and controls:

- maximise the areas of vegetation retained and progressively rehabilitate cleared sections where appropriate;
- diversion of stormwater from higher ground around disturbed areas where possible;
- stockpile materials and soils away from natural drainage areas;
- implement mechanisms to slow and/or prevent overland runoff, such as the planting of vegetation and/or the installation of artificial structures (ie: geofabric and bunds);
- effective erosion and sediment control measures to be installed prior to construction works commencing and regularly monitored (daily) and maintained to ensure their continued effectiveness throughout the duration of the construction phase;
- ensure dust suppression measures are implemented throughout the construction phase;
- chemical storage areas and wash down facilities are to be located away from existing drainage lines and have appropriate bunding and waste water collection mechanisms;
- chemical and hydrocarbon wastewater must be disposed to a liquid waste disposal facility or company, or treated to an acceptable level for discharge with the permission of the responsible authority; and
- waste storage facilities and spoil placement areas are to be located away from existing drainage lines and have appropriate bunding and drainage mechanisms.

Construction Surface Water Quality Monitoring Program

A water quality monitoring program for the construction phase would be established prior to construction to enable monitoring of compliance with identified water quality objectives and to enable any impacts to water quality to be identified, controlled and reported. This monitoring program would be included in the Environmental Management Plan.

In-situ parameters that would be measured include pH, conductivity, DO, turbidity, with a visual assessment of each monitoring site for the presence of oil or grease films on the water surface. Samples collected for laboratory analyses would be analysed for such parameters as nutrients, suspended sediment and standard suite of heavy metals (to be determined by the approval conditions for discharge criteria). Any non-conformances would be reported to the site environmental officer for immediate corrective action.

Regular inspection of the drainage channels within the construction areas would be undertaken, particularly after rainfall to monitor for areas of ponding. The removal of debris, as well as regrading of the channels would be undertaken, as required, to minimise mosquito breeding and reduce habitat for larvae.

Operational Phase

During the operational phase of the Project a number of management options may be employed to effectively manage and treat road runoff. The incorporation of Water Sensitive Urban Design (WSUD) methods enables the effective integration of water cycle management. This is utilised by most local councils for the effective treatment and management of stormwater and is particularly suited to road runoff. Achieving pollutant load reductions prior to discharge would be a principal objective in the design of the stormwater management strategy for the Project. A number of different components and controls would be investigated as part of this strategy, and those considered suitable and most effective would be developed during the detailed design phase and either included in the final design or in the detailed Environmental Management Plans. These include:

- grassed/vegetated swales located alongside roads and ramps;
- batter slopes to be grassed/vegetated and use of rock check dams to slow flow velocity and prevent scour;
- permanent settlement ponds and detention basins;
- use of Stormwater Quality Improvement Devices (SQIDs) to remove gross pollutants such as litter; and
- oil/grit separators to remove hydrocarbons and coarse sediments.

All permanent water quality treatment control devices would be designed for the adequate control of pollution and sediment and other coarse materials in the event of a flood.

The development and implementation of an Operational Environmental Management Plan would reduce potential operational water quality impacts.

Operational Surface Water Quality Monitoring Program

As runoff from road infrastructure has been identified as a significant contributor of heavy metals and other toxicants to local waterways, an appropriate operational monitoring program is essential to the assessment and management of potential long-term and cumulative impacts to surface waters.

The following guidelines would be utilised to establish a sound monitoring programme for the Project.

- Australian and New Zealand Guidelines for Fresh and Marine Water Quality 2000.
- Queensland Water Quality Guidelines 2006.
- EPA Water Quality Sampling Manual 1999.

Water quality would be compared with the WQOs of QWQG and ANZECC 2000. If concentrations are observed to exceed the trigger values additional investigation and mitigation measures would be implemented as required.

7.6 Potential Flood Impacts and Mitigation Measures

7.6.1 Western Connections

The Western Freeway and Toowong connections are located in separate catchments with separate flooding behaviour. Regional flooding from the Brisbane River and local drainage via surface flow and small drains are separate mechanisms that do not interact in these areas.

Both the Western Connection tunnel portals have been located well above the regional flood levels for the one in 10,000 AEP event. All surface works including portals, transition structures and road works for both the Western Freeway and Toowong connections are well above the Brisbane City Council defined flood level for the one in 100 AEP event in the Brisbane River. Therefore these works would not impact on regional flood levels for events up to and including the one in 100 AEP flood event as required by Brisbane City Council development guidelines.

Construction Phase

Mt Coot-tha Local Drainage

During construction, both the Transition and Cut and Cover Sections would be exposed and need protection from local flooding. This would be achieved by sheet pile/diaphragm walls along the two faces of construction exposed to flooding, or a combination of the two.

The construction area upstream of the Western Freeway, adjacent to the Botanical Gardens, would also need to be protected from local flooding during construction. This would be achieved by construction of a bund, to provide one in 100 AEP immunity to the construction area. The bund that would be approximately 400-600m long and 2m high at its highest point. An artificial channel would be constructed on the upstream face of the bund to allow flow from Catchment C4 into the detention area upstream of the Western Freeway. The existing 1650RCP culvert under the Western Freeway would be maintained during construction while the existing 900 RCP to the west would become redundant and be removed.

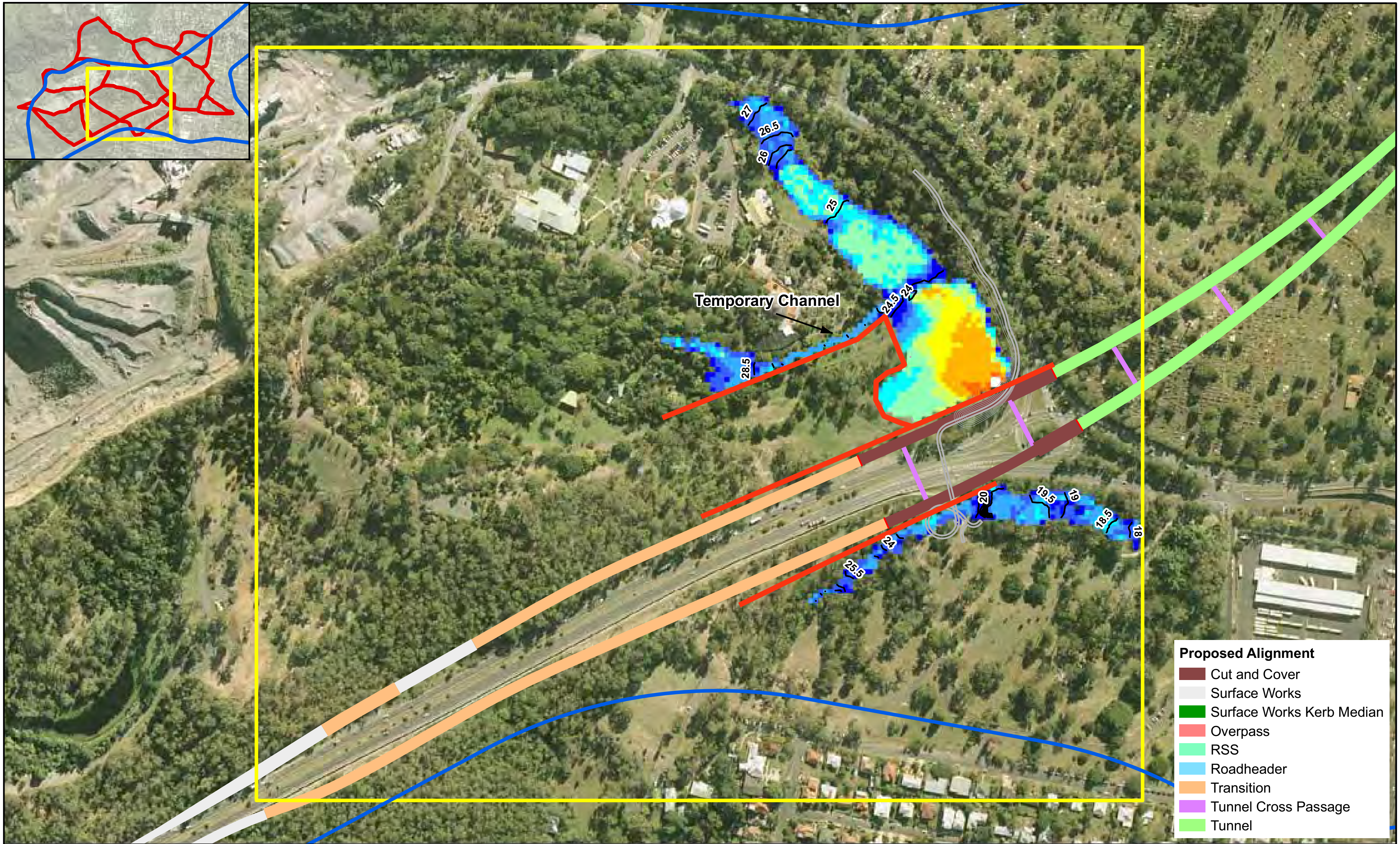
The Construction Phase of the project was modelled using the hydraulic model developed for the existing environment. The aspects of construction discussed above were incorporated into the model terrain to represent the Construction Phase. The results of the hydraulic model showed that during construction the flood behaviour of the area is similar to the existing. The 1650RCP under the Western Freeway was found to manage the increased flow, maintaining one in 100 AEP flood immunity to the Freeway during construction. The area upstream of the Western Freeway continues to act as a detention storage.

However, there is an increase in the peak water surface level of the water ponded upstream of the Western Freeway in the one in 100 AEP flood to 24.0 m AHD. This represents an increase of up to 0.7m. **Figure 7-12** presents the peak modelled depth and water surface levels for the one in 100 AEP flood while presents the impact of the Project on local flooding. The impact on flooding is localised to the area that currently acts as a detention storage upstream of the Western Freeway in the Botanical Gardens grounds. As no buildings or other infrastructure are impacted, and the construction period is only expected to be four years long, this impact is considered acceptable for the construction period.

Toowong Connection Local Drainage

No flooding protection is required for this portal during construction as it is located at the top of a ridge well above the one in 10,000 AEP flood level for both local and regional flooding.

The Toowong worksite between Frederick Street, Milton Road and Valentine Street is part of a very small local catchment (Catchment 11) and should have no significant flooding issues during the construction period. A bund on the downstream side of Valentine Street would provide sufficient protection to the site with the upstream flow continuing to the catchment outlet via the street.



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LEGEND

- Study Area Corridor
- Model Area
- Local Drainage Structures
- Peak Flood Level (m AHD)
- Bund Around Construction
- Bikeway

Peak Flood Depth (m)

- 0.0 - 0.2
- 0.3 - 0.5
- 0.6 - 1.0
- 1.1 - 1.5
- 1.6 - 2.0
- 2.1 - 2.5
- 2.6 - 3.0
- 3.1 - 3.5
- 3.6 - 4.0
- 4.1 - 4.5

0 100 200
metres
Scale 1:5,000 (A4)
N

NORTHERN LINK
ENVIRONMENTAL IMPACT STATEMENT

Figure 7 - 12

Mt Coot-tha Construction Phase: 1 in 100 AEP Flood Extent

Northern Link
SKM Connell Wagner
JOINT VENTURE

Operational Phase

Mt Coot-tha Local Drainage

At the Western Freeway connection, the Project would include several different aspects pertinent to flooding potential:

- sections of driven tunnel that are fully under the ground and create no change to the surface terrain;
- sections of cut and cover tunnel that would, before the end of construction, have the existing terrain reinstated over the top of the tunnel lid and therefore represent no net change to the surface terrain;
- sections of transition structure that are sections of road, sometimes significantly lower than the existing surface level, which join the tunnel level to the existing road level; and
- surface connections at the Western Freeway that are located where the transition structure meets the cut and cover tunnel sections.

In addition to these Project related aspects, Brisbane City Council plans to construct a water storage upstream of the Project within and for the use of the Botanical Gardens. This storage has been considered for the Operational Phase of the Project. The Project has been designed so as to avoid impact on the annual or seasonal availability of water from this storage.

The design of this storage makes the existing 900mm reinforced concrete pipe (RCP) culvert under the Western Freeway redundant because its catchment is diverted into the proposed storage. The existing 1650RCP culvert under the Western Freeway lies above the tunnel lid. It would be supported throughout construction and no change is expected to its behaviour once the tunnel is constructed.

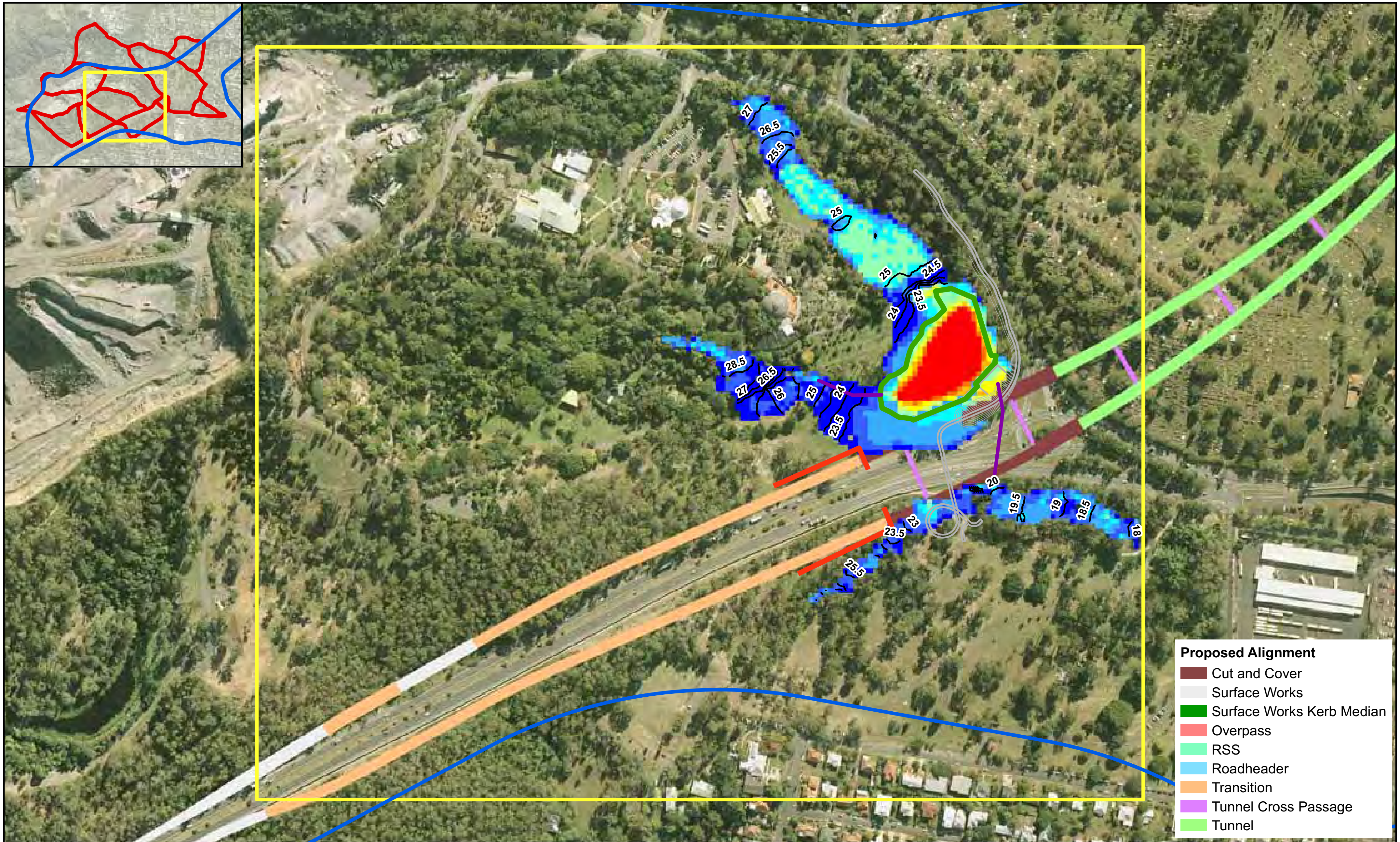
The bikeway planned by DMR at the Western Freeway which is to be constructed prior to construction of the Project, is included throughout the flooding assessment.

As part of the investigation of the existing environment, a hydraulic model was developed to simulate drainage from Mt Coot-tha through the Botanical Gardens and under/over the Western Freeway. **Figure 7-5** shows the existing peak flood extent for the one in 100 AEP flood.

The Operational Phase of the project was modelled using the same hydraulic model platform developed for the existing environment with the aspects of the Project discussed above incorporated into the model terrain. The hydraulic model shows that the flood behaviour of the area is little changed by the Project. The area upstream of the Western Freeway continues to act as a detention storage with the majority of water now contained within the proposed Brisbane City Council storage. The remaining 1650RCP under the Western Freeway continues to cope with the flow in the one in 100 AEP while the Freeway is overtopped in the one in 10,000 AEP flood.

Flood water would pond to a peak level of 23.4 m AHD upstream of the Western Freeway in the one in 100 AEP flood **(Figure 7-13).** This represents an increase of less than 100mm. No impact would be caused to any other property.

Catchments C5 and C6 are drained via culverts under the Western Freeway. Surface works undertaken as part of the Project may cause changes to these drainage requirements. These works would be undertaken in accordance with the Department of Main Roads Road Drainage Design Manual (DMR, 2002) such that the flood immunity of the road is maintained and there are no flood impacts on adjacent properties.



LEGEND

- Study Area Corridor
- Model Area
- Water Storage
- Local Drainage Structures
- Peak Flood Level (m AHD)
- Portal Protection Wall
- Bikeway

Peak Flood Depth (m)

- 0.0 - 0.2
- 0.3 - 0.5
- 0.6 - 1.0
- 1.1 - 1.5
- 1.6 - 2.0
- 2.1 - 2.5
- 2.6 - 3.0
- 3.1 - 3.5
- 3.6 - 4.0
- 4.1 - 4.5

0 100 200
metres

Scale 1:5,000 (A4)

N

NORTHERN LINK
ENVIRONMENTAL IMPACT STATEMENT

Figure 7 - 13

Mt Coot-tha Operations Phase:
1 in 100 AEP Flood Extent

Northern Link
SKM Connell Wagner JOINT VENTURE

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Toowong Connection Local Drainage

This connection is located on the eastern side of Frederick Street and to the north of Milton Road. Flooding for the one in 10,000 AEP event in this area is governed by local flooding from the Toowong Cemetery (C8) catchment. The modelling shows that the proposed connection is located well up the hill and above both local and regional flood levels for the one in 10,000 AEP event.

There is a risk that a small quantity of sheet flow from the local Catchment 11 may flow into the transition structure and into the tunnel. The final design for this portal should include walls along the Transition Section to protect the tunnel portal from this minor flow.

An overpass and reinforced soil structure connects the Transition Section to the surface level of Milton Road. This and some other associated road works along Milton Road, Croydon Street and Sylvan Road may impact on the existing local stormwater drainage structures. These works are to be designed in accordance with the appropriate standards such as the Department of Main Roads Road Drainage Design Manual (DMR, 2002) and Queensland Urban Design Manual (DNRW, 2007). The flood immunity of the existing roads would be maintained and no flood impacts on adjacent properties would occur.

7.6.2 Eastern Connections

The terrain adjacent to the connections is elevated and out of the influence of the Brisbane River or any other major creek or waterway. No regional flooding impacts are expected around the eastern connections.

Construction Phase

Lower Clifton Terrace Drainage Area

During construction, the area between Lower Clifton Terrace, the northern extension of Hale Street and Kelvin Grove Road would be used for site storage and offices. In the case of the existing structures being retained for this use, no change to the storage area would take place and so existing peak flood levels would apply.

However, if the site is cleared and used for new offices, the offices would be constructed in such a way as to avoid any change to the retention capacity of the basin.

ICB Connection

No significant construction or filling is proposed in the sports field detention basin, so no construction phase impacts are predicted and no mitigation would be required.

Operational Phase

ICB Connection Local Drainage

The sports field west of the Inner Northern Busway (INB) overpass functions as a detention basin under large to extreme rainfall events. Hydraulic performance is governed by its storage volume versus height relationship; and the discharge capacity versus height relationship of its outlet structure. The works would have the potential to influence the basin's hydraulic performance, and adversely affect peak water levels in the basin and/or peak discharges in the downstream channel. If widening of the existing Inner City Bypass (ICB) upstream from the INB overpass were to reduce the available flood storage volume; or if widening of the existing ICB beneath the INB were to reduce or remove the overflow capacity of the existing outlet structure. Downstream of the detention basin, flows are conveyed by a trapezoidal open channel. The hydraulic performance of the channel is governed by the area, roughness and hydraulic radius of its geometry. The works have the potential to adversely affect the drains performance if widening of the ICB formation were to reduce the area and hence hydraulic radius of the existing channel.

To achieve the one in 10,000 AEP flood immunity to the tunnels, protection to a level of 25.3m AHD would be required (including a 300mm freeboard).

Three different aspects of the design were considered:

- any potential reduction in flood storage available in the detention basin up to the one in 100 AEP flood level;
- any reduction in the capacity of the existing outlet structure; and
- any reduction in the capacity of the existing open channel downstream to York's Hollow.

The proposed widening of the existing ICB formation upstream from the INB overpass would be at levels above the one in 100 AEP water level in the basin. Thus, no hydraulic impacts would result under events up to one in 100 AEP from the filling.

Due to the widening of the existing ICB formation beneath the INB overpass, the works would unavoidably modify the existing outlet structure. The existing overtopping weir (8.9m long at RL 23.8m) would be reduced to a width of 4m.

RAFTS was used to investigate the effects of this reduction. The discharge relationship was revised to reduce the available outflow from the basin. The post development case, with no mitigation, resulted in a 50mm afflux at the one in 100 AEP to 24.3 m AHD. At 10,000 ARI, this increases to 25.25 m AHD, an additional 250mm above the existing situation.

To mitigate against the 50mm afflux for the one in 100 AEP case and to ensure protection for the tunnel entrance, additional capacity would be required at the outlet structure to compensate for the reduction in overflow width. To achieve the same discharge level relationship, any additional capacity would have to be created above 23.8m AHD, the level of the existing overflow weir.

RAFTS was used to investigate this, retaining the existing level discharge relationship to 23.8m AHD, which effectively means keeping the existing arrangement of the inclined grate, although it would need to be relocated slightly further upstream than it's present location, away from the widened ICB.

Above 23.8m AHD, an increase in the effective width of the weir by one metre above 23.8m AHD would provide sufficient capacity. An additional inlet grate of perimeter 16m would allow additional flow into the outlet structure. It was assumed for the hydraulic modelling that the grate may be up to 50% blocked. With this assumption, the model predicted the following peak water levels in the basin.

As shown in **Table 7-16**, no significant impacts upon peak water level in the basin are predicted for the one in 100 AEP design event with the additional capacity.

Table 7-16 Peak Water Level Predictions for Sports Field Basin

Event Magnitude (AEP event)	Peak Water Level Prediction (m AHD)		Afflux (m)
	Existing Conditions	Post-development *	
1 in 100	24.25	24.23	-0.02
1 in 10,000	25.0	25.12	+0.12

Table Note: * Post-development peak water levels assume supplementary grate 50% blocked

The required widening of the existing ICB formation would encroach upon the existing open channel. To offset this impact, two engineering design options have been identified in *Technical Report No. 6 - Flooding in Volume 3* of the EIS. The preferred option (included in the design presented in Volume 2 of the EIS) realigns the existing open drainage channel and the bikeway slightly to the north to allow the existing capacity of the channel to be maintained.

Kelvin Grove Road Connection Local Drainage

Upgrading of Kelvin Grove Road as far north as Blamey Street has the potential to impact on the storage capacity of the detention basin west of Kelvin Grove Road opposite McCaskie Park. It is important that the proposed works do not reduce the available flood storage volume below the one in 100 AEP flood level in this area. Provided that this criterion is satisfied, no increases in peak water level upstream of the road or peak discharge downstream from the road would occur.

The proposed works would be above the 39.5m AHD flood level and therefore satisfy this condition. Accordingly, no adverse hydraulic impacts are predicted under a one in 100 AEP rainfall event.