Northern Link

TECHNICAL REPORT NO. 6

FLOODING

- May 2008

Contents

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1. Description of Existing Environment

1.1 Flood Potential

The flood potential in and adjacent to the study corridor has been assessed for two purposes; firstly to understand how the project may alter the existing flooding regime of the investigation area, and secondly to ensure that flooding risks are accounted for in the design of the Project and avoid damage and flood hazards during the construction and life of the infrastructure. The focal points for this section are the principal points of interaction between the Project and the floodplains of the area which are around the points of connection to the surface road network.

Flood risk to existing property and infrastructure has been assessed for the 1 in 100 Average Exceedance Probability (AEP) flood event. The 1 in 100 AEP event is a standard tool for assessment of flooding impacts due to development. It particularly relates to property flooding impacts as it is a Brisbane City Council (BCC) requirement 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. Studies and design for the preceding components of the Council's TransApex plan have required that the tunnels have a 1% probability of receiving flood flow for each of the 100 years of design life which approximately translates to a requirement for the tunnels to have 1 in 10,000 AEP flood immunity. This section describes the flooding regime for the existing environment. Flood risk around the connection areas is of particular interest and the focus of this reporting. Flooding at the eastern and western connections do not interact and are influenced by completely different mechanisms. Section 1.1.1 discusses the existing flood mechanisms and potential at the western connection while Section 1.1.2 discusses those at the northern connection.

The description of the existing flooding regime is based on background investigations that have been supplemented by focussed technical studies and site inspections within and near the study corridor.

1.1.1 Western Connections

Existing flooding in the study corridor around the western connections can be characterised by two distinct hydrologic mechanisms; local drainage via surface flow and small drains and regional flooding from the Brisbane River. Figure 1 presents an overview of the western connections showing the study area, Brisbane River and local catchments.

Regional flooding is dominated by the Brisbane River. The Brisbane River catchment upstream of the Project is large and includes the Wivenhoe Dam catchment. Large and extreme floods in the Brisbane River will run over a long duration, producing large volumes of water and thus presenting a risk to the tunnel if the connections are overtopped.

The other potential threat from regional flooding is from storm surge. However, the topography of the study corridor is generally above 10 mAHD and thus well clear of that threat.

Local flooding risk is presented by small catchments draining from 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 which ultimately flows to the Brisbane River. Large and extreme events in these local catchments occur over short durations, result in rapid water level rise and fall and small volumes. However overtopping from local flooding still has the potential to be hazardous and damaging to the tunnels.

1.1.1.1 Local Drainage

Figure 1 shows the extent of the local catchments and drainage paths for the area of the western connections. Two distinct areas of interest have been identified; the Mt Coot-tha Quarry, Botanical Gardens and Anzac Park drainage, and the Toowong Cemetery. A site investigation of the western connection area confirmed the location and size of drainage structures under the Western Freeway and Milton Road.

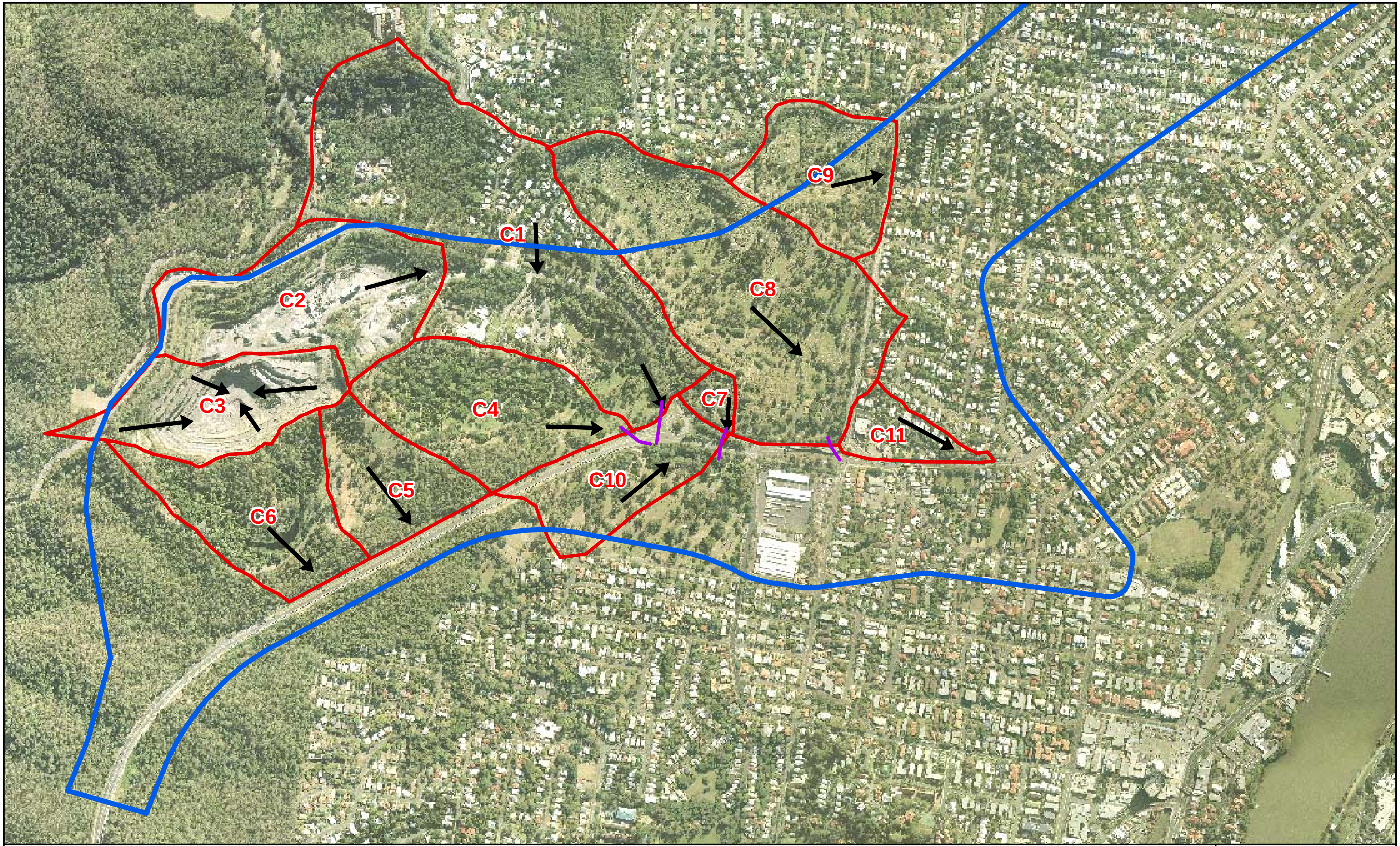
The hydrology of the Mt Coot-tha Quarry area (Catchments C2 and C3) has been significantly altered by quarry operations. Catchment C3 comprises the active pit and surrounding benches which drain into the pit. It has very steep, high sides and is large enough in volume to contain large rainfall events without risk of overtopping. Thus, this catchment has not been included in this assessment as it is completely self contained.

The drainage regime of the rest of the quarry (Catchment C2) has been altered such that it now includes storage and the benching of the quarry walls. The benching prevents direct drainage down the faces of the excavation, slowing catchment response. The *Mt Coot-tha Storm Water Directional Plan* (BCC, 2007) was used as part of the assessment of the existing environment to better understand the affects of the operation on the existing hydrologic regime and how this might change in the future.

Flow from the quarry (Catchment C2) is captured in small sedimentation ponds and then flows through the Botanical Gardens (Catchment C1). Catchment C1 incorporates a partly urbanised upper catchment and the majority of the Botanical Gardens. Drainage from Catchments C1 and C4 flows through culverts under the Western Freeway. In larger events, flow from the two catchments interacts and is detained in an existing basin formed upstream of the Western Freeway.

Catchment C7 is a small local catchment located between the Mt Coot-tha Rd Roundabout and Catchment C8. Runoff from this area flows through culverts under Milton Rd and away through the urban stormwater system. It is not expected that flow from this catchment will impact on flood levels at the portal locations and it has not been assessed in detail.

Catchment C10 is wholly located within Anzac Park to the south of the Western Freeway. Drainage from this catchment flows along a channel to the south of the Western Freeway. This flow joins with flow from culverts draining Catchment C1 and Catchment C4. It later flows into the urban stormwater network just upstream of the BCC Bus Depot.



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 1

Western Connection Local Catchments

The drainage path within the Toowong Cemetery (Catchment C8) is well defined and formalised and does not interact with any other local catchment. Flow from the catchment enters the urban stormwater network via a culvert under the Milton Road roundabout.

Catchment C11 is a local catchment located to the east of Frederick St. Runoff from this area flows through culverts under Milton Rd and away through the urban stormwater system.

Catchments C5, C6 and C9 are well removed from the proposed western connection areas. It is not anticipated that they will have a significant impact on flooding and they have not been assessed in detail.

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. Table 1 presents the inputs used for the *RAFTS* model.

Catchment rainfall for the 1 in 100 AEP event was estimated using the procedures described in *Australian Rainfall and Runoff* (IEAust, 2000). A log-log interpolation between estimated 1 in 2000 AEP and PMP rainfall depths was used to estimate the 1 in 10,000 AEP rainfall depths (IEAust, 2000). Probable Maximum Precipitation (PMP) rainfall depths were calculated using the Bureau of Meteorology (BoM) (2003) *Generalised Short-Duration Method* (GSDM). Total rainfall depths for the 1 in 2000 AEP were calculated using short duration growth curves (Jordan *et al.*, 2004) based on 1 in 50 AEP rainfall depths estimated using the CRC-Forge Method (DNRM, 2005).

Standard temporal patterns for *Australian Rainfall and Runoff* Zone 3 were used for the 1 in 100 AEP event while the BoM GSDM temporal pattern was adopted for the 1 in 10000 AEP event.

- **Table 1 *RAFTS* Inputs – Local Catchments**

Catchment	*RAFTS* Inputs				
	Area (Ha)	Average Slope (%)	Fraction Impervious (%)	PERN Pervious	PERN Impervious
C1	40.5	15.6	30%	0.060	0.015
C2	18.1	5.0	50%	0.060	0.015
C3	11.9	42.2	70%	0.060	0.015
C4	15.0	13.0	0%	0.060	-
C5	8.7	15.3	0%	0.060	-
C6	13.5	16.2	0%	0.070	-
C7	1.4	16.6	5%	0.050	0.015
C8	32.2	12.6	5%	0.050	0.015
C9	10.2	14.2	5%	0.050	0.015
C10	9.4	9.0	0%	0.05	-
C11	3.7	8.2	60%	0.060	0.015

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 1 in 100 AEP event.

Validation was undertaken for the key catchments C1, C4 and C8 and the *RAFTS* B multiplier adjusted so that peak discharges from the *RAFTS* model better matched those derived using the *Rational Method*. Care was taken during the hydrologic modelling and validation to account for the effects of the Mt Coot-tha Quarry and the way the benching can be expected to slow and store flood waters.

Table 2 presents the comparison between the *RAFTS* and Rational results.

Table 2 Validation of Peak Discharges – 1 in 100 AEP

Catchment	Peak Design Discharge (m^3/s)	
	RAFTS	*Rational Method*
C1	25.0	22.7
C4	5.7	6.7
C8	11.8	12.0

The validated model was used to determine design discharges and hydrographs for the 1 in 100 and 1 in 10,000 AEP events. A range of storm durations were considered and the critical duration storm determined to be the 1 hour storm for all catchments.

Table 3 present a summary of the peak discharges predicted for each local catchment in the 1 in 100 and 1 in 10,000 AEP events.

Table 3 Local Catchment Peak Discharges

Catchment	Peak Design Discharge (m^3/s)	
	1 in 100 AEP	*1 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
C10	3.3	7.3
C11	2.4	3.6

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 immediately upstream of the Western Freeway where a natural depression occurs (Figure 1). Flow through culverts under the Western Freeway joins with flow from Catchment C10 and flows along a channel to the south of the 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. Figure 2 shows the layout of the model and the terrain data used in the hydraulic modelling.

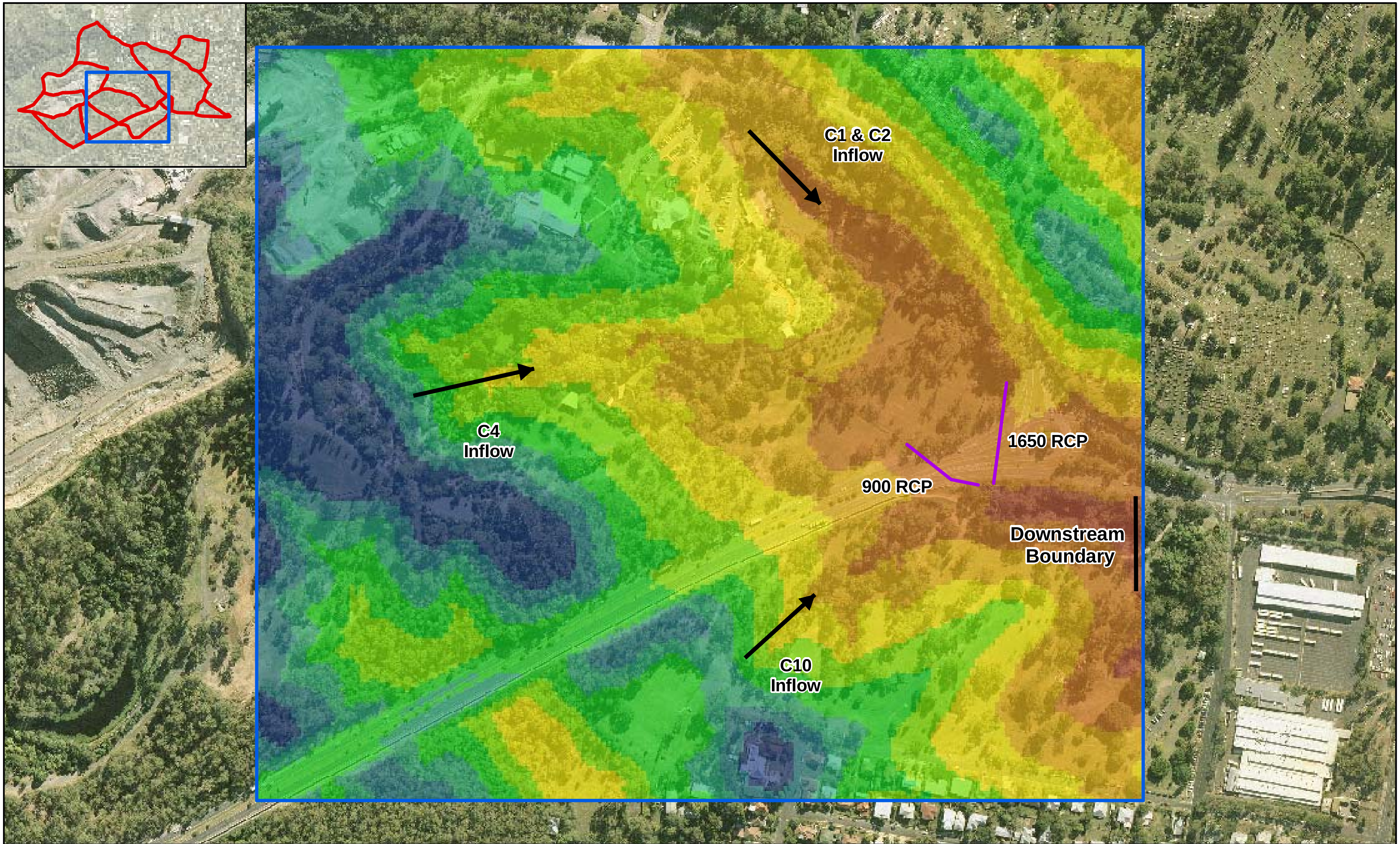
The *MIKEFLOOD* model was based on a digital elevation model that was constructed from Airborne Laser Survey (ALS) completed by Council in 2002. The terrain model was expected to have a vertical accuracy of +/- 150mm. The terrain data was simplified into a grid of terrain values for the purpose of hydraulic modelling. A grid resolution of 5m was selected for the investigation.

The model area contains a number of small ponds. However, inspection of the terrain showed that they had standing water when the ALS was flown. It was considered sufficient to assume that the ponds were full at the time of the flood and the terrain was therefore not altered to represent these structures.

DMR plans to build a bike overpass connecting Mt Coot-tha Road with the bikeway to the south of the Western Freeway. Construction of the bikeway is planned for 2008. As it will be in operation prior to commencement of construction for the Northern Link Project, the bikeway was included in the terrain for the Existing Conditions model. The bikeway design consists of an embankment in the Botanical Gardens grounds to the north of the Western Freeway, an elevated structure over the freeway and a piered ramp to the south of the Western Freeway connecting the elevated structure to the existing bikeway at surface level.

The downstream boundary condition was defined as a relationship between discharge and water depth (Q-H) developed for the downstream channel. The location of the Q-H boundary was positioned downstream from the investigation area to ensure that it did not influence the behaviour of the culverts nor the hydraulic modelling results.

A hydraulic roughness of 0.05 (Manning's 'n') was adopted across the model based on the aerial photography and site investigations. The initial surface water conditions were set as dry to simulate the expected catchment conditions at the time of a flood event.



LEGEND

- Model Area
- Local Drainage Structures
- Bikeway

Model Terrain Data (mAHD)

17 - 20	31 - 35	46 - 50
21 - 25	36 - 40	51 - 55
26 - 30	41 - 45	56 - 60

0 100 200
metres

Scale 1:5,000 (A4)

N

NORTHERN LINK
ENVIRONMENTAL IMPACT STATEMENT

Figure 2

Mt Coot-tha MIKEFLOOD Model Layout
Existing Conditions Model

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RAFTS output hydrographs for Catchments C1, C4 and C10 were input as dynamic inflows to the *MIKEFLOOD* model at three source points (Refer Figure 2) for both the 1 in 100 and 1 in 10,000 AEP events.

Table 2 presents the modelled details of the two culverts under the Western Freeway. The hydraulic performance of the modelled culverts was validated in *CULVERTW* using peak discharges and levels from the *MIKEFLOOD* model for the 1 in 100 AEP event. The Western Freeway road level is approximately 23.7 mAHD at its lowest point in the area.

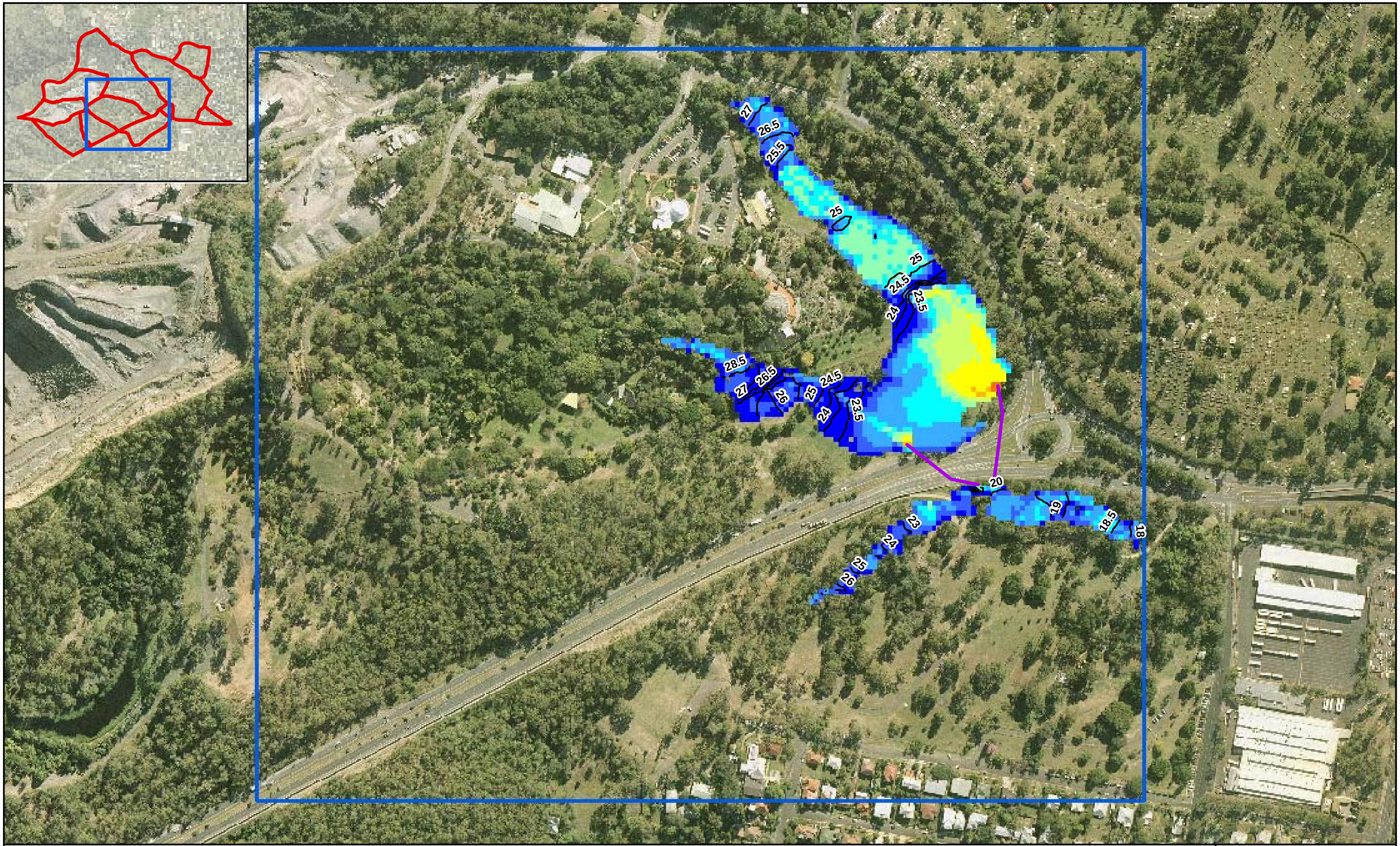
- **Table 4 Mt Coot-tha Culvert Details**

Name	Structure	U/S Invert (m AHD)	D/S Invert (m AHD)	Length (m)	Peak Discharge (m^3/s)
MC900	900 RCP	20.15	18.90	83	2.6
MC1650	1650 RCP	19.80	19.00	100	9.8

The results of the hydraulic model showed that the two catchments (C1 and C4) do interact in the 1 in 100 AEP flood event, however the flow was contained within the culverts and did not overtop the Western Freeway. The area upstream of the Western Freeway acted as a large detention storage allowing the culverts under the road to cope with the flow. The flood water ponded to a peak level of approximately 23.3 mAHD upstream of the Freeway. Figure 3 presents the peak modelled depth and water surface levels for the 1 in 100 AEP flood

Hydraulic modelling of the 1 in 10,000 AEP flood event showed that the Western Freeway would be overtopped by up to 0.8 m. The volume of the flood overwhelmed the upstream storage and drainage structures causing shallow and fast-moving flow across the roadway. The peak flood level upstream of the Western Freeway was approximately 24.4 mAHD. Figure 4 presents the peak modelled depth and water surface levels for the 1 in 10,000 AEP flood

This result demonstrates that flooding will be a significant issue in Concept Design of the Mt Coot-tha portal. Specific levels needed for protection of the portal from flooding will depend on its final location, as will local impacts.



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 3

**Mt Coot-tha Existing Conditions:
1 in 100 AEP Flood Extent**

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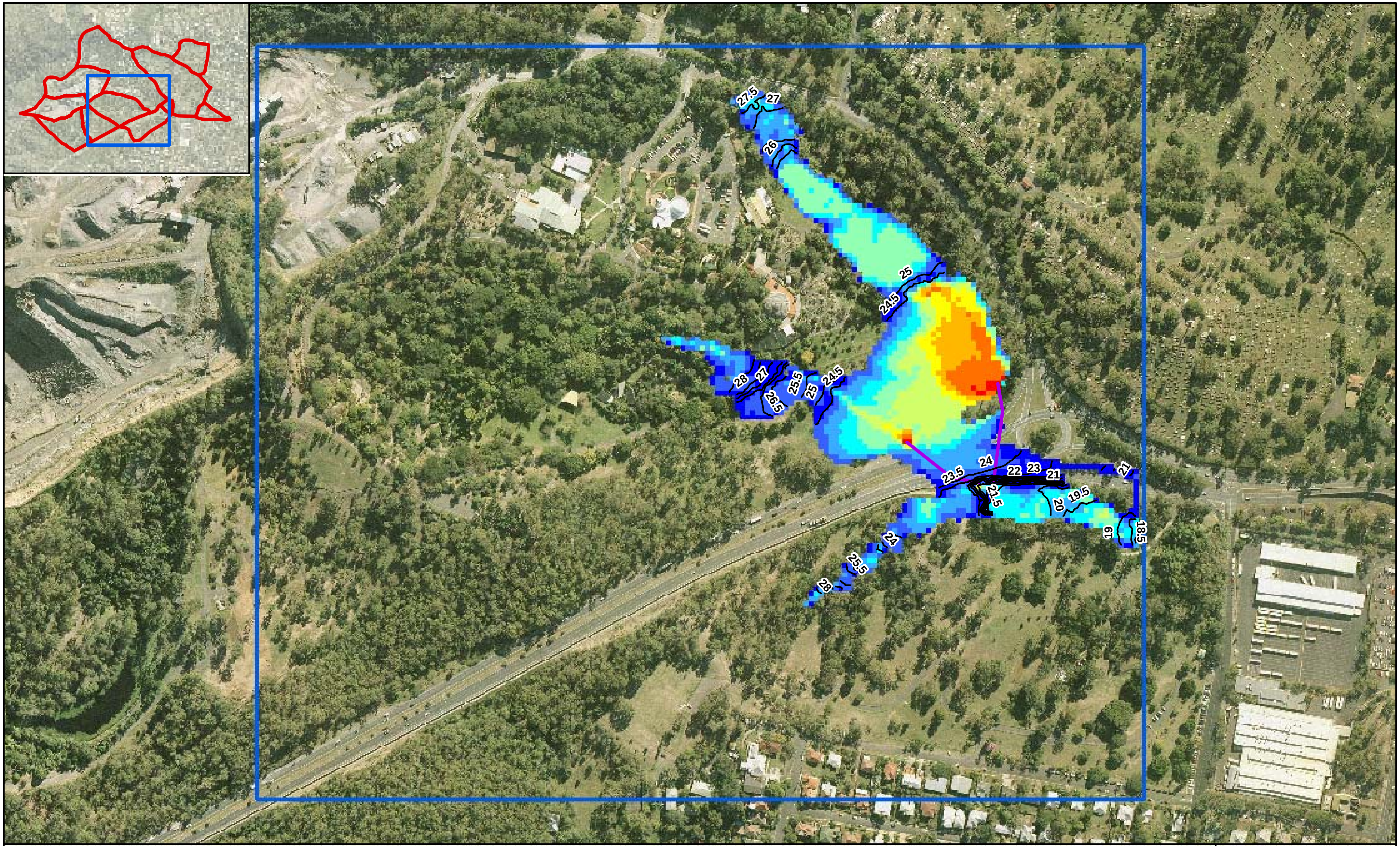

LEGEND

- 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 4

Mt Coot-tha Existing Conditions: 1 in 10,000 AEP Flood Extent

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Toowong Cemetery Drainage

A minor drainage line runs through the Toowong Cemetery. This was assessed to better understand the local flooding risks for a tunnel portal on Frederick Street above Milton Road.

The drainage line through the cemetery is a grassed natural channel in the upper catchment until it enters a concrete trapezoidal channel approximately 270 m from the cemetery entrance. The channel runs through a 90 m long 2/ 1200 x 1000 RCBC under several buildings and roads. An open trapezoidal channel runs for another 40m before reaching the catchment outlet which is through 1/ 900 RCP under the Milton Road roundabout. This culvert flows into the urban stormwater network and is a potential limiting factor on the drainage in the area. There are several small structures along the channel upstream however these were considered to be too small to include in the modelling for large events.

The local drainage through the cemetery is well defined and does not interact with neighbouring watercourses or floodplains. A one-dimensional modelling approach was adopted using the *HEC-RAS* software developed by the United Stated Army Engineering Corps. The modelling was constructed within a GIS environment using the software *HEC-GEORAS*.

Cross sections were extracted from the same terrain model described in the sections above. The cross sections were extracted at approximately 100m spacing with additional cross-sections extracted around locations of interest including the Milton Road intersection with Frederick Street.

A Mannings 'n' of 0.03 was adopted for the floodplain and upper channel while in the lower catchment where the channel enters a concrete channel a value of 0.015 was adopted. These values were based on observations made during the site inspection.

A steady-state model was used with peak discharges from the *RAFTS* model used as the flow input. A normal depth tailwater was adopted as the downstream boundary condition for both the 1 in 100 and 1 in 10,000 AEP flood events. The normal depth approach was considered conservative for the 1 in 10,000 AEP event as it exceeded the 1 in 10,000 AEP Brisbane River flood level discussed in Section 1.1.1.2.

Figure 5 shows the modelled inundation extent for the 1 in 100 AEP flood event above the Milton Road roundabout. It shows that 1in 100 AEP flooding will not overtop Frederick Street itself. However, the flood level immediately upstream of the Milton Road roundabout will be approximately 15.3 mAHD and overtop the roundabout by 300mm.

The results for the 1 in 10,000 AEP flood event are similar with the flood level immediately upstream of the Milton Road roundabout at 15.5 mAHD, overtopping the roundabout by approximately 500mm. The inundation extent for the in 10,000 AEP flood event above the Milton Road roundabout is presented in Figure 6.

It is therefore recommended that any portal on Frederick St below 15.5mAHD will need to be protected from local catchment flooding in the 1 in 10,0000 AEP event.

LEGEND

Local Catchments
Local Drainage Structures

1 in 100 Yr ARI Flooding

Local Flood Extent
15.3mAHD at Roundabout

0 100 200
metres

Scale 1:5,000 (A4)

N

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ENVIRONMENTAL IMPACT STATEMENT

Figure 5

Toowong Cemetery
1 in 100 AEP Flooding

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LEGEND

- Local Catchments
- Local Drainage Structures

1 in 10,000 Yr ARI Flooding

- Local Flood Extent
- 15.5mAHD at Roundabout
- Regional Flood Extent - Upper Bound - 14.9mAHD
- Regional Flood Extent - Lower Bound - 12.6mAHD

0 100 200
metres

Scale 1:5,000 (A4)

N

NORTHERN LINK
ENVIRONMENTAL IMPACT STATEMENT

Figure 6

Toowong Cemetery
1 in 10,000 AEP Flooding

Northern Link

SKM Connell Wagner
JOINT VENTURE

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1.1.1.2 Regional Flooding

The potential for the area of the western connections to be inundated by a flood from the Brisbane River was investigated as part of this study. Numerous previous studies have described flooding in the Brisbane River and the most relevant for this investigation are the:

- *Brisbane River Flood Study* (SKM, 1998);
- *Ipswich Rivers Flood Studies Phase One and Phase Two* (SKM, 2000);
- *Recalibration of the MIKE11 Hydraulic Model and Determination of the 1 in 100 AEP Flood Levels* (SKM, 2004a); and
- *Calculation of Floods of Various Return Periods on the Brisbane River* (SKM, 2004b).

These reports used a hydraulic model of the same basis, constructed in the modelling software *MIKE11*. This hydraulic model was provided by Brisbane City Council, as custodians, and was used as the basis of the assessment of the Project. The reported flooding characteristics for the Brisbane River adjacent to the Project (i.e. near the western end of Toowong Reach) relate to the hydraulic model's Brisbane River cross section chainage 1050430 from the studies listed above.

The flood levels for various floods of different recurrence intervals are presented in Table 5. The reported Probable Maximum Flood (PMF) level is from the original *Brisbane River Flood Study* (SKM, 1998) as this event was not re-estimated by the 2004 studies. The original 1998 study was not aimed at predicting extreme events such as the PMF and it is believed that the reported PMF level is significantly larger than the real value. BCC City Design is currently undertaking further work to re-estimate large and extreme flood levels for the Brisbane River.

Table 5 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

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

#MIKE11 Results (SKM, 1998)

1 in 100 AEP Flooding

The adopted BCC 1 in 100 AEP flood level in the Brisbane River closest to the western connections is 4.5 mAHD (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 14mAHD. Therefore Brisbane River flooding will not impact on the Project in a 1 in 100 AEP event and the Project will not impact on flood levels developed by the Brisbane River in a 1 in 100 AEP flood event.

1 in 10,000 AEP Flooding

The 1 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 1 in 10,000 AEP event in the Brisbane River near the western connections of the Project was undertaking as part of this investigation and this was carried out in consultation with both Council and SEQWater.

Catchment Description

The Brisbane River catchment upstream of the Project covers an area of approximately 13,300 km² and includes both Somerset and Wivenhoe Dams. Figure 7 shows the location of the study corridor relative to the Brisbane River Catchment and Wivenhoe Dam.

Wivenhoe Dam is operated by SEQWater and is designed to provide flood mitigation downstream of the dam to the City of Brisbane. In 2005, planning was put in place to upgrade Wivenhoe Dam to increase flood discharge capacity such that the dam can safely pass all floods up to the Probable Maximum Flood (PMF). The upgrade was proposed to be completed in two stages and included the construction of fuse plug spillways. Stage I has been completed (2005) and Stage II is to be completed by 2035. SEQWater were consulted during this investigation and provided information on both the current and proposed (Stage I and Stage II) operation of the dams. This information is Commercial in Confidence. Any request for access to this report must be made directly through SEQWater.

Three independent rainfall mechanisms could occur in the Brisbane River catchment to create a flood level with a recurrence interval of 1 in 10,000 years. These are:

1) A 1 in 10,000 AEP rainfall event centred over the Wivenhoe Dam catchment;
2) A 1 in 10,000 AEP rainfall event centred over the catchment downstream of Wivenhoe Dam; and
3) A 1 in 10,000 AEP rainfall event centred over the entire Brisbane River catchment.

The extents of the three catchments are illustrated in Figure 7. Due to catchment size, it was expected that storms focused on the catchment to Wivenhoe and on the catchment downstream of Wivenhoe would have similar magnitude while a storm centred over the whole Brisbane River catchment would be significantly larger. Therefore, only option three was tested here.

Hydrologic Model

Catchment rainfall for each of the three events described above was calculated. Probable Maximum Precipitation (PMP) rainfall depths were calculated using the BoM (2003) *Revised Generalised Tropical Storm Method* (GTSMR). Total rainfall depths for events up to and including the 1 in 2000 AEP were calculated using the CRC-Forge Method (DNRM, 2005). A log-log interpolation between the estimated 1 in 2000 AEP and PMP depths was used to estimate the 1 in 10,000 AEP rainfall depths (IEAust, 2000). Standard temporal patterns for *Australian Rainfall and Runoff* Zone 3 were used for the 1 in 100 AEP event while the BoM GTSMR Average Variability Method (AVM) temporal patterns were adopted for the 1 in 10,000 AEP event.

LEGEND

- Brisbane River Catchments
- Catchment to Toowong
- Catchment to Wivenhoe
- Major Waterways

0 15,000 30,000
metres
Scale 1:800,000 (A4)
N

NORTHERN LINK
ENVIRONMENTAL IMPACT STATEMENT

Figure 7
Overview of Brisbane River Catchment

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The *RAFTS* hydrologic model used in the updated *Brisbane River Flood Study* (2004) was adopted for this Project and augmented to include potential flood operations for Wivenhoe Dam.

A review of the available previous studies showed that there was inconsistency between the approaches used and the parameters adopted amongst the studies. Given that the purpose of this Project was to characterise the 1 in 10,000 AEP at Toowong, an assessment of flooding at Toowong was made based on the previous studies and their assumptions and the range of estimates were developed. This enabled the flood risk to be reported as a range with an upper and lower limit.

The first step was to undertake a hydrologic model run that adopted all inputs from the 2004 study. This produced a peak discharge of 21,200 m^3/s for a 120 hour storm centred on the whole Brisbane River catchment to Toowong. This was considered to be an upper estimate based on the adopted losses and flood operations assumed for Wivenhoe Dam.

Secondly, the peak outflow from Wivenhoe Dam for a storm focused on the Wivenhoe catchment, based on the 2004 study was compared to the peak outflow predicted by SEQWater. The discharge from the 2004 study was found to be significantly larger than the SEQWater estimate. The Continuing Loss in the 2004 hydrologic model was increased from the 1mm/hr used in the 2004 model to 5mm/hr to better match the lower SEQWater estimates. This provided a good comparative match between both peak inflow and outflows at Wivenhoe when comparing the 2004 hydrologic model with the SEQWater estimates. The adjusted loss parameter was used globally in the model to run the second scenario which produced a peak discharge of only 12,000 m^3/s for a 48 hour storm centred on the whole Brisbane River catchment to Toowong. Of note, this discharge estimate is similar to that reported for the 1 in 2000 AEP in the updated Brisbane River Flood Study (2004). Because this estimate was so low compared to other studies, it was discarded for concept design purposes and is only reported here as a lower bound estimate and as advice that such a method is likely to be erroneous.

A third estimate of the 1 in 10,000 AEP event for the Project was performed based on the findings adopted by Council from the 2004 study. In this case a log-log extrapolation was undertaken from the 1 in 100 and 1 in 2000 AEP discharge reported in Table 5 to give an estimated peak 1 in 10,000 AEP discharge at Toowong of 17,500m^3/s. This was an extrapolation of flood discharges based on the hydrology from the SKM (2004) report. The hydrographs generated for the first scenario were then scaled down relative to the magnitude of 17,500m^3/s at Toowong. These hydrographs had a critical duration of 120 hours. This method does not account for some of the intricacies of the operation of Wivenhoe Dam however it is still of suitable accuracy given the nature of the study. For the purpose of the Concept Design, this estimate can be adopted as a lower bound

Hydraulic Model

The *MIKE11* hydraulic model used in the updated *Brisbane River Flood Study* (2004) was adopted for this investigation. Outputs from the *RAFTS* model for the three scenarios described above were used as inputs directly to the *MIKE11* model and run to simulate the possible flooding behaviour of the Brisbane River at the point of interest in a 1 in 10,000 AEP event.

Sensitivity of Results

The sensitivity of hydrologic and hydraulic modelling to input parameters defines the level of certainty surrounding the estimates produced. This investigation has found that hydrologic modelling of the Brisbane River catchment is sensitive to:

- Catchment losses;
- Dam operations; and
- The location of the centre of the storm.

This sensitivity is due to the size of the catchment and the long duration of critical storms which mean that Brisbane River flooding in a 1 in 10,000 AEP event is driven by volume rather than the capacity of the river to convey the flood.

Flood levels at the site will also be sensitive to future development in the downstream floodplain. Current BCC policy requires that proposed developments assess and mitigate upstream flood impacts for events up to and including the 1 in 100 AEP event. There is currently no requirement for the assessment of impacts in rarer events. Thus there is potential for future downstream development to impact on upstream flood levels within the Project area in events such as the 1 in 10,000 AEP event.

Discussion with BCC City Design and the Department of Infrastructure and Planning (DIP) highlighted 10 key potential developments that may impact on 1 in 10,000 AEP flood levels in the floodplain. These are at varying stages of approval and design and include:

- Hale St Link bridge,
- Merivale Bridge Duplication,
- Tank St bridge,
- The Northbank Development,
- South Bank Marina,
- South Bank Redevelopment.

A sensitivity analysis was undertaken to better understand the sensitivity of Brisbane River 1 in 10,000 AEP flood levels around the Western Connections with downstream development in the floodplain. The Northbank Development was represented in the model by removing approximately 25% of the active channel in the affected reach. A maximum increase in flooding of 300mm was observed at the Project site.

The sensitivity of the hydrology and hydraulics to both model parameters and future downstream developments means that a pre-cautionary approach is recommended when adopting flood levels around the western connections for the 1 in 10,000 AEP event for the Project.

Results and Conclusions

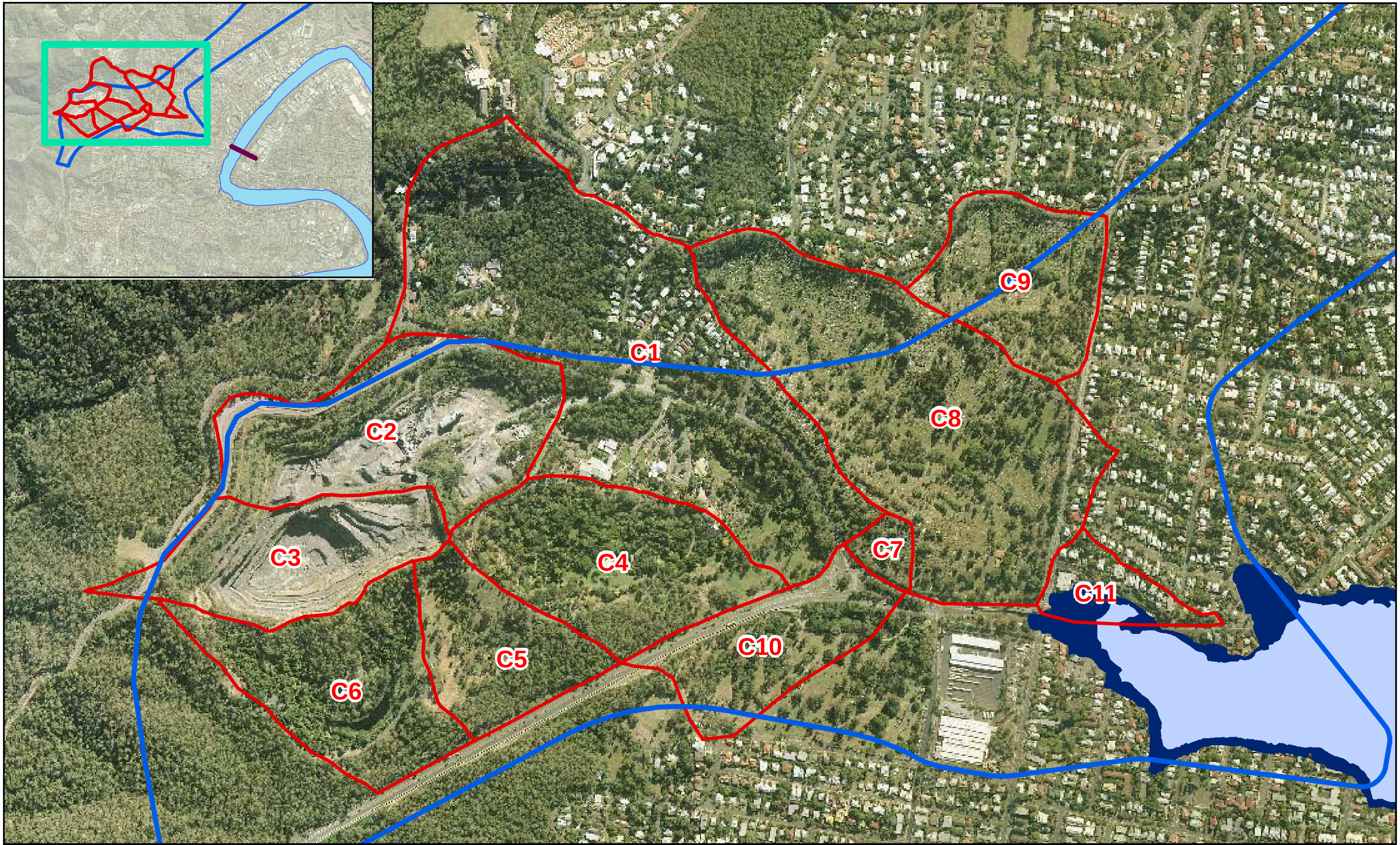
Table 6 presents estimates of the 1 in 10,000 AEP flood for the purposes of the Project with an upper and lower bound to show the level of confidence of this estimate. Given the unknowns and sensitivity described above, it is recommended that a level of 14.9mAHD is adopted for the Concept Design of the Project with a freeboard of at least 300mm. Further modelling, supported by Council and SEQWater will be required for detailed design.

- **Table 6 Flood Characteristic of Brisbane River for 1 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

* 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.

The flood levels and extents presented in Table 6 and Figure 8 show the 1 in 10,000 AEP flood levels relative to the connection areas.



LEGEND

Study Area Corridor
Local Catchments
Chainage 1050430

Regional Flood Extent - 1 in 10,000 AEP

Lower Bound - 12.6 mAHD
Upper Bound - 14.9 mAHD

0 200 400
metres

Scale 1:10,000 (A4)

N

NORTHERN LINK
ENVIRONMENTAL IMPACT STATEMENT

Figure 8

**Regional Flooding -
1 in 10,000 AEP Event**

I:\QENV\Projects\QE07311\SpatialArc_MXD\Hydrology\Figures\080527_Updated_Drafts\080512_NL_Fig8_RegionalFlooding_10000Yr.mxd Produced: 27/5/2008

1.1.2 Eastern Connections

Two potential surface connections are anticipated for the eastern end of the project. Hydrologic and hydraulic investigations have been undertaken, focussing on each of the areas listed below:

- Kelvin Grove Road connection – north of portals;
- Kelvin Grove Road connection – south of portals; and
- Inner City Bypass (ICB) connection.

Unlike the western connections, there is not expected to be regional flooding impacts around the eastern connections. The terrain of the investigation area is well elevated and away from the influence of the Brisbane River or any of the major creeks or waterways of the region. Therefore, the focus of the investigation at the eastern connections is on local drainage only.

Previous hydrologic/hydraulic studies in the vicinity of the three focus areas include:

- Kelvin Grove Urban Village;
- Inner City Bypass;
- Brisbane River Flooding Studies (various described in previous sections);
- Local Stormwater Management Plan (LSMP).

Where available, model files and reports from these projects were collected and reviewed at the outset of the project.

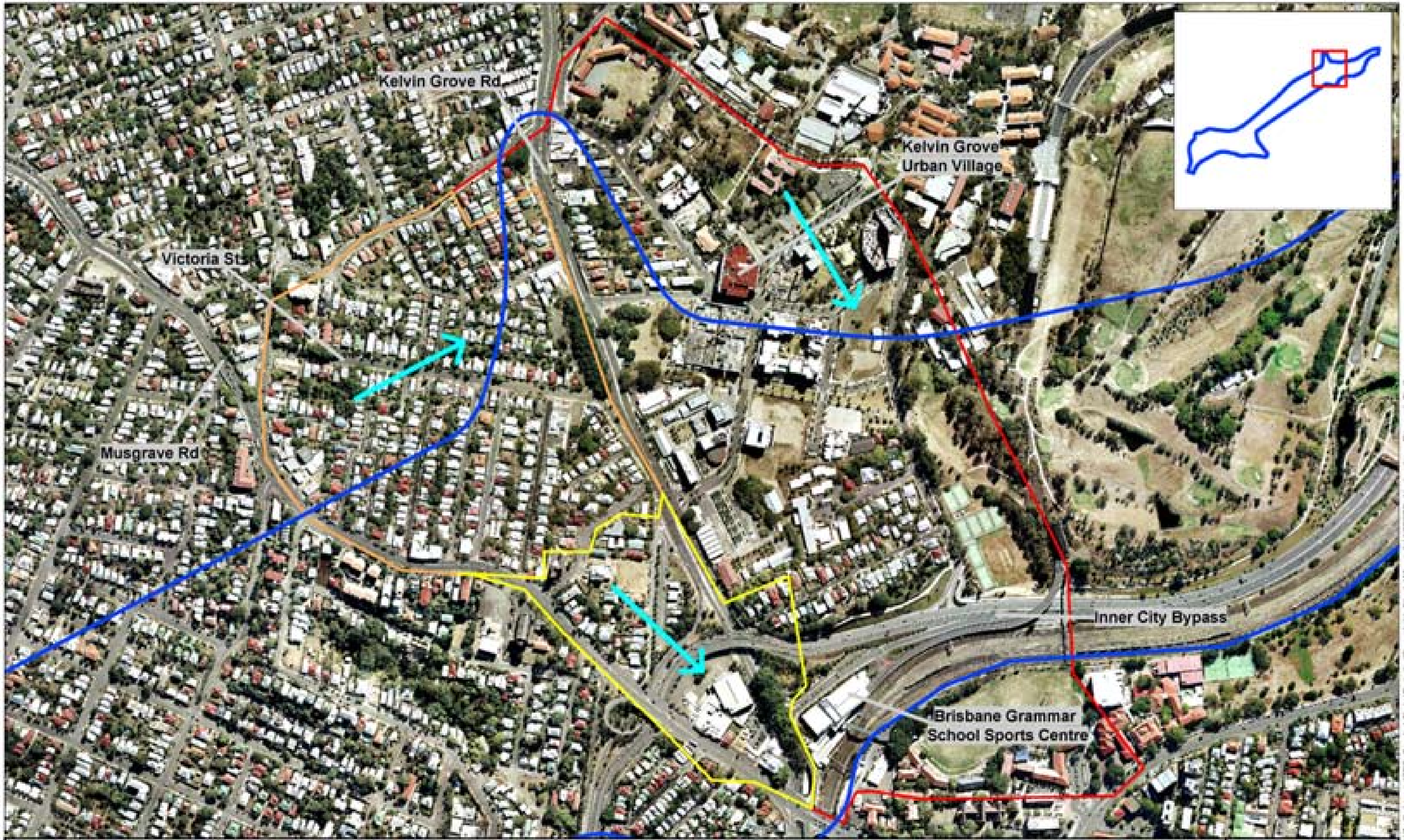
1.1.2.1 Local Drainage

All three focus areas for the eastern connections lie within a single catchment. The catchment has an area of approximately 81.7 ha 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 College Road. Subcatchment boundaries are shown in Figure 9.

The subcatchment to the north of the Kelvin Grove Road portals has an area of approximately 21.9ha. The existing terrain forms a basin at the outlet of this focus area and in the area of the potential connection. The existing basin is formed behind the Kelvin Grove Road embankment under which the drainage passes in pipework.

The subcatchment to the south of the Kelvin Grove Road portals has a contributing catchment area of approximately 6.5ha. The existing catchment again 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 subcatchment has a contributing catchment area of 81.7ha, which includes the sub-catchments described above north and south of the Kelvin Grove Road portals. A further detention area is located at this connection, and is used as school sporting fields. The detention area is bounded by the existing ICB and Inner Northern Busway embankments and the natural hillside at Victoria Park Road.



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)

NORTHERN LINK
ENVIRONMENTAL IMPACT STATEMENT

Figure 9
Eastern Connection
Local Catchments

SKM Connell Wagner
JOINT VENTURE

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.

Hydrologic Modelling

The hydrologic (*RAFTS*) model developed for the Kelvin Grove Urban Village project was available for use in this analysis. The *RAFTS* model encompasses all three focus areas and was adapted as the basis of the hydraulic analysis for this investigation.

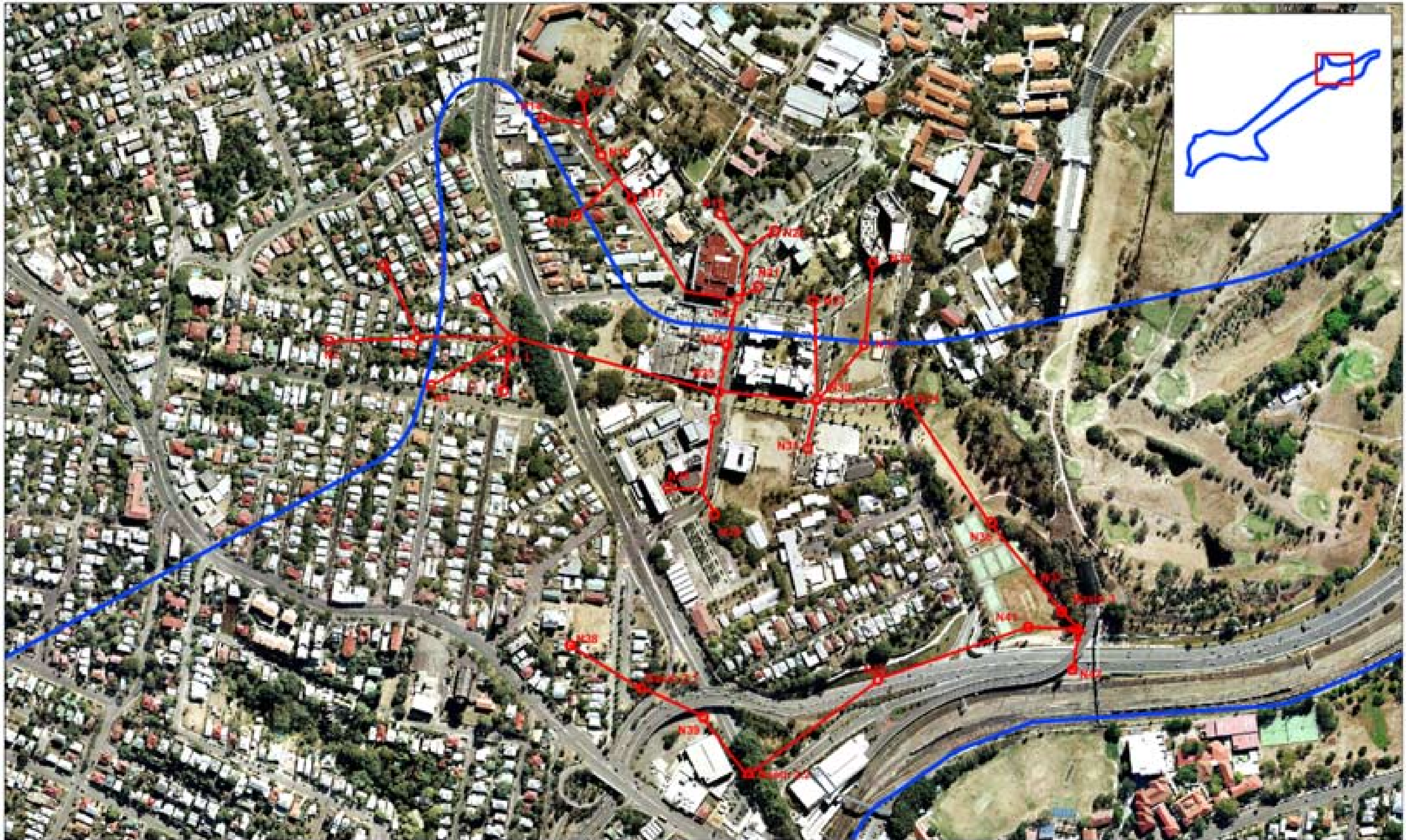
Minor modifications were required to model the three focus areas in more detail. Additional detail was added to the focus areas based on the updated terrain data available for the Project. This enabled a revision of the storage and height relationships data around the connections.

Stormwater drainage information was sourced from Council's *BiMap* system. Council also provided as-constructed stormwater drainage information, including pipe sizes, invert levels and slopes where available. It is important to note that complete information is not available for the entire network. These data were supplemented by detailed drawings of the existing road, bridge, structure and drainage networks associated with the ICB project. Details included relevant pipe sizes, lengths and network configurations, as well as significant culvert sizes and inverts. Information on the drop inlet structure adjacent to the ICB was not available.

The adopted hydrologic methods described in Section 1.1.1 were consistent between the western and eastern connection areas.

The resulting hydrologic model focused on the three key areas. The model consisted of forty-one nodes, forty links and four detention basins. Detention basins were employed at each of the three focus areas to consider the attenuation provided by existing local flood storage and in order to predict peak water levels for the simulated rainfall events. Figure 10 shows the layout for the model.

Peak flows predicted by the *RAFTS* model at several locations were verified using the Rational Method. Good consistency was found between the two methods, providing confidence in the RAFTS model predictions.



LEGEND

Study Area Corridor

RAFTS Layout

0 120 240

metres

Scale 1: 6,000 (A4)

N

NORTHERN LINK
ENVIRONMENTAL IMPACT STATEMENT

Figure 10

RAFTS Layout

Northern Link

SKM Connell Wagner
JOINT VENTURE

Kelvin Grove Road Drainage -North

The Project includes a connection to Kelvin Grove Road directly opposite Musk Avenue. Just north in the area of Victoria Street is a storage basin 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 and subsequently into an overland flow-path designed into the Kelvin Grove Urban Village development. Any reduction in storage volume therefore also has the potential to increase discharges and hence peak water levels in this downstream system.

The hydrologic model predicted a peak discharge of 16.8m^3/s to the basin for a 1 in 100 AEP design event. A peak basin outflow of approximately 4m^3/s is predicted and this is all pipe flow with no overtopping of Kelvin Grove Road. Figure 11 shows the predicted inundation extent in the 1 in 100 AEP flood.

Under existing conditions for 1 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 20 m^3/s was predicted and this included flow through the pipe network and overtopping of Kelvin Grove Road by approximately 340mm. The results of the modelling are summarised in Table 7.

Table 7 RAFTS Model Predictions - Kelvin Grove Road Basin

AEP	WSL (mAHD)	Minimum Road Level (mAHD)	Freeboard to Road (m)	Peak basin Outflow (m^3/s)
1 in 100	39.5	40.2	0.67	4
1 in 10,000	40.5	40.2	Overtopped	20

LEGEND

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

0 80 160
metres
Scale 1: 4,000 (A4)

N

NORTHERN LINK
ENVIRONMENTAL IMPACT STATEMENT

Figure 11

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

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Detention Basin south of Kelvin Grove Road portals

It is proposed that connections to the existing public network infrastructure may be provided as part of the Project and this would involve a ramp to the tunnels from Kelvin Grove Road near the intersection with Ithaca Street, adjacent to the existing ICB overpass.

As previously noted, two detention areas exist in this vicinity; one upstream of the ICB overpass, and one adjacent to the Kelvin Grove Road – Ithaca Street intersection. The upper existing storage basin (Hale St basin) discharges to the lower 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.

When storage capacity of the basin is exceeded, overflows discharge over Ithaca Street into an open corridor between Kelvin Grove Road and the Brisbane Grammar School's gymnasium building. This flow discharges away from the study area to the nearby railway corridor.

An assessment of the terrain data found that overflows from the downstream basin can occur once water levels reach 34.4m AHD. This level represents the top level of an existing retaining wall surrounding the gymnasium building. It is important to note that the existing Ithaca Street pavement has a crest level of approximately 35.2 m AHD, which prevents overland flow from the intersection flowing down the road. As no works are proposed on the Ithaca Street pavement in the vicinity of the crest this immunity may be expected to be maintained.

1 in 100 AEP and 10,000 AEP design rainfall events were simulated in the hydrologic model. Model predictions are summarised in Table 8 and Table 9 below. Predicted extents of inundation are shown in Figure 12.

- **Table 8 RAFTS Model Predictions – Upper Basin (Hale St Basin)**

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

- **Table 9 RAFTS Model Predictions – Ithaca Street Basin**

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

Model predictions in Table 8 and Table 9 show the following key findings:

- Discharge from the upstream basin is primarily via the existing pipe drainage. Overtopping onto Kelvin Grove Road is not predicted to occur under 1 in 100 AEP conditions. Under 1 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 1 in 100 AEP and 1 in 10,000 AEP conditions.
- Significant weir flow from the intersection, over the existing retaining wall, is predicted for both the 1 in 100 and 10,000 AEP flood events.
- Peak water levels are not predicted to reach the Ithaca Street crest under 1 in 100 AEP or 10,000 AEP conditions.

Based on these findings it is important to note that that 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 Project requires a connection with the ICB and this connection is likely to occur near Victoria Park Road, adjacent to the existing ICB and Northern Busway flyover and Brisbane Grammar School playing fields. Under large to extreme flood events the playing fields function 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 originate from the two previously described catchments.

Hydrologic model predictions for the detention basin are presented in Table 10 and the predicted extents of inundation are shown in Figure 13. 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. Detailed survey of the structure will be required to facilitate detailed design of the Project.

- **Table 10 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)
1 in 100	24.3	22.5	1.8	29
1 in 10,000	25.0	22.5	2.5	60

LEGEND

Study Area Corridor

100 Year Hale Street Basin

10000 Year Hale Street Basin

0 80 160

metres

Scale 1: 4,000 (A4)

N

NORTHERN LINK
ENVIRONMENTAL IMPACT STATEMENT

Figure 12

100 & 10000 Year Inundation Hale Street Basin

Northern Link

SKM Connell Wagner

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The hydrologic modelling found that ponding will 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 will 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 will 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 will be important that such a measure does not adversely affect the foundations of the existing reinforced earth wall for the Inner Northern Busway.

1.1.3 Limitations

All flood levels predicted in this study, and subsequent conclusions and recommendations drawn about the existing conditions, are subject to several key limitations:

- Extensive hydraulic modelling has not been completed at the eastern connections and predictions are based on hydrologic modelling to represent existing storage areas. Further definition of flooding will be required for detailed design.
- Storage height relationships for the basins have been determined using the provided ALS data. Detailed ground survey data were not available at the time of this study.
- Details of piped stormwater drainage were provided by Brisbane City Council and have not been ground verified. Any inaccuracies in the information available may influence the accuracy of the model predictions.
- Detailed design of the proposed works is still under development. Final impacts of the works upon existing-case hydraulics will need to be determined in future stages of the investigations and management measures designed.
- Detailed information of the ICB basin outlet structure was not available for these investigations. Additional information is being sought. In the absence of additional information, the structure will need to be surveyed to facilitate future stages of the investigations.
- Information relating to the operation of Wivenhoe Dam was drawn from SEQWater. This information is commercial in confidence and all subsequent work for this study must be done with the full cooperation and consent of SEQWater.

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 13

**100 & 10000 Year Inundation
Inner City Bypass**

Northern Link

SKM Connell Wagner

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2. Potential Flood Impacts and Mitigation Measures

2.1 Flood Potential

This section details the potential impacts of the Project on the flooding behaviour of the study area. Protection of the tunnel portals from flooding is discussed, as are the potential flood impacts for the surrounding area. This includes impacts and mitigation measures during both the construction and operational phases of the Project.

2.1.1 Western Connections

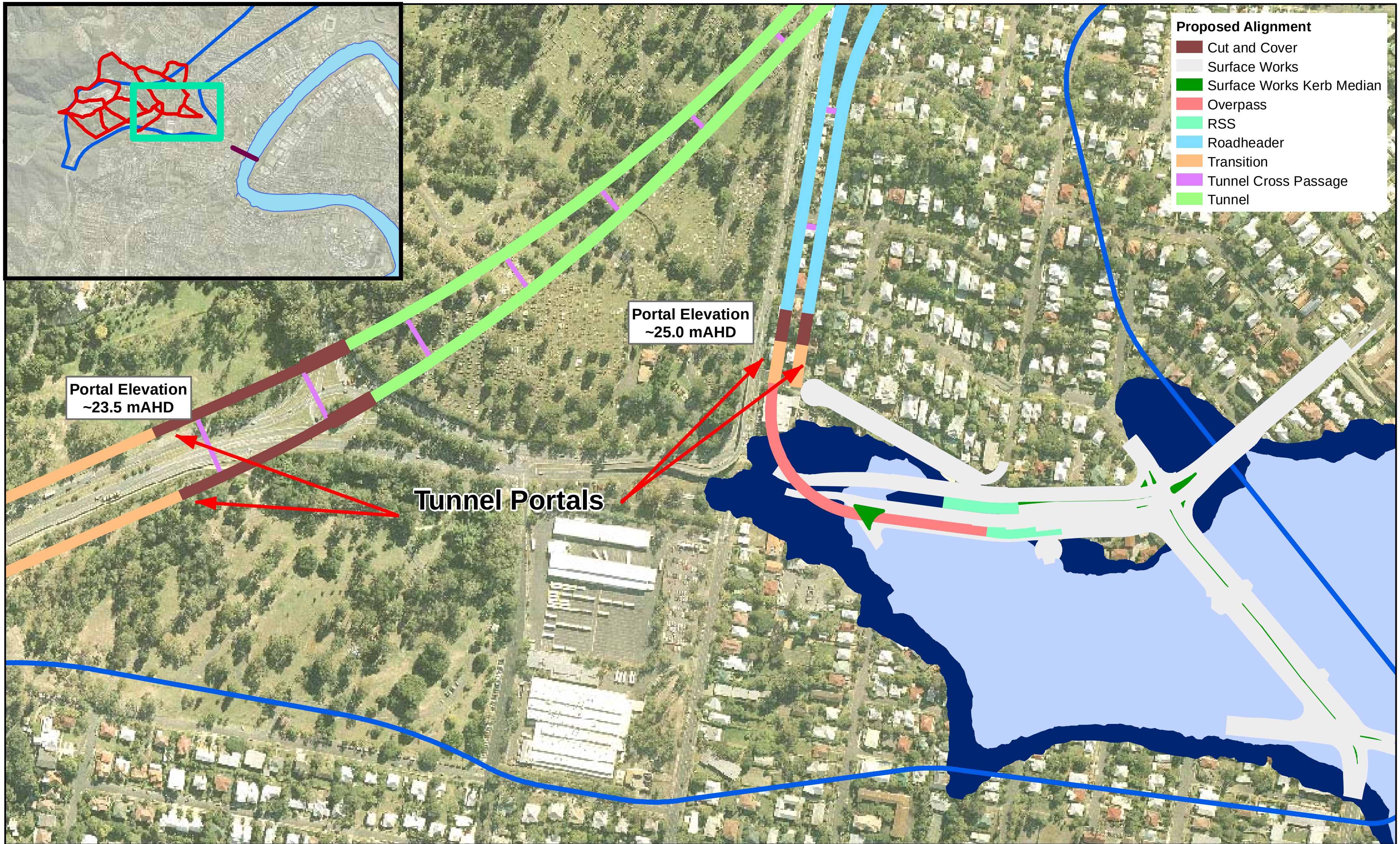
This section details the potential impacts of the Project on the flooding behaviour around the western connections and protection of the tunnel portals from flooding.

Section 1.1.1 characterised existing flooding in the area around the western connections. Both regional flooding from the Brisbane River and local drainage via surface flow and small drains were discussed and shown to be separate mechanisms that do not interact. The two western (Western Freeway and Toowong) connections are located in separate catchments with separate flooding behaviour.

Regional flooding behaviour was discussed in Section 1.1.1. Figure 14 shows that both the Western Connection portals have been located well above the regional flood levels for the 1 in 10,000 AEP event. This means that the portals are protected from, or have immunity to, regional flooding for the adopted design event. Some filling and cutting is proposed for surface works on Milton Road between Sylvan Road and Quinn St. These works lie within the regional 1 in 10,000 AEP flood extent. The detailed design will need to ensure that the volumes of filling and cutting are balanced such that there is no net change to the flood storage in the 1 in 10,000 AEP event to maintain the immunity of the proposed Toowong portal.

All surface works including portals, transition structures and road works for both the Western Freeway and Toowong connections are well above the BCC defined flood level for the 1 in 100 AEP event in the Brisbane River. Therefore these works will not impact on regional flood levels for events up to and including the 1 in 100 AEP flood event as required by BCC development guidelines.

Local drainage issues are dominant for both western connections and are discussed in detail in the following sections.



LEGEND

Study Area Corridor
Chainage 1050430

Regional Flood Extent - 1 in 10,000 AEP

Lower Bound - 12.6 mAHD
Upper Bound - 14.9 mAHD

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

NORTHERN LINK
ENVIRONMENTAL IMPACT STATEMENT

Figure 14

Portals and Regional Flooding - 1 in 10,000 AEP Event

Northern Link
SKM Connell Wagner

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2.1.1.1 Operations Phase

This section details the impacts and associated mitigation measures for local drainage around the western connections during the *Operations Phase* of the Project.

Mt Coot-tha Local Drainage

At the Mt Coot-tha connection, the *Operations Phase* of the Project includes several different aspects including:

- 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 will 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.
- Surface connections at the Western Freeway that are located where the transition structure meets the cut and cover tunnel sections.

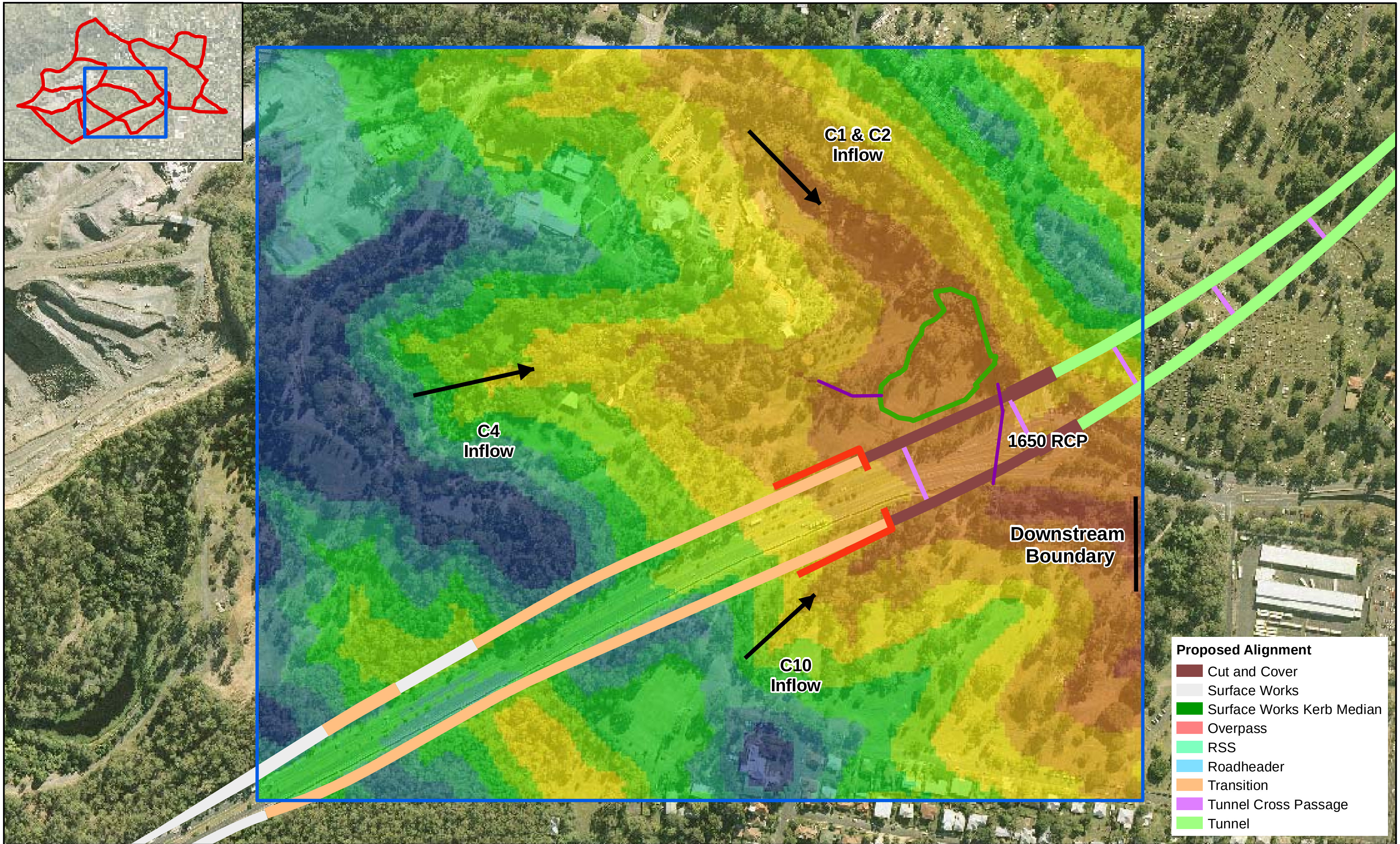
In addition to these Project related aspects, BCC plans to construct a water storage upstream of the Western Freeway Connection within the Botanical Gardens grounds to supply water for Botanical Gardens needs. This storage is not part of the Project, as this is expected to occur at the start of the operation of the Northern Link Project, however it has been considered as part of the *Operations Phase*. The Project has been designed in a manner so as to not impact on the annual or seasonal availability of water from this storage.

The design of this storage makes the existing 900RCP culvert under the Western Freeway redundant (refer Figure 15). This is because of Council's design to divert the culvert catchment into the proposed storage. Therefore this culvert has been removed as part of the *Operations Phase*. The existing 1650RCP culvert under the Western Freeway lies above the tunnel lid. It will be supported throughout construction and no change is expected to its behaviour once the tunnel is constructed.

As discussed in Section 1.1.1, DMR plans to construct a bikeway at the Western Freeway connection. As this will be constructed prior to commencement of the Project, this has been incorporated as part of the *Existing Environment*. It has also been included in the *Operations Phase* model.

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 4 and Figure 5 presented the existing peak flood extent for the 1 in 100 and 1 in 10,000 AEP floods, respectively.

The *Operations Phase* of the project was modelled using the same hydraulic model platform developed for the existing environment. The aspects of the Project discussed above were incorporated into the model terrain to represent the *Operations Phase*. Figure 15 presents the layout of *Operations Phase* model and terrain.



LEGEND

Model Area
Water Storage
Local Drainage Structures
Portal Protection Wall
Bikeway

Model Terrain Data (mAHD)

17 - 20
21 - 25
26 - 30
31 - 35
36 - 40
41 - 45
46 - 50
51 - 55
56 - 60

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

NORTHERN LINK
ENVIRONMENTAL IMPACT STATEMENT

Figure 15

Mt Coot-tha Operations Phase: MIKEFLOOD Model Layout

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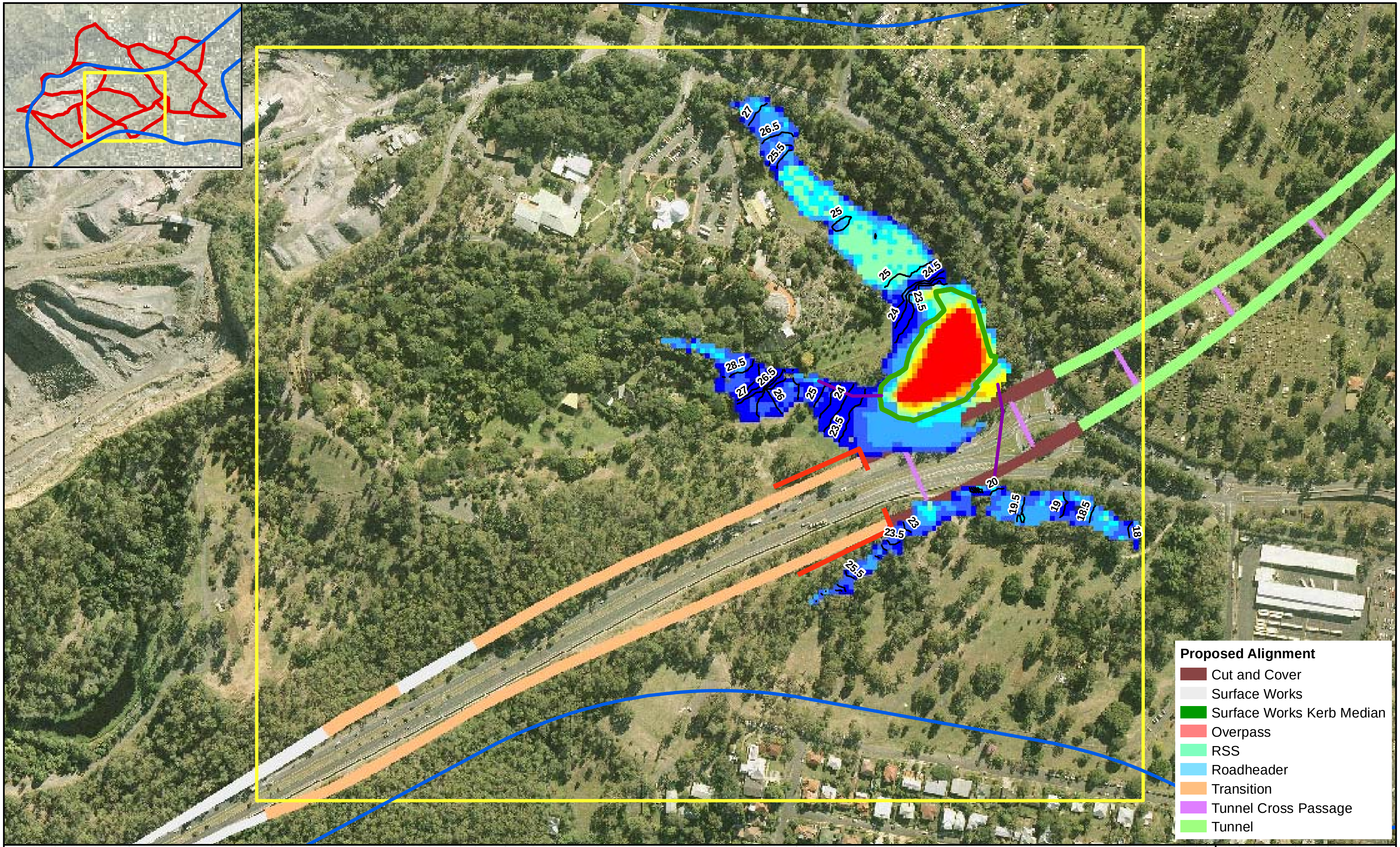
The results of the hydraulic model showed that the flood behaviour of the area is little changed by the Project. The area upstream of the Western Freeway continues to act as a detention storage with the majority of water now contained within the proposed BCC storage. The remaining 1650RCP under the Western Freeway continues to cope with the flow in the 1 in 100 AEP while the Freeway is overtopped in the 1 in 10,000 AEP flood.

The flood water ponds to a peak level of 23.4 mAHD upstream of the Western Freeway in the 1 in 100 AEP flood. This represents an increase of less than 100 mm. Figure 16 presents the peak modelled depth and water surface levels for the 1 in 100 AEP flood while Figure 17 presents the impact of the Project on local flooding. The impact on flooding generally less than 100mm and is localised to the Botanical Gardens grounds with the majority of the increase located within existing ponds and water features.

Figure 18 presents the peak modelled depth and water surface for the 1 in 10,000 AEP flood event. It can be seen that the tunnel portals are protected from local flooding and have the required 1 in 10,000 AEP design immunity.

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 will 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 16
Mt Coot-tha Operations Phase: 1 in 100 AEP Flood Extent

Northern Link
SKM Connell Wagner
JOINT VENTURE

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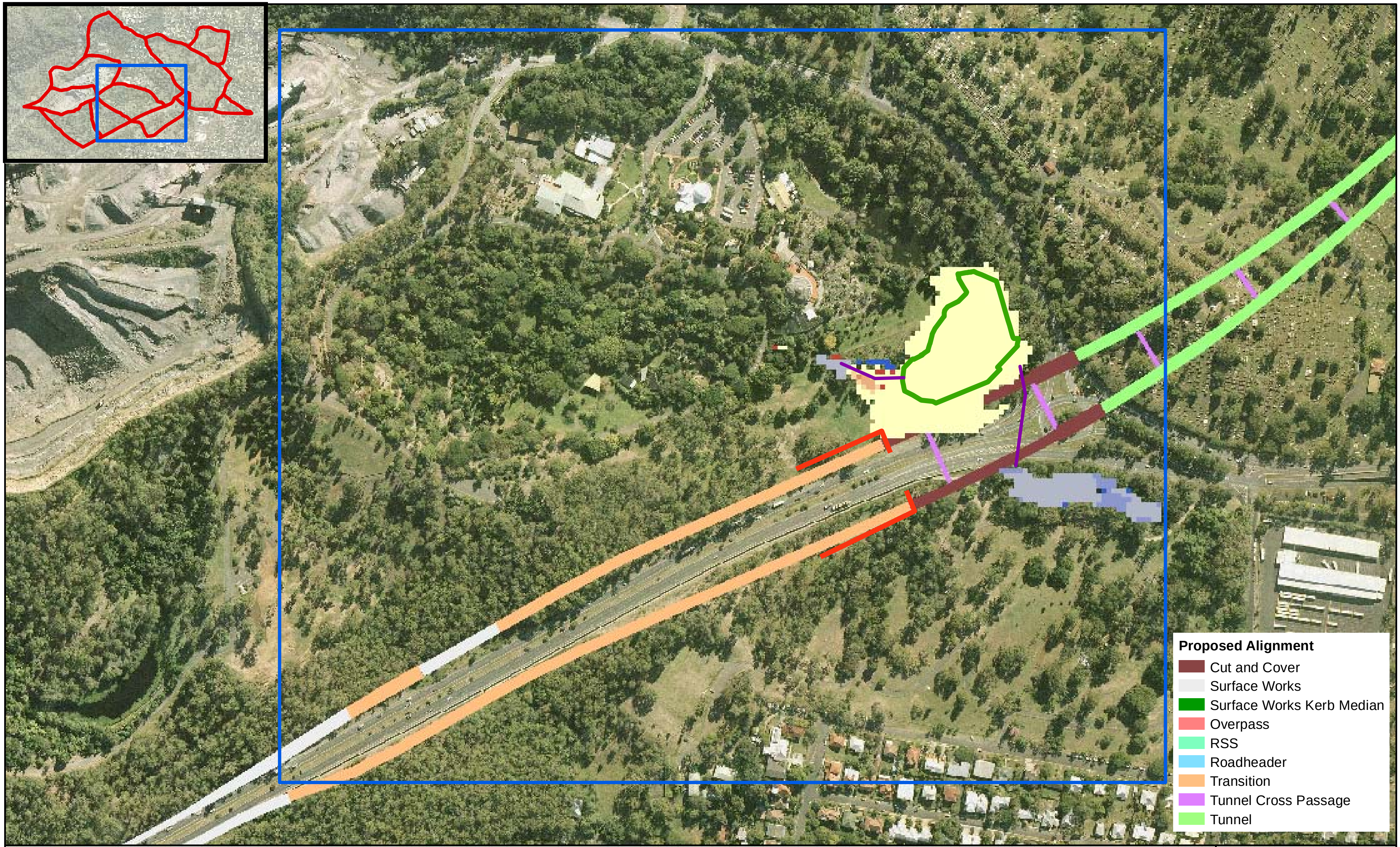

Legend

- Model Area
- Water Storage
- Portal Protection Wall
- Local Drainage Structures

Afflux (m)

- < -1
- -1 - -0.5
- -0.5 - -0.1
- -0.1 - -0.01
- 0
- 0.01 - 0.1
- 0.1 - 0.25
- 0.25 - 0.5
- 0.5 - 0.75
- 0.75 - 1
- > 1

0 100 200
metres

Scale 1:5,000 (A4)

N

NORTHERN LINK
ENVIRONMENTAL IMPACT STATEMENT

Figure 17

**Mt Coot-tha Operations Phase:
1 in 100 AEP Afflux**

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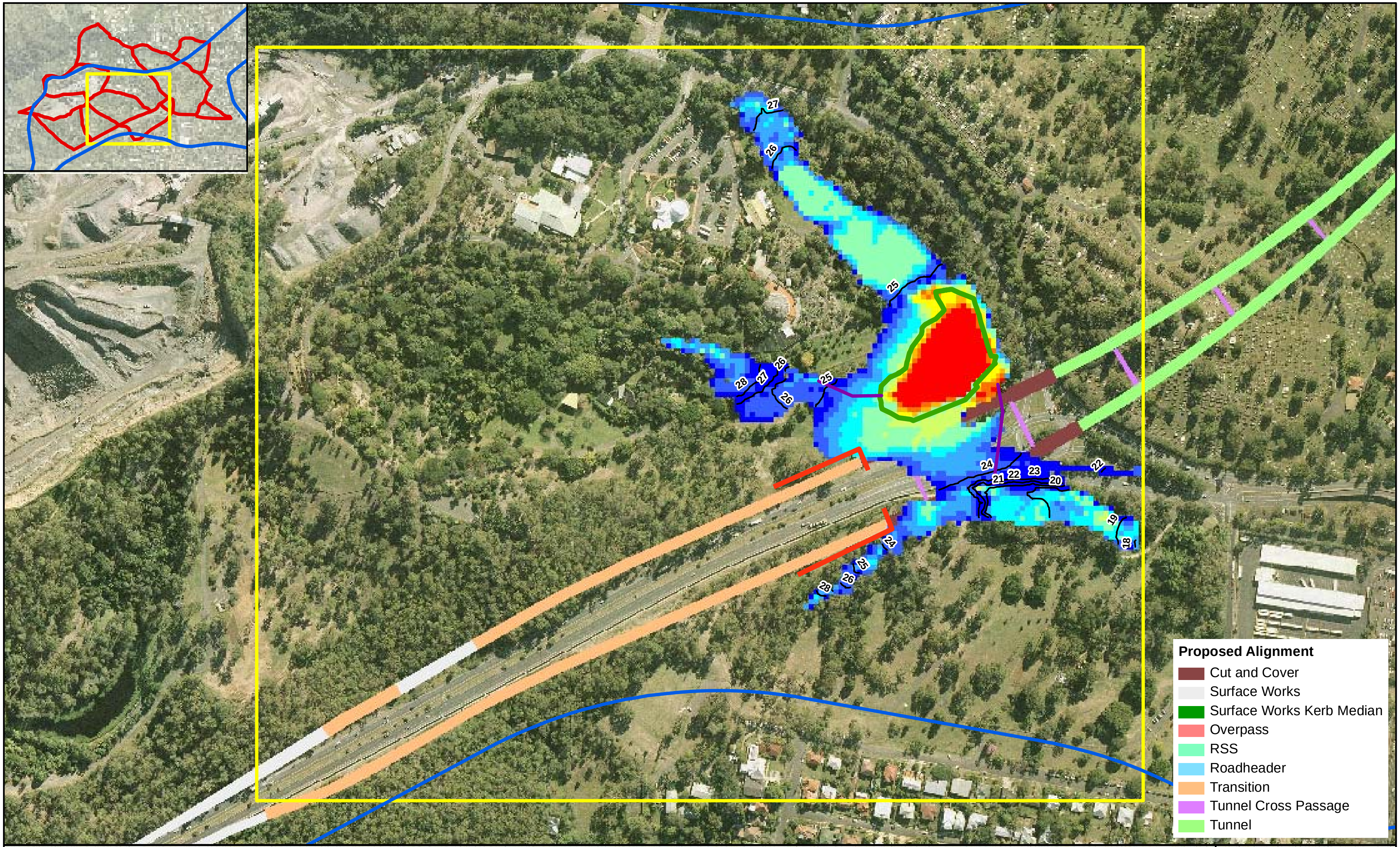

LEGEND

- 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

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ENVIRONMENTAL IMPACT STATEMENT

Figure 18

**Mt Coot-tha Operations Phase:
1 in 10,000 AEP Flood Extent**

Northern Link

SKM Connell Wagner
JOINT VENTURE

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Toowong Connection Local Drainage

The Toowong connection is located on the eastern side of Frederick St and to the north of Milton Road. Flooding for the 1 in 10,000 AEP event in this area is governed by local flooding from the Toowong Cemetery (C8) catchment. Figure 19 shows that the proposed connection is located well up the hill and above both local and regional flood levels for the 1 in 10,000 AEP event.

There is a risk that a small quantity of sheet flow from the local Catchment 14 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 St and Sylvan Road may impact on the existing local stormwater drainage structures. These works will 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 will be maintained and there will be no flood impacts on adjacent properties.

LEGEND

- Study Area Corridor
- Local Catchments
- Local Drainage Structures
- Portal Protection Walls
- Proposed Construction Area
- Bund For Construction

1 in 10,000 AEP Flooding

- Local Flood Extent - Toowong Cemetery
- Local Flood Extent - 15.5m AHD at Roundabout
- Regional Flood Extent - Upper Bound - 14.9 mAHD
- Regional Flood Extent - Lower Bound - 12.6 mAHD

0 50 100
metres

Scale 1:2,500 (A4)

N

NORTHERN LINK
ENVIRONMENTAL IMPACT STATEMENT

Figure 19

Toowong Portal
1 in 10,000 AEP Event

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2.1.1.2 Construction Phase

This section details the impacts and associated mitigation measures for local drainage around the western connections during the *Construction Phase* of the Project.

Mt Coot-tha Local Drainage

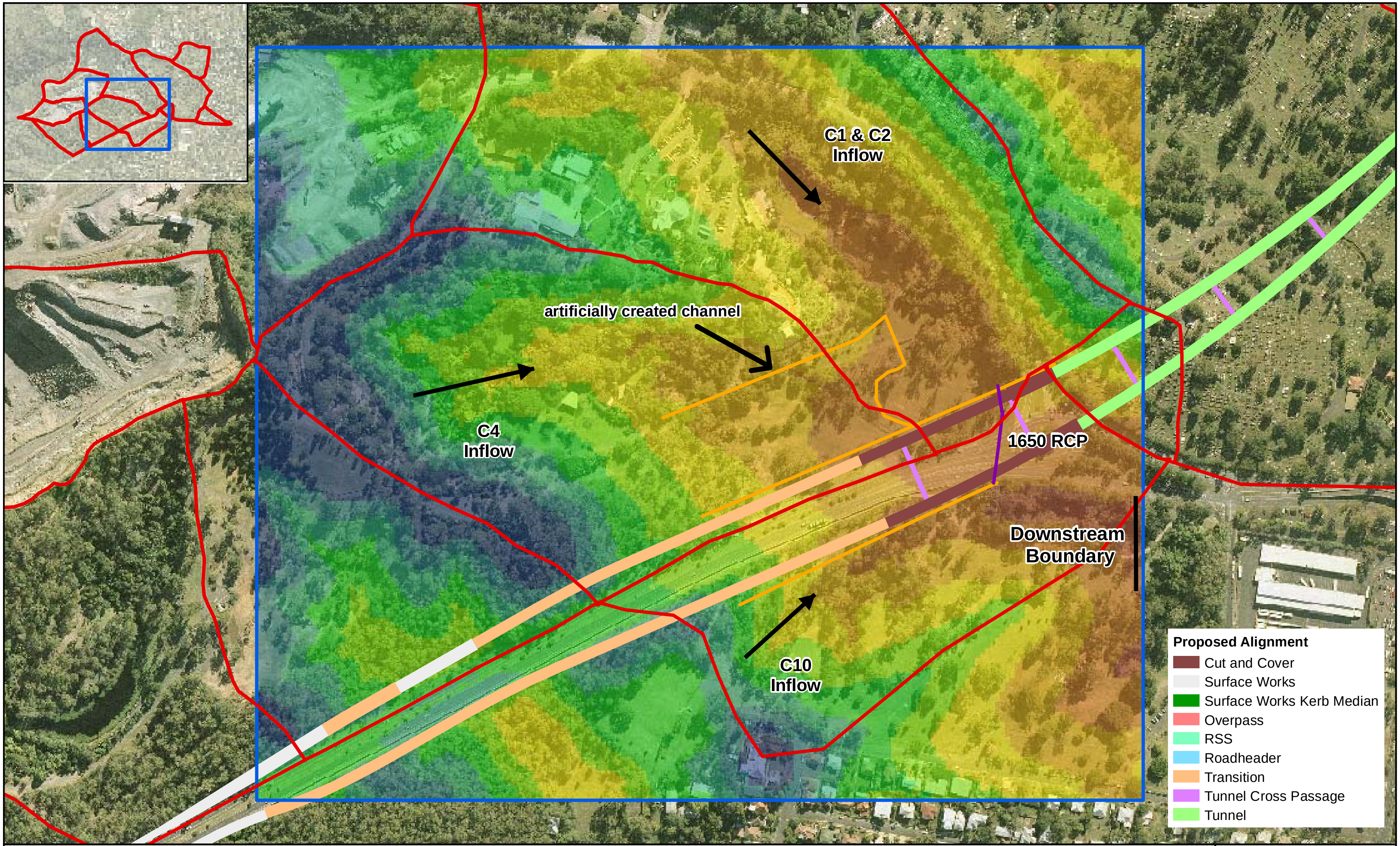
During construction, both the Transition and Cut and Cover Sections will be exposed and need protection from local flooding. This will be achieved by a walls or sheet piles / diaphragm walls along the two faces of construction exposed to flooding, or a combination of the two.

In addition, a construction area has been identified upstream of the Western Freeway in the Botanical Gardens grounds. This area will also need to be protected from local flooding during construction. This will be achieved by construction of a bund, to provide 1 in 100 AEP immunity to the construction area that would be approximately 400-600 m long and 2 m high, at its highest point. An artificial channel will be constructed on the upstream face of the bund to allow flow from Catchment C4 to flow into the detention area upstream of the Western Freeway. The existing 1650RCP culvert under the Western Freeway will be maintained during construction while the existing 900 RCP to the west will 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 proposed DMR bikeway was retained in the model as for the *Existing Environment* model. Figure 20 presents the layout of *Construction Phase* model and terrain.

The results of the hydraulic model showed that the flood behaviour of the area is similar to existing during construction. The remaining 1650RCP under the Western Freeway was found to manage the increased flow, maintaining 1 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 1 in 100 AEP flood to 24.0 mAHD. This represents an increase of up to 0.7 m. Figure presents the peak modelled depth and water surface levels for the 1 in 100 AEP flood while Figure 20 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 (4) years long, this impact is considered acceptable for the construction period.



LEGEND

- Model Area
- Local Catchments
- Local Drainage Structures
- Bund Around Construction

Model Terrain Data

17 - 20	31 - 35	46 - 50
21 - 25	36 - 40	51 - 55
26 - 30	41 - 45	56 - 60

0 100 200
metres

Scale 1:5,000 (A4)

N

NORTHERN LINK
ENVIRONMENTAL IMPACT STATEMENT

Figure 20

Mt Coot-tha Construction Phase: MIKEFLOOD Model Layout

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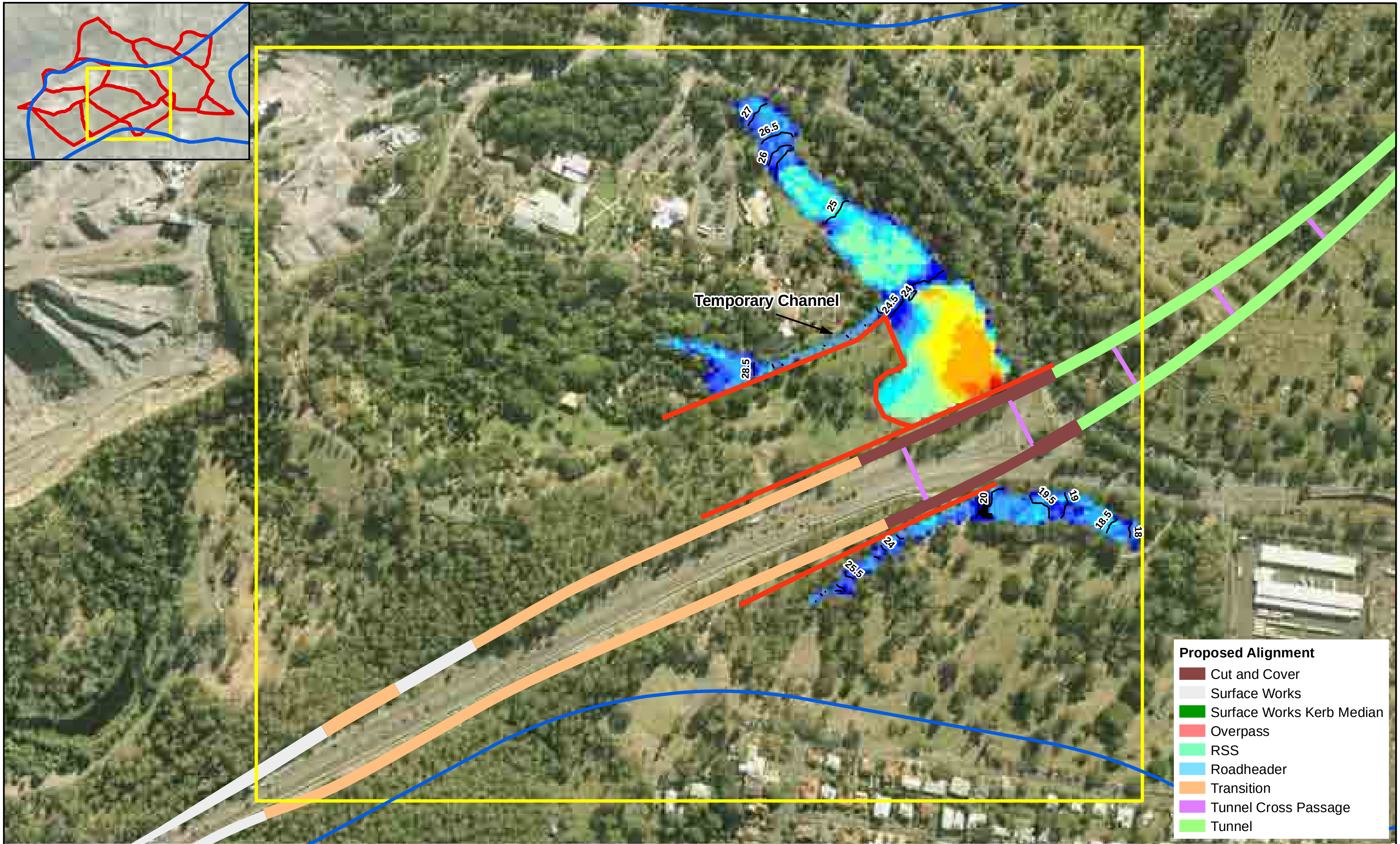

LEGEND

- 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 21

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

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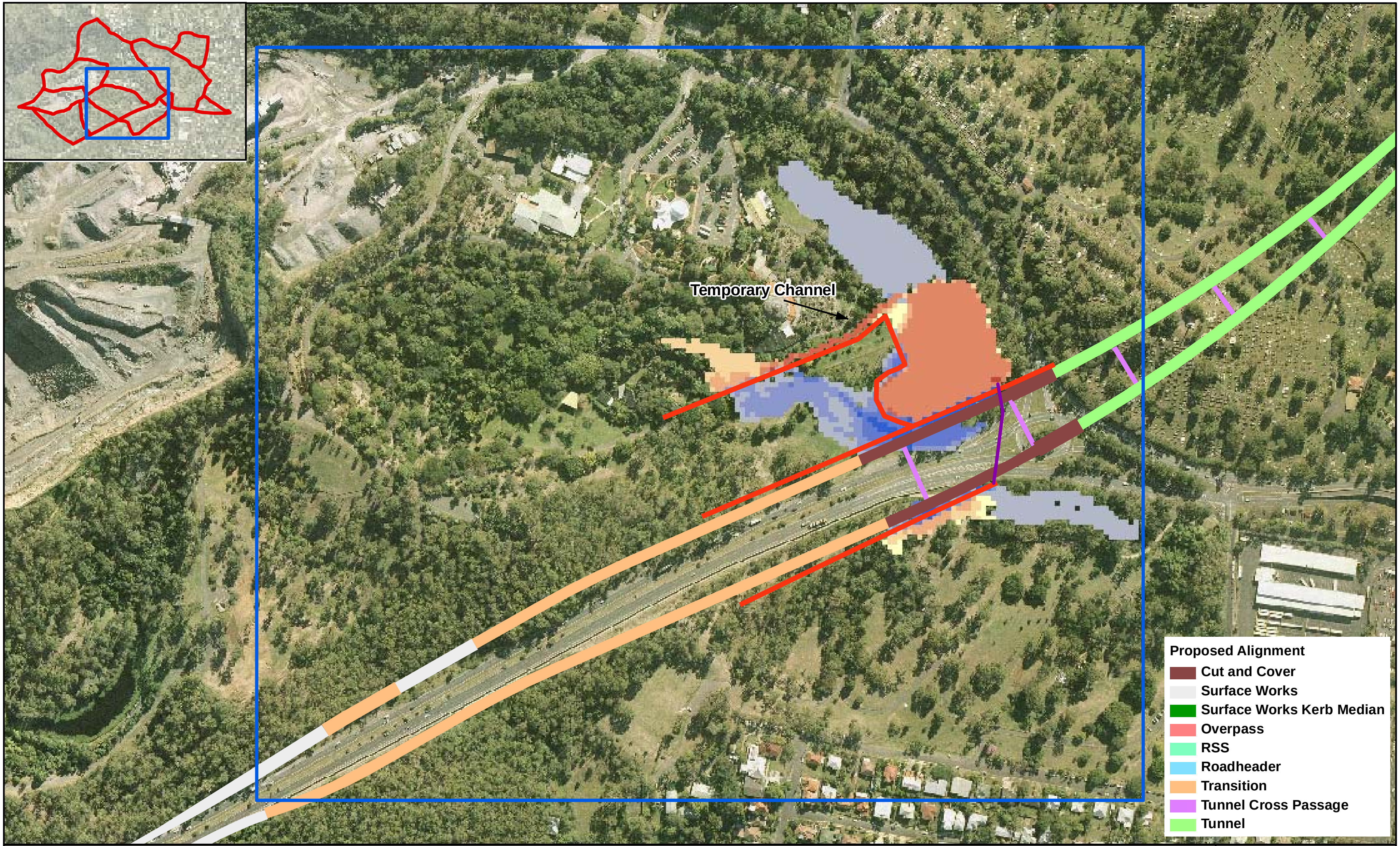

LEGEND

- Model Area
- Local Drainage Structures
- Bund Around Construction
- Bikeway

Afflux (m)

< -1	0	0.5 - 0.75
-1 - -0.5	0.01 - 0.1	0.75 - 1
-0.5 - -0.1	0.1 - 0.25	> 1
-0.1 - -0.01	0.25 - 0.5	

0 100 200
metres

Scale 1:5,000 (A4)

N

NORTHERN LINK
ENVIRONMENTAL IMPACT STATEMENT

Figure 22

Mt Coot-tha Construction Phase: 1 in 100 AEP Afflux

Northern Link
SKM Connell Wagner
JOINT VENTURE

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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 1 in 10,000 AEP flood level for both local and regional flooding.

A construction area is proposed for the area in the triangle between Frederick Street, Milton Road and Valentine Street (Figure 19). This area is part of a very small local catchment (Catchment 14) 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.

Filling of the site should be avoided as this will remove flood storage for the 1 in 10,000 AEP flood event and has the potential to reduce the flood immunity of the portal. Earth movement around the site with no net cut or fill volume would be appropriate for providing a level construction site.

2.1.2 Eastern Connections

This section details the potential impacts of the Project on the flooding behaviour around the Eastern connections and protection of the tunnel portals from flooding.

The terrain in proximity to the connection is well elevated and away from the influence of the Brisbane River or any other major creek or waterways of the region. There is not expected to be regional flooding impacts around the eastern connections.

Local drainage issues are dominant at the Eastern End and are discussed in detail in the following sections.

2.1.2.1 Operational Phase

This section details the impacts and associated mitigation measures for local drainage around the eastern connections during the Operational Phase of the project.

ICB Connection Local Drainage

As noted above, the existing sports field upstream of the INB overpass functions as a detention basin under large to extreme rainfall events. Hydraulic performance of the basin 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 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 1 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;

a) Any potential reduction in flood storage available in the detention basin up to the 1 in100 AEP flood level;
b) Any reduction in the capacity of the existing outlet structure; and
c) Any reduction in the capacity of the existing open channel downstream to Yorks Hollow.

The proposed widening of the existing ICB formation upstream from the INB overpass will be at levels above the 1 in 100 AEP water level in the basin. Thus, no hydraulic impacts will result under events up to 1 in 100 AEP from the filling.

Due to the widening of the existing ICB formation beneath the INB overpass, the works will unavoidably modify the existing outlet structure. The existing overtopping weir (8.9m long at RL 23.8m) will 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 1 in 100 AEP to 24.3mAHD. At 1 in 10,000 AEP, this increases to 25.25 mAHD, an additional 250mm further to the existing case.

The mitigate against the 50mm afflux for the 1 in 100 AEP case and also to ensure protection for the tunnel entrance, additional capacity will be required at the outlet structure to compensate for the reduction in overflow width.

To achieve the same discharge level relationship, any additional capacity will have to be created above 23.8mAHD, the level of the existing overflow weir.

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

Above 23.8mAHD, an increase in the effective width of the weir by 1 metre above 23.8mAHD would provide sufficient capacity. An additional inlet grate of perimeter 16 metres will allow additional flow into the outlet structure. It was assumed for the purposes of 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.

- **Table 11 Peak Water Level Predictions for Sports Field Basin**

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

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

As shown in Table 11, no significant impacts upon peak water level in the basin are predicted for the 1 in 100 AEP design event with the additional capacity.

The required widening of the existing ICB formation will encroach upon the existing open channel. To offset this impact, two options have been identified;

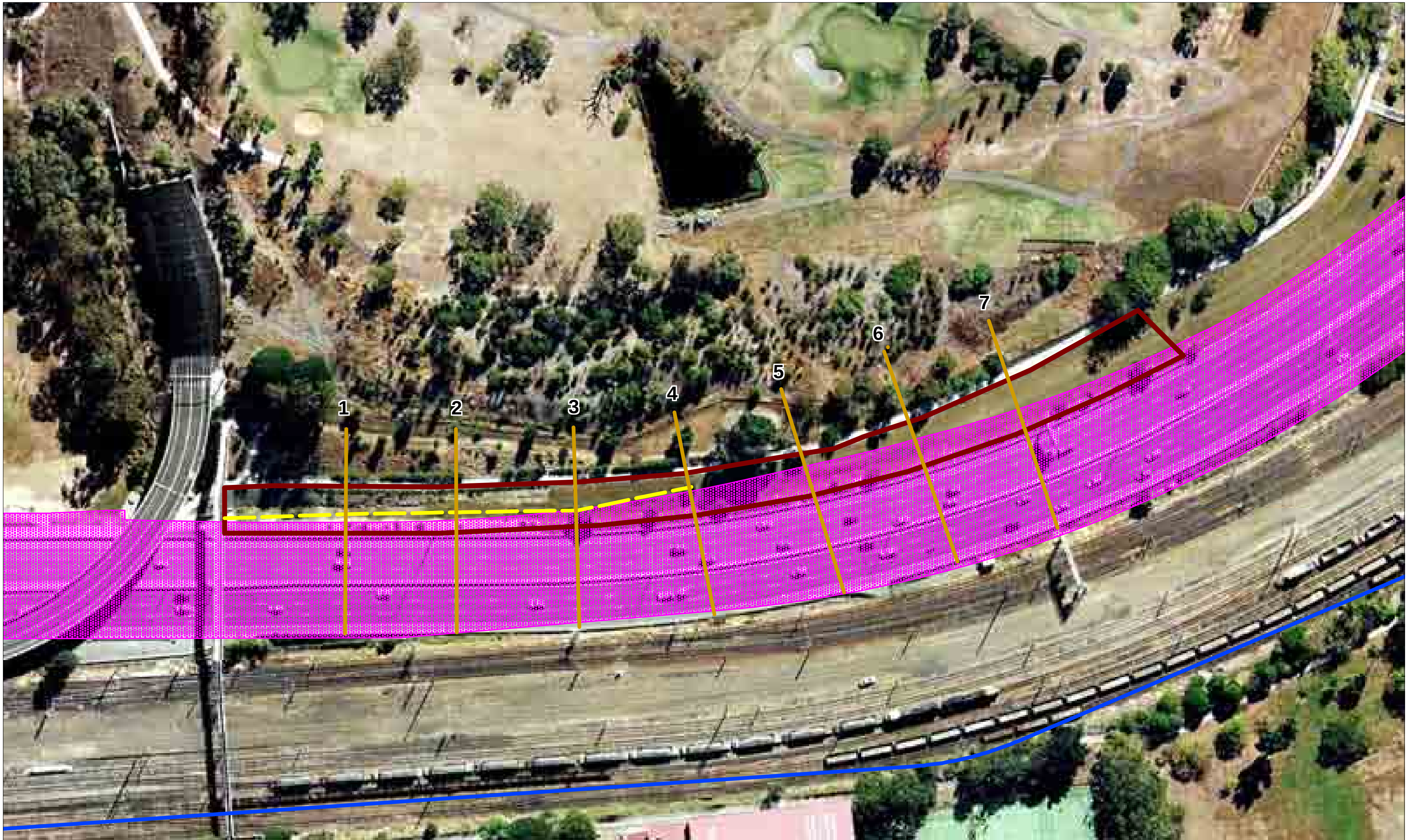
Firstly the open channel could be realigned to the north. As shown in Figure 23, it is proposed to replace the affected length of the existing channel with a new channel of the same dimensions. This will require resumption of a small portion of the existing hillside and realignment of the existing bikeway. By replacing the existing channel with a realigned channel of the same dimensions, the works will not affect its hydraulic performance and hydraulic impacts will be avoided. Two scenarios are presented in Table 12, a channel with 1.1 batters and also 1 in 2 batters. This will mean the channel will require lining to prevent scour during events

- **Table 12 Channel Dimensions with 1 in 1 / 1 in 2 batters**

Section location	Bankfull depth(m)	Invert (mAHD)	Base width	Total Width	Base width	Total Width
			1 in 1 side slopes		1 in 2 side slopes	
1	2.8	20.2	4	9.8	3	14.6
2	2.9	20.1	4	9.8	3	14.6
3	2.73	19.9	6	11.8	3.5	15.1
4	2.39	19.8	7	12.3	5	15.5
5	2.23	19.6	8.5	13.3	6	15.6
6	2.07	19.4	9	13.5	7	16
7	1.64	19.35	13	16.5	11	18

**Section locations identified in Figure 23*

A second option that lengthens the existing culvert exiting around section 4 (Figure 23) has the advantage of retaining the existing channel alignment and reduces the requirement for resumption to the north. This option would continue to allow for the reduced overflow path on top of the culvert for extreme events. Any increase in friction losses over this length is unlikely to be significant due to the size of the culvert.



LEGEND

Study Area Corridor

Proposed Alignment

Surface Works

Channel Area Affected

Cross Sections

Culvert Extension

0 30 60

metres

Scale 1: 1,500 (A4)

N

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ENVIRONMENTAL IMPACT STATEMENT

Figure 23

Channel Impact
Inner City Bypass ICB

Northern Link

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Kelvin Grove Road Connection Local Drainage

Widening of Kelvin Grove Road has the potential to impact on the storage capacity of the detention basin between Lower Clifton Terrace and Kelvin Grove Road as outlined in section 1.1.2.1.

Given that this area immediately to the west of Kelvin Grove Road functions as a detention basin, it is important that the proposed works do not reduce the available flood storage volume below the 1 in 100 AEP flood level. Provided that this criterion is satisfied, no increases in peak water level upstream of the road or peak discharge downstream from the road will occur.

The proposed widening works will be above the 39.5m AHD flood level and therefore satisfy this condition. Accordingly, no adverse hydraulic impacts are predicted under a 1 in 100 AEP rainfall event.

Located upstream of the Kelvin Grove Urban Village, an area bounded by Victoria Street and Kelvin Grove Road opposite McCaskie Park has the potential to act as a basin during extreme events. Any filling below the 1 in 100 AEP level would be a problem but because filling is proposed above this level only, there are no impacts for the 1 in 100 AEP event.

2.1.2.2 Construction Phase

This section details the impacts and associated mitigation measures for the local drainage around the eastern connections during the Construction Phase of the project. Construction works areas are shown in Figure 24.

Kelvin Grove Road Connection (South)

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

In the event of new offices being constructed on the site, they should be located to the north of the site if possible to maximise protection, however, it is not proposed any earthworks be carried out for the duration of the building programme so far as the buildings are of a temporary nature

LEGEND

Study Area Corridor
Victoria Street Basin
Hale Street Basin

Proposed Alignment
Surface Works
Tunnel Underground

0 80 160
metres
Scale 1: 4,000 (A4)
N

NORTHERN LINK
ENVIRONMENTAL IMPACT STATEMENT
Figure 24
Hale and Victoria St Basins Operational and Construction Impacts

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