BaT project

Chapter 6
Soils and topography

Contents

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6. Soils and topography

6.1 Introduction

The purpose of this chapter is to assess potential impacts of the Project relevant to soils, geology, topography and contamination. It provides an overview of existing landforms, dominant geological units and processes, soil landscape characteristics and significant features of in-situ material that are likely to be encountered or disturbed during construction. Strategies to manage potential impacts are also recommended, where required.

This chapter addresses sections 9.3, 9.4, 9.5, 10.8 and 10.9 of the Terms of Reference (ToR).

6.1.1 Methodology

The methodology included desktop review of previous investigations, available mapping and database searches. It is focussed on the study corridor described in **Chapter 1 – Introduction**. For issues related to contamination, geology and acid sulphate soils, databases searches beyond the extent of the study corridor have also been considered.

Topography

The existing topographical conditions for the study corridor were derived from the 1m Brisbane City Council contour data to create Brisbane 5m Digital Elevation Model (DEM) terrain data with respect to Australian Height Datum (AHD).

Geology

Relevant geological mapping was reviewed to gain a desktop appreciation for the existing geological and geomorphological features across the study corridor including the Queensland Government (July 2008) 1:100,000 Digital Geological Maps and Geological Survey of Queensland (Department of Mines, 1974).

The detailed geotechnical investigation to support the detailed design for this Project is ongoing. Consequently, a full geotechnical investigation report is not available for inclusion in the EIS. The information collected from the ongoing geotechnical investigation has been considered for this assessment, in combination with geotechnical information from other published sources and with information gathered in the study corridor for other projects.

Soil Types

The Commonwealth Scientific and Industrial Research Organisation (CSIRO) (2005) Soil Landscapes of Brisbane and South-eastern Environs, Queensland (1:100,000 mapping) was used to describe the existing soil types of the study corridor.

The Australian Soil and Land Survey Field Handbook (McDonald, R C; Isbell, R F, Speight; J G, Walker, J; and Hopkins, M S, 1990) and the Australian Soil Classification (Isbell, R F, 2002) were referenced in the assessment of erosion risk and potential impacts to stormwater runoff quality.

Recommendations for the mitigation and management of erosion risks have been developed with reference to:

- Best Practice Erosion and Sediment Control (International Erosion Control Association (IECA) Australasia, 2008)
- Soil Erosion and Sediment Control – Engineering Guidelines for Queensland Construction Sites (Institute of Engineers Australia (Qld Division), 1996)
- Urban Stormwater Quality Planning Guidelines (Department of Environment and Resource Management, 2010).

Acid sulphate soils

The assessment for acid sulphate soils (ASS) was completed with reference to the Queensland Acid Sulphate Soils Technical Manual. The review included mapping at a scale of 1:100,000 for South East Queensland (Acid Sulphate Soils – Tweed Heads to Teewah, South East Queensland (DSITIA, 2014)). Where required, recommendations for management of disturbed ASS material have been developed with reference to:

- Guidelines for Sampling and Analysis of Lowland Acid Sulphate Soils (ASS) in Queensland 1998 (Ahern, C R, McElnea, A E, Sullivan, L A, 2004)
- Queensland Acid Sulphate Soil Technical Manual – Soil Management Guidelines (Dear, S E, Moore, N G, Dobos, S K, Watling, K M, and Ahern, C R, 2004).

Contaminated land

The Environmental Management Register (EMR) and Contaminated Land Register (CLR) databases are the principal data sources for contaminated land in Queensland.

The EMR provides information on historic and current land uses, including whether the land has been, or is currently used for a notifiable activity, or has been confirmed as having a hazardous contaminant present onsite.

The CLR includes land which is proven through investigation, to be contaminated land which is causing or has the potential to cause serious environmental harm.

The assessment of potential impacts associated with contaminated sites involved the review of:

- data from the EMR and CLR provided by the Department of Environment and Heritage Protection (DEHP)
- past land uses based on the review of current and historical aerial photographs and the Brisbane City Council ‘1965 Land Use Plan’
- potential for unexploded ordnance and supporting Area Management Advice as described on the Australian Government Department of Defence website
- Brisbane City Council records relating to flammable/ combustible goods and historic landfills
- Queensland Rail records of contaminated land
- relevant contaminated land findings of other EIS studies undertaken for projects within or near to the study corridor.

Where required, mitigation measures are proposed to manage potential impacts associated with land contamination during construction and operation of the Project.

6.1.2 Legislative and policy framework

This assessment was undertaken under the following legislative and policy framework relevant to the environmental values within the study corridor.

Acid sulphate soils

In Queensland, ASS are managed under a range of legislation and planning policy, including:

- *Environmental Protection Act 1994* (EP Act)
- State Planning Policy (SPP)
- State Development Assessment Provisions (SDAP), under the *Sustainable Planning Act 2009* (SP Act)
- *Coastal Protection and Management Act 1995*
- *Fisheries Act 1994*
- *Water Act 2000*
- *Vegetation Management Act 1999*.

Specific guidance is also provided under the Queensland Acid Sulphate Soil Technical Manual. The manual includes:

- Queensland acid sulphate soils technical manual: legislation and policy guide
- Queensland acid sulphate soils technical manual: laboratory methods guidelines
- Queensland acid sulphate soils technical manual: soil management guidelines
- Guidelines for sampling and analysis of lowland acid sulphate soils.

Contaminated land

Contaminated land is managed in Queensland under a range of statutory and guidance measures, including:

- the EP Act
- the SPP
- the SDAP, under the SP Act
- National Environment Protection (Assessment of Site Contamination) Amendment Measure 2013 (No. 1) (the NEPM) (National Environment Protection Council 2013)
- Guidelines for the Assessment of On-Site Containment of Contaminated Soil (National Containment Guidelines) (ANZECC, 1999)
- Queensland Guideline for Contaminated Land Professionals (DEHP, 2012).

The key guidelines for the assessment of contaminated land in Queensland include the NEPM and the 'Queensland Guideline for Contaminated Land Professionals'.

In Queensland the soil investigation thresholds used to assess potentially contaminated land are based on values presented in the NEPM (NEPC, 1999). This NEPM presents investigation levels for the protection of environmental and human health. The investigation levels are not intended for use as default remediation trigger criteria, but instead are intended to prompt an appropriate site-specific assessment when they are exceeded (NEPC, 1999).

Similarly, levels nominated for the protection of ecosystem health should be developed at a regional level and related to land use (NEPC, 1999). For the purposes of this assessment, generic levels set for urban land uses have been adopted.

The Queensland Guideline for Contaminated Land Professionals establishes best practice for managing land contamination through the planning and development control processes. These guidelines also provide guidance to contaminated land professionals on the assessment, remediation and disposal of potentially contaminated land.

In Queensland, activities that have been identified as likely to cause land contamination are defined as notifiable activities under the EP Act. Land that was historically, or is currently used for notifiable activities, is reported to DEHP and recorded on the EMR. Inclusion of land on the EMR does not necessarily mean that the land is contaminated, as it may or may not pose a risk to human health or the environment.

Land is recorded on the CLR when an investigation has proven that contaminants are present at concentrations that represent a risk to human health. For such sites, action is required to remediate or manage the land to prevent adverse environmental and human health impacts.

Where land has previously been subject to a notifiable or industrial activity, the SPP requires that consideration is given to the determination of potential contamination. The SPP prescribes a risk-based approach be undertaken when considering potentially inconsistent future use on, or adjacent to, the potentially affected premises. Although the Project is exempt from assessment against the SPP as per Schedule 4 of the *Sustainable Planning Regulation 2009* (SP Regulation), the SPP has been considered in this assessment to address the requirements of the ToR.

6.2 Existing environment

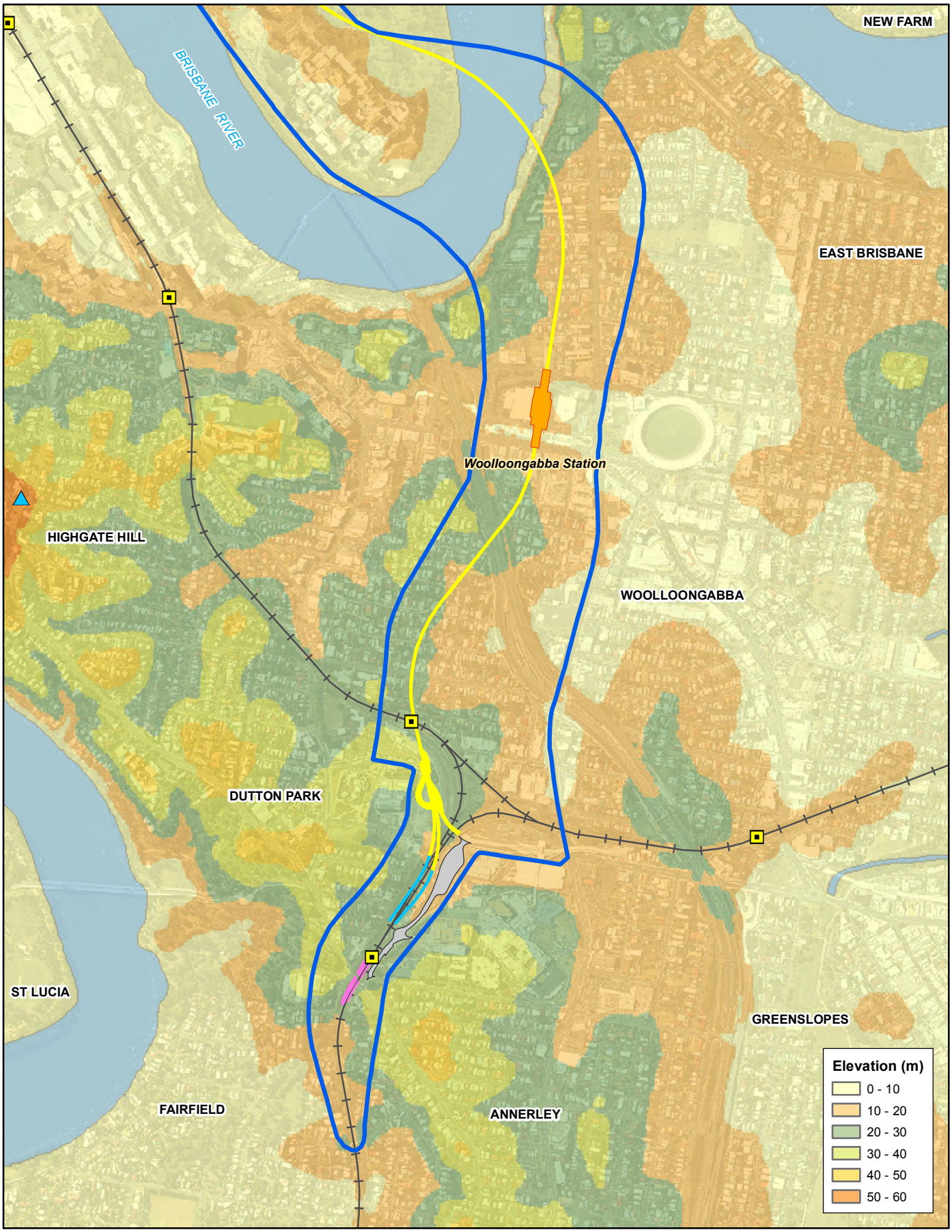
6.2.1 Topography

The terrain of the study corridor is presented in **Figure 6-1** and **Figure 6-2**. The highest point within the study corridor is on Wickham Terrace in Spring Hill at 55m AHD and the lowest point is within the Brisbane River channel at less than 0m AHD. The dominant topographic feature with the study corridor is the meandering channel of the Brisbane River.

On the southern side of the Brisbane River, an isolated high point is evident on Wild Street in Kangaroo Point (25m AHD to 35m AHD). Also of note is a ridgeline that runs toward the Princess Alexandra Hospital (PA Hospital) and extends through Annerley (refer to **Figure 6-1**). This ridgeline creates a barrier to surface drainage within the study corridor and is part of the boundary of the Brisbane River floodplain occurring, within the study corridor, in the vicinity of the Dutton Park Station.

The topography of the northern section of the study corridor and surrounding area is generally characterised by the elevated ridgeline of Spring Hill (approximately 45m AHD to 55m AHD), which is part of the northern boundary of the Brisbane River drainage area that intercepts the study corridor (refer to **Figure 6-2**). This ridgeline slopes downwards towards the Brisbane Central Business District (CBD), which is occupied mostly by a low-lying flood plain located east of George Street and in the vicinity of Queensland University of Technology (QUT) Gardens Point and the Riverside Centre in Eagle Street.

George Street sits along a low ridge trending south to north in the Brisbane CBD. On the northern side of the Brisbane River, a low ridgeline extends south-east from the Merivale Bridge to QUT Gardens Point. In the Brisbane CBD, this ridgeline lies between, and runs approximately in line with George Street and the Riverside Expressway.



LEGEND

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

Project Infrastructure

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

Alignment

- Above ground
- Underground

Aerial Photo: Brisbane City Council 2012

BUS AND TRAIN PROJECT
ENVIRONMENTAL IMPACT STATEMENT

FIGURE 6-1

Digital Elevation Model - south

N

0 0.25 0.5
Kilometres
1:15,000 (at A4)
Projection: GDA 1994 MGA56

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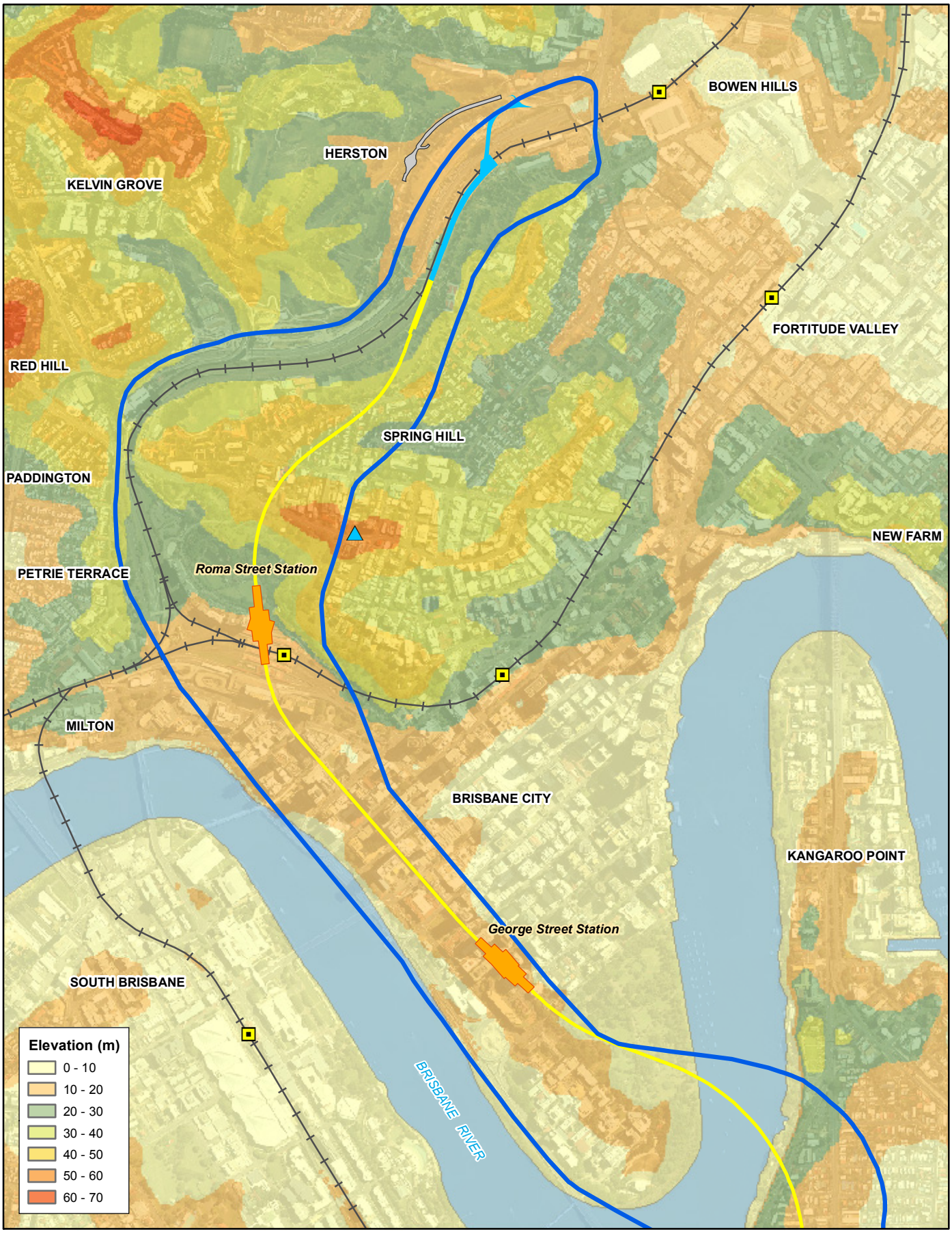

LEGEND

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

Project Infrastructure

- Underground station
- Bus layover

Alignment

- Above ground
- Underground

Aerial Photo: Brisbane City Council 2012

BUS AND TRAIN PROJECT
ENVIRONMENTAL IMPACT STATEMENT

FIGURE 6-2

Digital Elevation Model - north

N

0 0.25 0.5
Kilometres
1:15,000 (at A4)
Projection: GDA 1994 MGA56

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The topography of the mid-section of the study corridor and the surrounding area is generally characterised by a landscape that drains down from Spring Hill in the north and Dutton Park in the south, towards the Brisbane River. Kangaroo Point is the exception, creating a barrier drainage along the southern bank of the Brisbane River and directs drainage pathways towards the east and into the floodplain of Norman Creek. The landscape at Kangaroo Point rises up to an elevation of about 30m AHD near the intersection of the Bradfield Highway and Shafston Avenue. The Kangaroo Point cliffs are the remains of historical quarrying activities within Brisbane where extensive extraction of rock (Brisbane Tuff) has occurred.

6.2.2 Geology

Geological history

A review of the geological and geomorphological formations encountered in in the Brisbane area is provided in the following sections.

Devonian-Carboniferous (approximately 416-360 million years ago)

The Bunya Phyllite and the Neranleigh-Fernvale Beds are the oldest bedrock formations in the inner Brisbane area and consist of sequences of deep-water marine sediments. In inner Brisbane, the two formations are separated by a north-west trending thrust fault, the Normanby Fault, which lies on the western side of the Roma Street Railway Yard (refer to

Figure 6-3) and was encountered in the South-East Transit Project during the construction of the Vulture Street Busway tunnel (SKM-Connell Wagner JV, 2005).

Late Triassic (approximately 250-200 million years ago)

In the late Triassic era, there was deposition of the volcanic ash on the exposed land surface. These volcanic depositions have formed the Brisbane Tuff. Surface mapping suggests that the Brisbane Tuff has been preserved as a valley-fill deposit trending in a north–south direction through Brisbane.

After the Brisbane Tuff was deposited, erosion of the large valleys partially filled with tuff deposits recommenced and the surface of the tuff itself became deeply incised. Subsequently these incised channels were filled predominantly with gravels and coarse grained sands. These deposits formed the conglomerate, coarse sandstone and shale beds of the Aspley Formation. The Aspley Formation in turn was overlain by siltstone, shale and thin coal seams of the Tingalpa Formation. These two formations were deposited in the Late Triassic, within a few million years of the formation of the Brisbane Tuff.

Previous assessment (SKM-Connell Wagner JV, 2005) noted that the unconformity zone (abrupt contact between the two formations of disparate age) between the Brisbane Tuff and the Neranleigh-Fernvale Beds consists of a competent rock sequence, but in some places where claystones have formed, zones of weakness were observed. Not being a planar surface, when the unconformity zone is exposed in excavations, it can present as a sloping surface of weakness along which, sliding failures can occur.

Quaternary (approximately 2.6 million years ago)

The Quaternary deposits intercepting the study corridor were deposited along major stream channels during periods of fluctuating sea levels associated with the Ice Ages. During the initial periods of low sea level, the Brisbane River and its tributaries incised their channels deep into the underlying bedrock. During subsequent rises in sea level extensive deposits of alluvium were deposited both in the beds of the streams and in the developing floodplains.

The floodplains were periodically re-incised to form a series of riverbank terraces which are recognisable in certain areas. At present, the bed of the Brisbane River is incised into bedrock at around RL-33m but the bottom of the channel is filled with between 10m and 25m of sand, gravel and mud.

Generally, continuous deposits of Quaternary alluvium infill the majority of the topographic valleys and low-lying areas within the study corridor. The alluvium comprises variable deposits of clay, silt, sand and gravel (SKM-Connell Wagner JV, 2005).

Brisbane River

The cutting of the Brisbane River channel is likely to have begun before the Quaternary period. Sargent (1978) suggested that the present Brisbane River channel is likely to date back to the earlier stages of the Pleistocene (approximately 2.6 million years ago) or late Pliocene epoch (approximately 3.6 to 2.6 million years ago). Riverbed levels within the Brisbane River channel at the proposed river crossing have been observed through previous geophysical investigation (AECOM, 2010) to range between RL-2m and RL-21m. The shallowest part of the investigation area was identified as the exposed alluvium deposits south-east of the City Botanic Gardens. Two scour locations were inferred at the deepest parts of the channel (RL-21m and RL-19m).

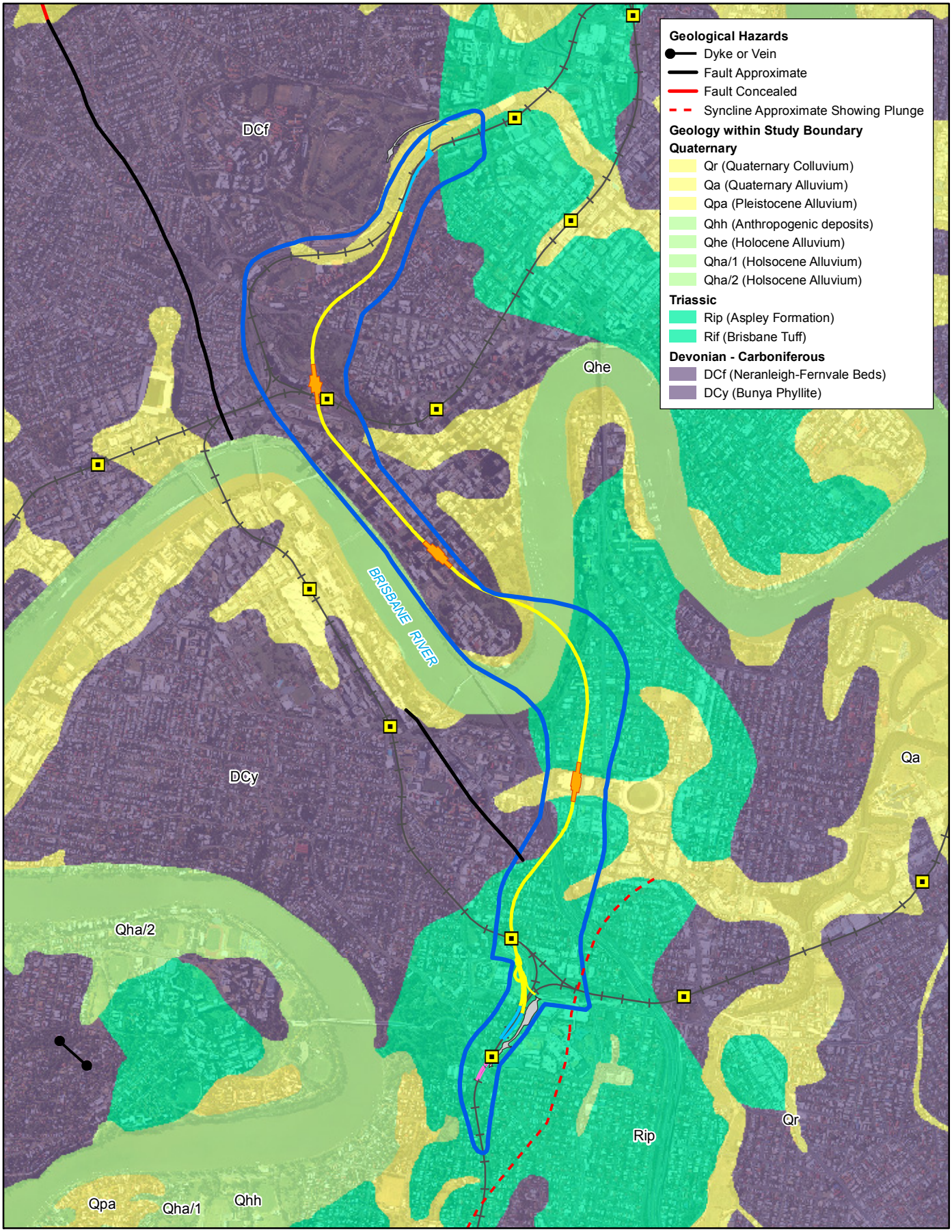
Water table elevations indicate that the central section of the study corridor intercepts areas of shallow groundwater (less than 3m below ground level) extending from the vicinity of the Riverside Centre to Gardens Point. Further detail regarding the hydrogeological regimes is presented in **Chapter 9 – Hydrology**.

Geology of the study corridor

Figure 6-3 provides an overview of the major geological units intercepted by the Project and **Figure 6-4** provides a summarised geological profile for the Project. This geological profile has been informed by previous investigations and refined based on geotechnical data collected specifically for this Project, through ongoing investigations.

All of the dominant geological formations are overlain by Quaternary alluvium within low-lying and floodplain areas associated with the Brisbane River and its tributaries.

A more detailed description of the geological formations and general characteristics of the various geological formations within the study corridor have been presented in **Appendix E**.



LEGEND

- Existing rail station
- Existing rail line
- Study corridor

Project Infrastructure

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

Alignment

- Above ground
- Underground

BUS AND TRAIN PROJECT
ENVIRONMENTAL IMPACT STATEMENT

FIGURE 6-3

Regional geology and geological features

N

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

Aerial Photo: Brisbane City Council 2012

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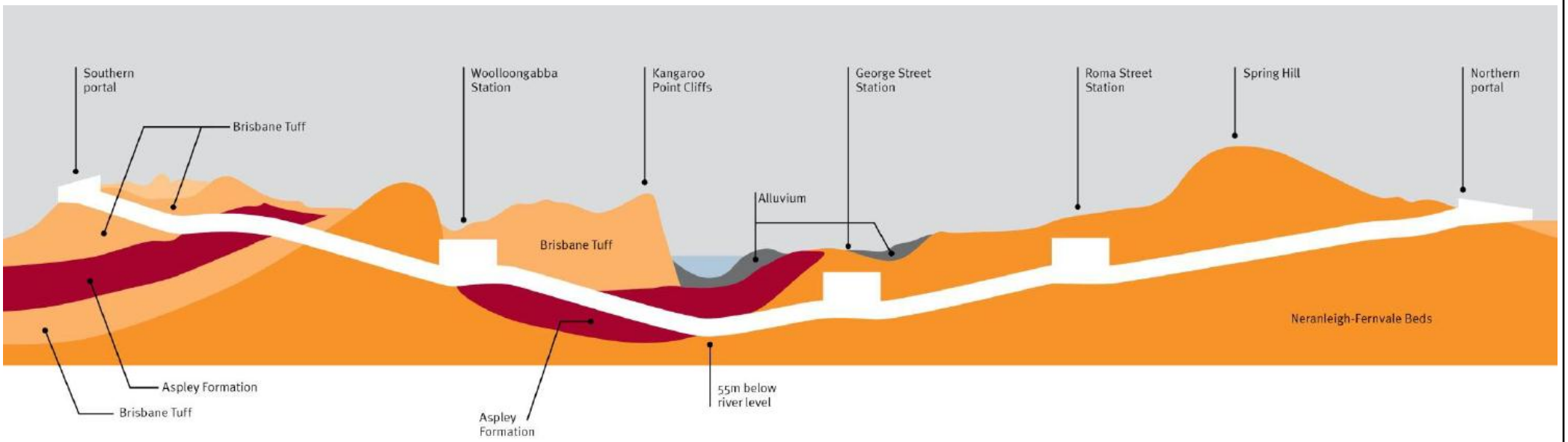


BUS AND TRAIN PROJECT
ENVIRONMENTAL IMPACT STATEMENT

FIGURE 6-4

Geological profile

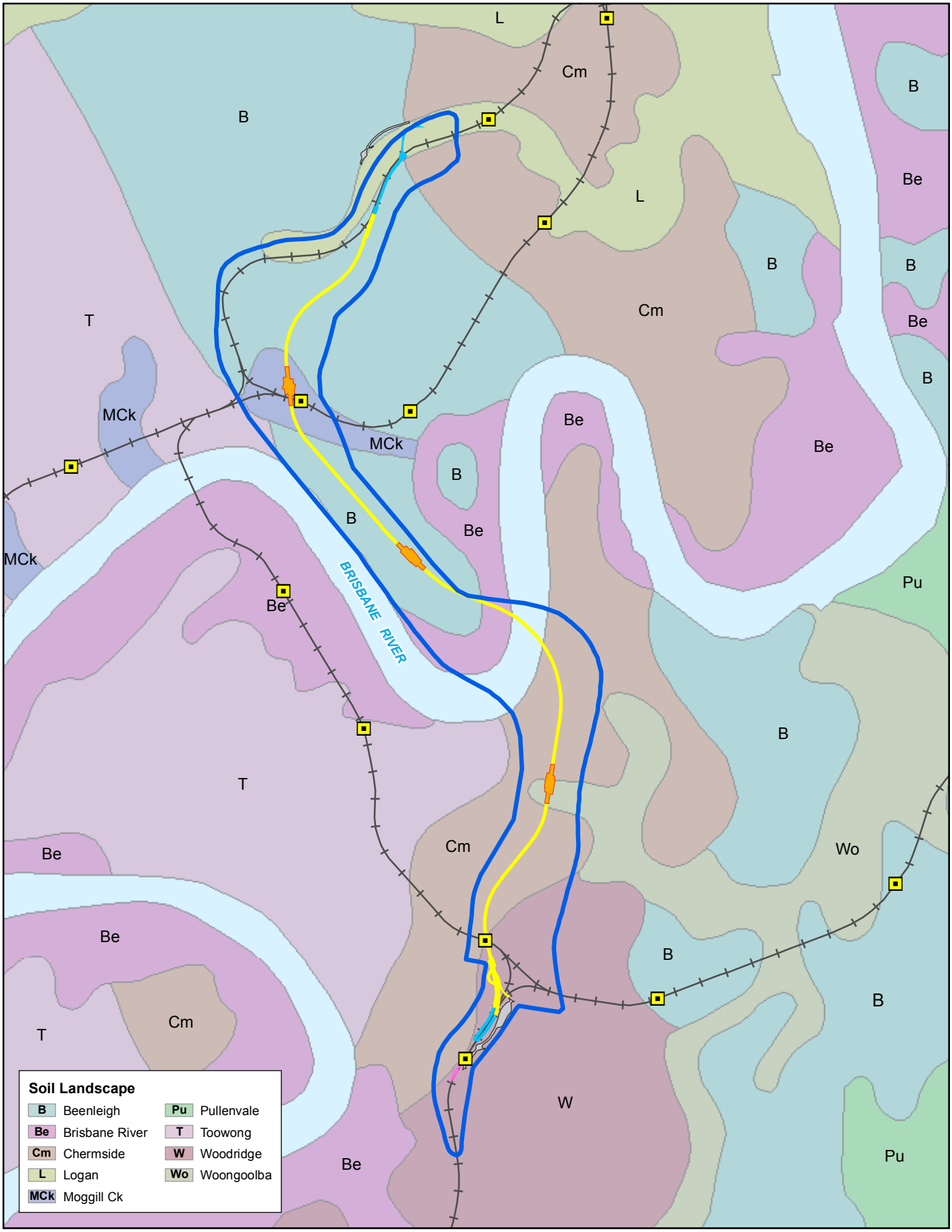
6.2.3 Soils

The mapping from Soil Landscapes of Brisbane and South-Eastern Environs (Beckman, G G, Hubble, G D, and Thompson, C H, 1987) was used to identify the soil landscapes throughout the study corridor.

The mapping (1:100,000) shows the study corridor intercepts eight soil landscape types (refer to **Figure 6-5**). These are summarised in **Table 6-1**.

Table 6-1 Soil landscape

Soil landscape	Dominant soil group	Landscape and parent rock	Intercepts the study corridor	Erosion hazard
Chermside (Cm)	Lithosols with shallow podzolic soils	Low hills, some with steep slopes of rhyolitic tuff	Northern extent of the Project in Spring Hill and from south of Brisbane River to Dutton Park	Low to moderate – erosion is an active process within this soil landscape
Logan (L)	Alluvial, soils with some humic gleys	Low terraces and flood plain of river sediments	Primarily north of the Victoria Park	Low
Beenleigh (B)	Red to yellow podzolic soils, with lithosols and some gleyed podzolic soils	Low hills of greywacke, phyllite and shale	Victoria Park to north of Roma street and within the Brisbane CBD to Brisbane River	Moderate
Brisbane River	Prairie soils with some sandy alluvial soils	Low undulating plain and terrace remnants of sandy alluvium	Immediately north of the Brisbane River	Moderate to high – susceptible to wind erosion
Moggill Creek	Gleyed podzolic soils with minor prairie and alluvial soils	Creek flats of sandy and clayey alluvium	Roma Street Station	Moderate
Toowong	Red podzolic soils with lithosols	Low hills of phyllite	North and south of the Brisbane River, generally adjacent to study corridor	Moderate
Woodridge	Red to yellow podzolic soils, with lithosols, gleyed podzolic soils and lateritic podzolic soils	Low hills of sandstone and shales	Dutton Park	Moderate to high
Woongoolba	Humic gleys, ‘peaty gleys’ and solonchaks	Low (coastal) plains of alluvium and narrow valley floors of alluvium	Woolloongabba Station	High



LEGEND

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

Project Infrastructure

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

Alignment

- Above ground
- Underground

BUS AND TRAIN PROJECT
ENVIRONMENTAL IMPACT STATEMENT

FIGURE 6-5

Soil landscapes

N

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

Aerial Photo: Brisbane City Council 2012

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Acid sulphate soils

Acid sulphate soils (ASS) are a characteristic feature of low-lying coastal environments in Queensland, particularly where landform elevations are less than 5m AHD. ASS are generally present within the sub-surface profile in an undisturbed anaerobic environment. When undisturbed they have a pH of neutral or slightly alkaline and are referred to as potential acid sulphate soils (PASS). Actual ASS are the oxidised form.

When the iron sulphides are oxidised, sulphuric acid is produced and the soil becomes strongly acidic. Oxidation may occur as a result of disturbance from changes in groundwater levels and/ or when PASS are exposed to air. Under these conditions, metal contaminants, if present, can be mobilised. Runoff or drainage water from uncontrolled or poorly managed ASS has the potential to impact on sensitive receiving environments.

A review of the 'Acid Sulphate Soils – Tweed Heads to Teewah – South East Queensland' Map 1 (DSITIA, 2014) has identified the potential for ASS to be present in an area directly adjacent to the northern side of the Brisbane River channel extending beneath the Brisbane CBD in the vicinity of the Riverside Centre and QUT Gardens Point (refer to **Figure 6-6**). As sediments in this area are deposited between the 5m AHD contour and the outer limit of Holocene sediments, they are considered to have a low potential for the presence of ASS.

A narrow band of sediment is mapped between the 5m AHD contour and the outer limit of Holocene sediments, within the southern bank of the Brisbane River, in the vicinity of Woolloongabba. These sediments are associated with the western extent of the Norman Creek floodplain, and extend between the Brisbane River and Fairfield. These areas are also mapped as areas with low potential for ASS to be present.

6.2.4 Contamination

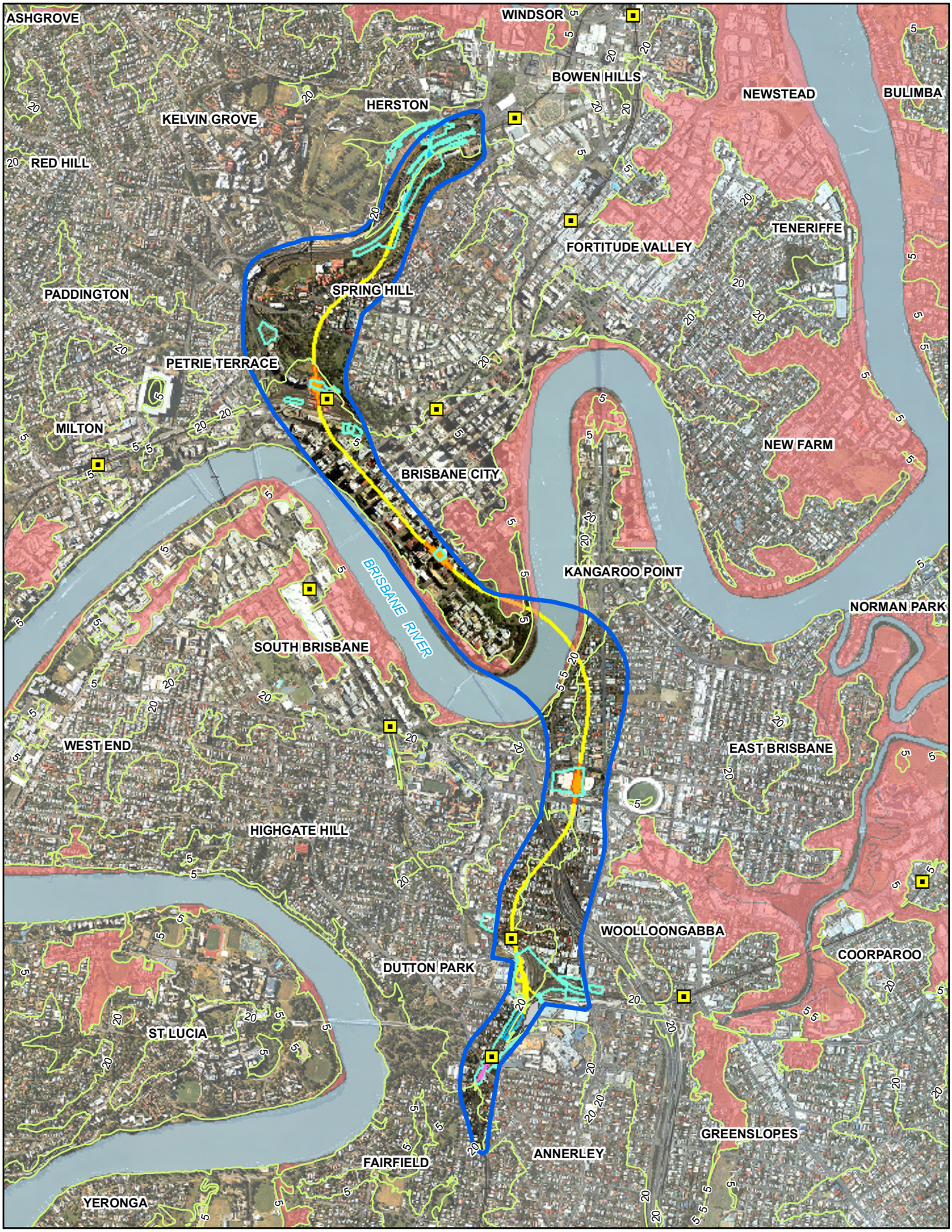
Review of environmental management and contaminated land registers

As part of the desktop assessment, each notifiable activity from the EMR was classified as being of either higher or lower risk. Notifiable activities considered to be of higher risk include those activities which present a greater risk of generating contaminants that are likely to be mobile in groundwater. Land parcels listed on the EMR for hazardous contaminants are also considered to be of higher risk. Where more than one notifiable activity is listed for a land parcel, the notifiable activity considered to be of higher risk is described.

The EMR records obtained in May 2010 (SKM Aurecon CRR JV, 2011) have been used as the basis for the current review. Select higher risk properties in the Roma Street Station and Woolloongabba Station precincts were searched again in March 2014 to confirm the basis of Site Management Plans (SMP) attached to the listings. EMR records of properties directly affected by the Project will be searched during later stages of the Project to confirm EMR status closer to detailed design and construction.

A search extending up to 1km beyond the study corridor identified a total of 1,987 listed land parcels. Of these, 1,067 are considered to be listed for higher risk land uses. Of the higher risk land uses, 126 land parcels are located within the study corridor. There are no land parcels adjacent to or within the study corridor listed on the CLR.

Table 6-2 provides a summary of higher and low risk land parcels listed on the EMR potentially affected by the Project. These are also shown on **Figure 6-7** and **Figure 6-8**. A list of property description information including lot and plan number and notifiable activity is presented in **Appendix E**.



LEGEND

- Existing rail station
- Existing rail line
- 5m Contours
- Watercourse
- Possible acid sulphate soils
- Study corridor

Project Infrastructure

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

Alignment

- Above ground
- Underground

Aerial Photo: Brisbane City Council 2012

BUS AND TRAIN PROJECT
ENVIRONMENTAL IMPACT STATEMENT

FIGURE 6-6

Acid sulphate soils

N

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

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Table 6-2 Land parcels on the EMR and potentially affected by the Project

Notifiable activity	Land parcels within the study corridor		Land parcels within 1km of the study corridor	
	EMR listed land parcels	SMP managed land parcels	EMR listed land parcels	SMP managed land parcels
Higher risk				
Chemical manufacture or formulation	0	0	4	2
Hazardous contaminant	11	2	126	10
Landfill	2	0	126	6
Petroleum product or oil storage	55	0	593	10
Railway yards	54	1	83	0
Service stations	3	0	135	5
Total higher risk land parcels	125	3	1,067	33
Lower risk				
Asbestos manufacture or disposal	0	0	1	0
Chemical storage	0	0	1	0
Dry cleaning	0	0	1	0
Foundry operations	0	0	7	0
Metal treatment or coating	0	0	907	8
Pest control	1	0	1	0
Waste storage, treatment or disposal	0	0	2	1
Total lower risk land parcels	1	0	920	9

Review of other records indicating potential contamination

In addition to the EMR and CLR searches, other records collected as part of a previous assessment (SKM Aurecon CRR JV, 2011) have been reviewed as part of the desktop assessment. These records have been reviewed to identify possible additional potentially contaminated land parcels within 1km of the study corridor. Records reviewed included:

- historical aerial imagery of Brisbane, including runs flown in 1946, 1950, 1960, 1970, 1983, 1994, 2001 and 2007
- 1965 Land Use Mapping compiled by Brisbane City Council
- Flammable/ Combustible Goods licenses held by Brisbane City Council under the *Dangerous Goods Safety Management Regulation 2001*
- anecdotal evidence collected from key stakeholders[1] and other EISs within the general vicinity of the study corridor[2]
- Area Management Advice records for unexploded ordnance, held by the Australian Government Department of Defence
- preliminary roadside inspection of properties within the study corridor.

[1] Including Queensland Rail and Brisbane City Council
[2] Including Northern Link EIS (SKM-Connell Wagner JV, 2008) and North South Bypass Tunnel EIS (SKM-Connell Wagner JV, 2006)

A total of 337 additional potentially contaminated land parcels were identified from searches extending up to 1km beyond the study corridor. Of these, 73 additional potentially contaminated land parcels are within the study corridor.

Additional potentially contaminated land parcels are summarised in **Table 6-3** and are shown in **Figure 6-9** and **Figure 6-10**. A full list of the additional potentially contaminated land parcels has been included as **Appendix E**.

Table 6-3 Additional potentially contaminated land parcels

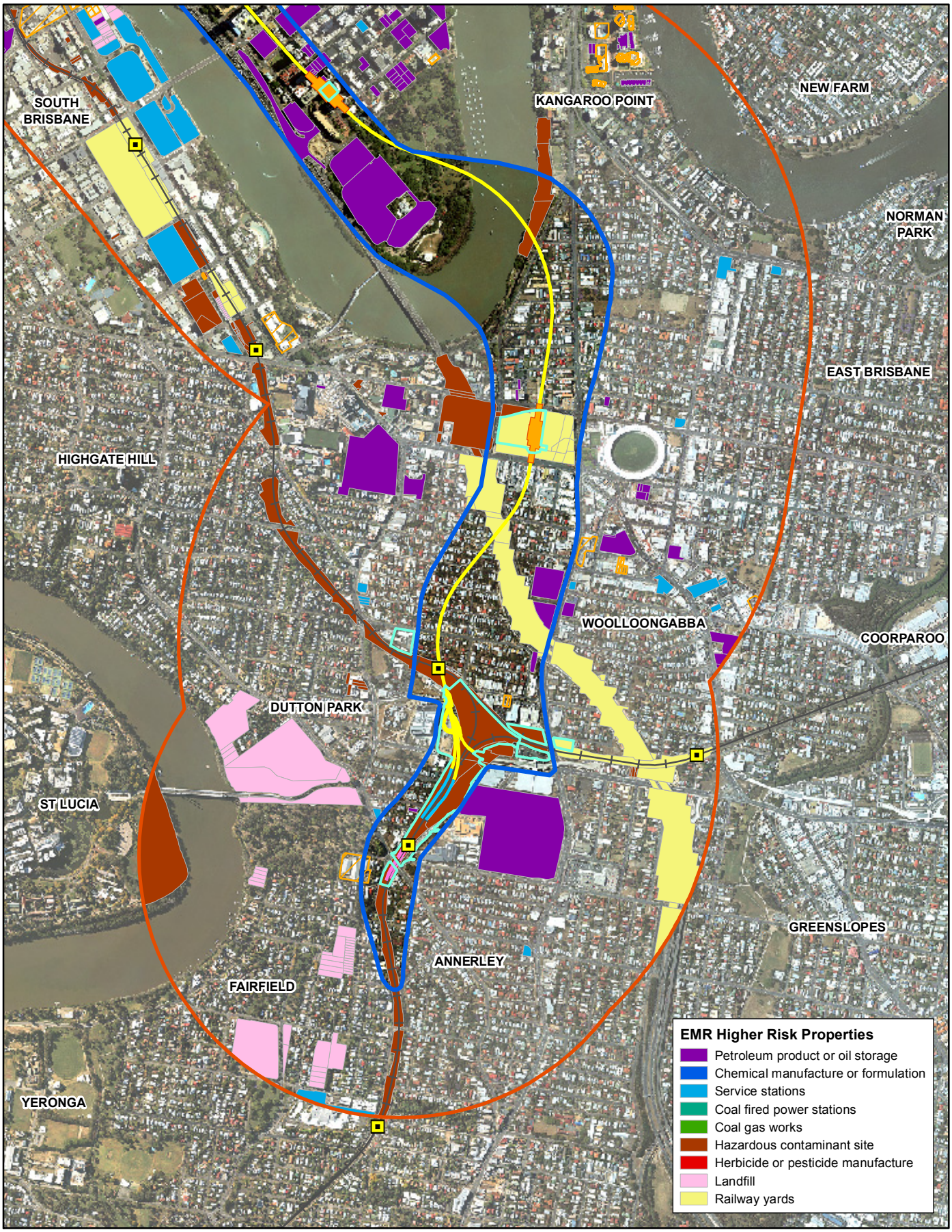
Land use	Land parcels within the study corridor	Land parcels within 1km of the study corridor
Asbestos manufacture or disposal	0	11
Dry cleaning	0	2
Foundry operations/ metal treatment or coating	0	2
Hazardous contaminant	1	15
Paint manufacture or formulation	0	1
Petroleum product or oil storage/ service stations/ engine reconditioning works	50	24
Railway yards	0	1
Scrap yards/ landfill	1	5
Wood treatment and preservation	21	31
Total	73	337

Sites on or adjacent to worksites

The sites that have the greatest potential for impacts related to the Project are those that would be located within the footprint of construction worksites, or lie immediately adjacent to them.

From the review of the EMR and other sources, eleven potentially contaminated sites would be located within the extent of construction worksites, with a further nine located adjacent to the construction worksites. Each of these potentially contaminated sites is described in greater detail in the following sections.

Contamination on these sites, if present, would be from above-surface or shallow sub-surface sources and is not expected to be encountered at the depths of tunnelling work for this Project. Therefore this assessment has focused primarily on the potential for contamination to be encountered by surface works. However, where the potential exists for contamination to be encountered at greater depths, this has been identified.



LEGEND

- Existing rail station
- Existing rail line
- Study area
- EMR Low risk properties
- Study corridor

Project Infrastructure

- Construction worksite
- Underground station
- Dutton Park Station (upgraded)

Alignment

- Above ground
- Underground

Aerial Photo: Brisbane City Council 2012

BUS AND TRAIN PROJECT
ENVIRONMENTAL IMPACT STATEMENT

FIGURE 6-7

Land parcels listed on the EMR - south

N

0 0.25 0.5
Kilometres
1:20,000 (at A4)
Projection: GDA 1994 MGA56

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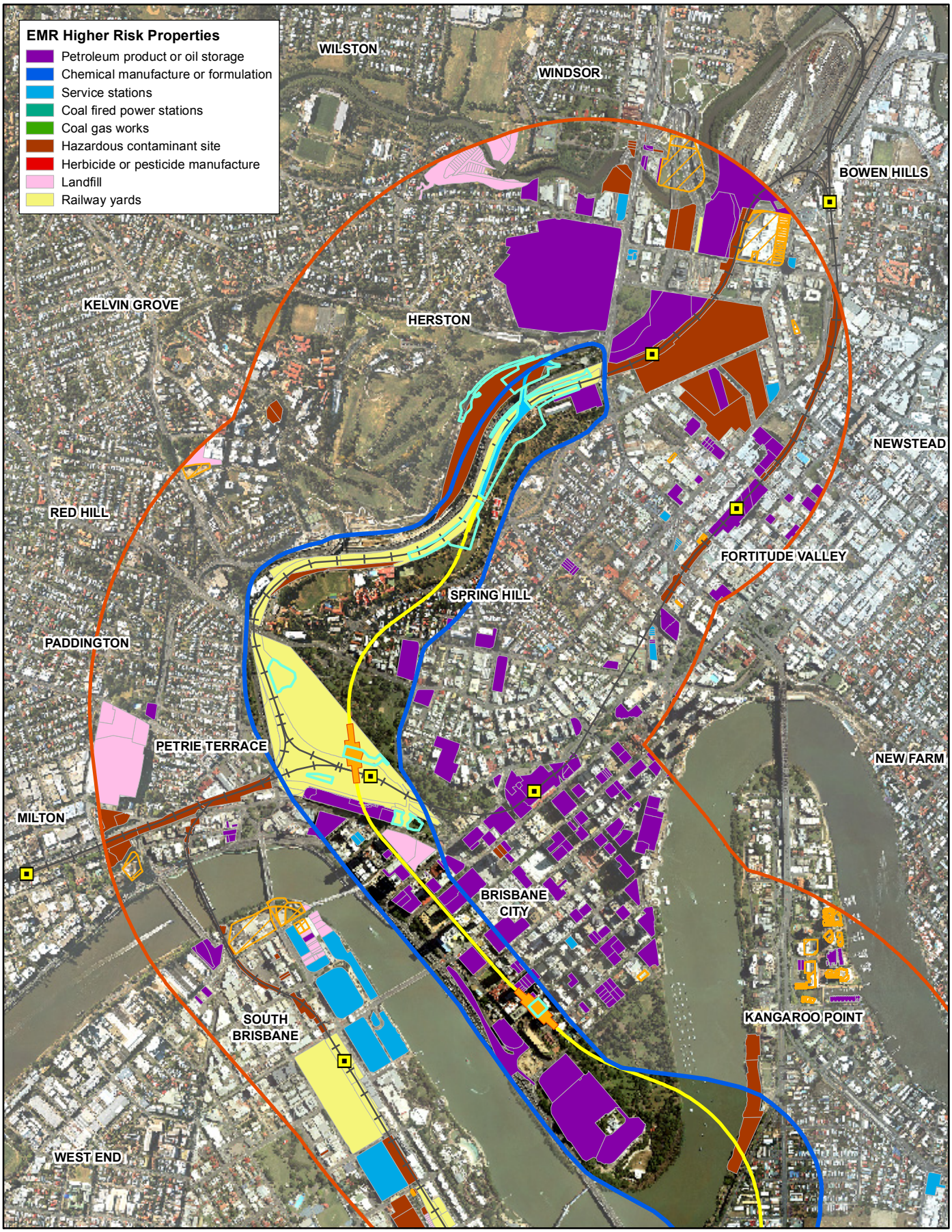

LEGEND

- Existing rail station
- Existing rail line
- Study area
- EMR Low risk properties
- Study corridor

Project Infrastructure

- Construction worksite
- Underground station

Alignment

- Above ground
- Underground

BUS AND TRAIN PROJECT
ENVIRONMENTAL IMPACT STATEMENT

FIGURE 6-8

Land parcels listed on the EMR - north

N

0 0.25 0.5
Kilometres
1:20,000 (at A4)
Projection: GDA 1994 MGA56

Aerial Photo: Brisbane City Council 2012

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LEGEND

- Existing rail station
- Existing rail line
- Study area
- Additional low risk properties
- Study corridor

Project Infrastructure

- Construction worksite
- Underground station
- Dutton Park Station (upgraded)

Alignment

- Above ground
- Underground

Aerial Photo: Brisbane City Council 2012

BUS AND TRAIN PROJECT
ENVIRONMENTAL IMPACT STATEMENT

FIGURE 6-9

Additional potentially contaminated land parcels - south

N

0 0.25 0.5
Kilometres
1:20,000 (at A4)
Projection: GDA 1994 MGA56

G:\QENV2\Projects\QE06863\SpatialArcGIS\Figures\Final_EIS_Figures\06_Soils_ContaminatedLand\ContamLand_Figure6-X_Additional_Potentially_Contaminated_Land_Parcels_MapBk.mxd Date: 14/08/2014

LEGEND

- Existing rail station
- Existing rail line
- Study area
- Additional low risk properties
- Study corridor

Project Infrastructure

- Construction worksite
- Underground station

Alignment

- Above ground
- Underground

BUS AND TRAIN PROJECT
ENVIRONMENTAL IMPACT STATEMENT

FIGURE 6-10

Additional potentially contaminated land parcels - north

N

0 0.25 0.5
Kilometres
1:20,000 (at A4)
Projection: GDA 1994 MGA56

Aerial Photo: Brisbane City Council 2012

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Dutton Park

Three Queensland Rail properties, listed on the EMR for the notifiable activity of Hazardous Contaminant, would be directly impacted by proposed surface works at Dutton Park. These include:

- Lot 420 SP116165
- Lot 421 SP116165
- Lot 195 SP198200.

Typically, railway corridor land is listed on the EMR. Listing is generally based on the potential for hazardous contaminants from arsenic residue as a result of herbicide/ pesticide spraying during the 1940s and 1950s. Limited soil sampling and testing has been conducted within metropolitan corridors. However, it is expected that levels of arsenic are low as procedures were in place to prevent or limit the herbicide treatment near sensitive areas (e.g. residential buildings and creeks). The application of herbicide was limited by equipment, with a thin strip spray directed on the track. Residues of arsenic still exist in track formation soils as arsenates bind well to soil particles. There has been no indication of arsenic contamination effects on groundwater in any Queensland Rail land in the study corridor (SKM-Connell Wagner JV, 2008b). There is also the potential for oils and other contaminants to be discharged to the track with incidental leakage of fluids from carriage mechanics or freight.

The presence of asbestos containing materials has been noted in the Asbestos Registers for Queensland Rail owned facilities (Dutton Park Station and depot) at this location (Queensland Rail, 2013a).

The PA Hospital (Lot 702 SP183568), adjacent to the south-eastern border of the surface works, has been included on the EMR for the notifiable activity of Petroleum Product or Oil Storage. A review of the Brisbane City Council Flammable/ Combustible Goods licenses has been unable to confirm the nature or volume of petroleum hydrocarbon stored onsite, however, given the use of the site as a hospital, the listing would likely be associated with diesel storage for backup generators. Petroleum hydrocarbon storage is considered to have a high risk for potential contamination, particularly if storage tanks are buried underground. Hydrocarbon contamination is typically associated with soil, groundwater and ground gas (soil vapour) contamination.

Woolloongabba

Three properties listed on the EMR for the notifiable activity of Railway Yards would be directly impacted by proposed surface works at Woolloongabba. These include:

- Lot 63 SP184386
- Lot 4 SP149278
- Lot 1291 CP899829.

One property on the worksite is listed on the EMR for the Notifiable Activities of Hazardous Contaminant (Lot 1291 CP899829). A property (Lot 61 SP188566) adjacent to the construction worksite is listed on the EMR for the notifiable activity of Railway Yards.

A former freight rail line running along Logan Road used to service a former railway yard on the GoPrint site. The rail line then headed north toward the former wharves at South Brisbane and Kangaroo Point. The yards were developed prior to 1946 and were decommissioned prior to 1983 (observed through aerial imagery).

The construction worksite has since been used as the main printery for the Queensland Government until the closure of operations at the GoPrint site in January 2014.

Based on the former land uses listed above, contaminants of concern at this site include petroleum hydrocarbons, polycyclic aromatic hydrocarbons and metals. These may be present as contamination of soils, groundwater and as ground gas (sourced from volatile hydrocarbons).

The asbestos register for the GoPrint site indicates that asbestos is present in the building and printery infrastructure (Department of Housing and Public Works, 2014).

George Street

Six properties adjacent to George Street Station surface works are listed on the EMR for the notifiable activity of Petroleum Product or Oil Storage. These include:

- Lot 18 RP209685
- Lot 4 RP43986
- Lot 3 RP43986
- Lot 2 RP43986
- Lot 2 RP640
- Lot 1 RP43986.

There is limited information of potential contamination through the George Street area, although the historic and widespread use of uncontrolled fill materials throughout the greater Brisbane area is well documented.

Properties in the vicinity of the surface works are also listed on the EMR for Petroleum Product or Oil Storage. A review of the Brisbane City Council Flammable/ Combustible Goods licenses has been unable to confirm the nature or volume of petroleum hydrocarbon stored on-site, however, it is likely that on-site diesel storage for backup generators would be the origin of this listing. Petroleum hydrocarbon storage is considered to have a high risk for potential contamination, particularly if storage tanks are buried underground. Hydrocarbon contamination is typically associated with soil, groundwater and ground gas (soil vapour) contamination.

A Hazardous Materials Removal Report was prepared for 63 George Street (Parsons Brinkerhoff, 2006). Whilst the majority of asbestos has been removed from the site, several areas with asbestos or potential asbestos remain present within buildings and/ or infrastructure.

Roma Street

Two properties adjacent to Roma Street Station surface works are listed on the EMR for the notifiable activity of Railway Yards. These include:

- Lot 37 SP169852
- Lot 60 SP207215.

A property (Lot 1 SP207220) adjacent to surface works is listed on the EMR for the notifiable activity Petroleum Product or Oil Storage.

Roma Street Parkland formerly contained the Roma Street goods and freight yards. The yards were decommissioned in 1991 and redeveloped as parkland in 2000 (Blake, 2004). The site is currently managed under a SMP (DEHP, 2014). A containment cell houses some contaminated materials beneath the parklands. This containment cell is located in the southern area of the parklands, possibly within 10m of the proposed surface works. The entire site has been capped with ‘clean’ fill materials for a minimum of 1.5m depth over residual ‘low level impacted’ soil materials.

Conditions of the SMP include restrictions on excavation at the site, workplace health and safety requirements (including provision for general environmental protection), advice for designers and management provisions in the case of intersection of unexpected or cross contamination (including odours or other evidence of contamination).

Given the contaminants of concern as listed in the SMP (petroleum hydrocarbons, polycyclic aromatic hydrocarbons, metals), there is the potential for non-aqueous phase liquids (NAPL) contamination within the deeper ground profile. This may include lighter NAPL products (such as petroleum hydrocarbons) sitting on top of groundwater, but is more likely to include dense NAPL products (those derived from heavy hydrocarbons such as tars) which would sink and accumulate in deeper rock fractures. NAPL products, if present, may result in the generation of potentially noxious ground gases and cause a source of contamination for groundwater. Details of previous environmental works including records of existing residual contamination (such as NAPL) and ongoing monitoring works were not available to be reviewed for this assessment.

The presence of asbestos containing materials has not been noted in the Asbestos Registers for Queensland Rail owned facilities at Platform 10 (Queensland Rail, 2013b). However, limitations within this assessment may not exclude the presence of asbestos containing materials in areas previously unable to be assessed. An Asbestos Management Plan for the Roma Street Parklands indicates that buried asbestos containing materials have been identified in the past, and have been removed (Department of Housing and Public Works, 2013).

Spring Hill

There is limited information on potential contamination through Victoria Park, although the historic and widespread use of uncontrolled fill materials throughout the greater Brisbane area is well documented.

Properties with proposed surface works are listed on the EMR for the Notifiable Activities ‘Railway Yards’ (Lot 32 SP172136, Lot 34 SP172136) and ‘Hazardous Contaminant’ (Lot 5 SP123915).

Typically, railway corridor land is listed on the EMR for hazardous contaminant for arsenic residue from herbicide/ pesticide spraying during the 1940s and 1950s. The presence of asbestos containing materials has been noted in the Asbestos Registers for Queensland Rail owned facilities at this location (Queensland Rail, 2013c).

6.3 Impact assessment

6.3.1 Geology and topography

Localised geological and topographical variations within the Project alignment will be influential in the detailed design. It has been necessary to position the tunnel within suitable, competent geological units and at the same time achieve safe design gradients for rail operations. Similarly, topography has also influenced the design and placement of surface structures associated with the Project, such as stations, station access locations, feeder station building locations and their height above flood levels.

This assessment has been based on a review of existing data and recently completed geotechnical investigations along the Project alignment. At this stage of the Project, the major perceived geotechnical risks are considered to be associated with:

- poor/ weak/ adverse ground and reduced rock cover
- alignment groundwater conditions and the potential for significant groundwater inflows
- the potential for construction induced impacts (settlements, ground movement).

A full list of the anticipated geotechnical risks by Project section, and associated potential construction issues, is provided as **Appendix E**. Completion of the current investigations, interpretation of these conditions and further geotechnical investigations at later stages of the Project will assist in mitigating the identified risks.

Settlement in tunnelling projects may arise due to many factors including groundwater drawdown and local ground relaxation effects around excavations and underground openings. Desktop assessment of the water table depth indicates that the study corridor intercepts areas of shallow groundwater (less than 3m below ground level) in the vicinity of the George Street Station, the river crossing and the Woolloongabba Station. During construction, where the Project intercepts the water table, groundwater inflow may occur. This may result in consolidation settlement of the soft alluvial material. Generally the presence of soft alluvium along the alignment is limited to the river crossing. As there are no properties or other structures vulnerable to the effects of settlement overlying this soft alluvium, the impact of settlement along the river crossing, if it occurs, is considered to be negligible.

Subsidence may also occur where tunnel boring machine (TBM) excavation is proposed under areas of shallow cover or weak ground. One such area has been identified for the Project, between the TBM launch shaft and the Quarry Street road reserve at the Southern Connection. The tunnelling methodology through this section of the Project alignment would need to be specifically tailored to manage the risk of subsidence in overlying material. The reference design proposes an arrangement of supporting structural beams above the main tunnel to support land and infrastructure in this area.

An unconformity exists at the base of the Brisbane Tuff and is documented by published geological records and has been intersected by other tunnelling projects (at the time of assessment the unconformity had not yet been encountered by the geotechnical drilling for the Project). The unconformity may represent a zone of lesser competent (or stronger) rock between the Brisbane Tuff and the Neranleigh-Fernvale Beds. The geometry and nature of this interface represents a risk to proposed tunnelling activities and is required to be delineated and assessed for geotechnical stability before tunnelling commences. There is also the potential for some lateral relaxation of soils, or trench collapse, associated with soil retaining structures that would be required in the vicinity of the surface works (e.g. cut and cover or shaft excavations). Detailed design would be informed by further geotechnical investigations prior to construction which would assist in mitigating this risk.

Preliminary settlement mapping for the Project has been prepared and is provided in **Appendix E**. The potential for damage to structures is dependent on the structure type and the differential settlement across the structure. Generally where differential settlement is less than 1 in 1000 (ratio between vertical and horizontal), property impacts would be negligible.

The range of potential impacts for levels of differential settlement are outlined in **Table 6-4**.

Table 6-4 Potential for damage due to differential settlement

Differential settlement (V:H)	Potential impacts
Less than 1 in 1000	Negligible – hairline cracks less than 0.1mm.
1 in 1000 to 1 in 500	Very slight – potential for cracks less than 1mm.
1 in 500 to 1 in 200	Slight – cracks easily filled. Potential for some door sticking. Potential for cracks less than 5mm.
1 in 200 to 1 in 50	Moderate to severe* – may impact structural elements, service pipes and water tightness. Extensive repair or rebuilding. Cracks from 15mm to >25mm.

Source: based on the work published by Boscardin, M.D. and Cording, E J. (1989).

*Note: *Potential impact is dependent upon limiting tensile strain and maximum settlement of building*

Differential settlement at key areas along the Project alignment is outlined in **Table 6-5.** Generally the potential for property damage is negligible to very slight. Greater potential for impacts occurs around the dive structures, notably the cut and cover tunnels. These areas are not located near sensitive structures and impacts to private properties are not anticipated. Prior to construction, detailed condition surveys of potentially affected structures would be conducted to enable any potential impacts to be made good.

Table 6-5 Differential settlement in key locations

Location	Typical differential settlement (V:H)	Range of absolute settlement	Potential impacts
Woolloongabba Station	1 in 2000 to 1 in 5000	0 to 10mm	Negligible
George Street Station	1 in 2000 to 1 in 5000	0 to 5mm	Negligible
Roma Street Station	1 in 2000 to 1 in 5000	0 to 5mm	Negligible
General TBM tunnel	1 in 1000	0 to 5mm	Negligible
Shallow cover TBM tunnels near Connections (Dutton Park, Quarry Street and Victoria Park)	1 in 600	0 to 20mm	Very slight
Areas adjacent to cut and cover tunnels (Dutton Park and Victoria Park)	1 in 500	5 to 15mm	Very slight
Dive structures (Dutton Park and Victoria Park)	1 in 200	10 to 60mm (within rail corridor)	Slight

An important principle in the Project design has been to minimise excavation by optimising tunnel depth and length within design geometry, geological and other infrastructure and property constraints, and reuse excavated spoil material where possible. In addition:

- there are no key resource areas[3] within the study corridor given the surrounding area is urbanised and former deposits of extractive materials have been effectively sterilised by urban development
- the study corridor is located in an area of very low seismicity such that earthquakes are not considered a significant geological hazard to the Project
- there are no documented fossil sites within the study corridor.

6.3.2 Soils

Erosion risk

Potential erosion and sediment impacts within the study corridor have been considered for:

- surface works associated with construction worksites, stations, track work and road network changes/ upgrades, tunnel portal locations, ancillary surface works and structures, such as service relocation/ installation
- on-site spoil management and waste removal activities.

[3] Key resource areas are locations across Queensland that are identified as containing important extractive resources of state or regional significance worthy of protection for future use.

The soil landscapes likely to be intercepted and disturbed as a result of the Project are illustrated in **Figure 6-5**. The Erosion Hazard Map of South East Queensland (Department of Primary Industries, 1995) indicates that the Project alignment generally intercepts land where the erosion hazard has been assessed as low to negligible.

Areas with slopes greater than 10 per cent gradient are identified at each of the construction worksites at Dutton Park, Woolloongabba and Spring Hill (refer to **Figure 6-11** and **Figure 6-12**).

A review of the gradient differences and soil type erosion risk at the key construction worksites (refer to **Table 6-6**) indicates standard sediment control measures would be appropriate for mitigating this risk. It should be noted that erosion risk at some of these worksites will be reduced through ground surface cover (e.g. concrete or bitumen) and the relatively small extent of the disturbance footprint.

Table 6-6 Summary of erosion risk at construction worksites

Project site	Soil landscape	Erosion risk based on soil type	Slope across the construction worksite	Erosion risk based on slope
Southern Connection	Chermside/ Woodridge	Low to moderate to high	<10% for 90% area	Low
Woolloongabba Station	Chermside	Low to moderate	<10% for 80% area	Low
George Street Station	Beenleigh/ Brisbane River	Moderate to high	<10% for 90% area	Low
Roma Street Station	Moggill Creek	Moderate	<10% for 70% area	Low to moderate
Northern Connection	Beenleigh	Moderate	<10% for 50% area	Moderate to high

Acid sulphate soils and associated risks

Typically disturbance of ASS during construction can result from direct excavation of ASS material, or indirectly through groundwater drawdown exposing the ASS, or downward loading pressure on unconsolidated sediments from stockpile placement. The potential environmental impacts associated with disturbance of ASS include:

- accelerated oxidation of ASS and uncontrolled release of acid leachate
- changes to water chemistry and aquatic ecosystem values of receiving waters
- mobilisation of contaminants from contaminated soils due to contact with acidified groundwater flows.

The probability of ASS presence as mapped within Acid Sulphate Soils – Tweed Heads to Teewah – South East Queensland Map 1 (DSITIA, 2014) is shown in **Figure 6-6**. The probability of ASS presence is considered to be low, within or directly adjacent to the George Street Station. ASS is likely to be absent at all other construction worksites, including Woolloongabba Station, Roma Street Station and the Southern Connection and Northern Connection. As a result, the potential for exposure of ASS from excavation is considered to be low. Some potential exists for oxidisation of PASS due to groundwater drawdown associated with the deep shaft and cavern in the George Street Station. However, given the extent of existing construction (and excavation) in this area, the potential for PASS presence within the drawdown zone (refer to **Chapter 9 – Hydrology**) is considered to be low.

While the assessment indicates the potential for exposure of ASS as a result of the Project is low, further sampling and analysis for ASS would be conducted as part of the detailed geotechnical investigations. This investigation will enable confirmation of the presence or absence, and status of ASS. If the presence of ASS is confirmed, management and mitigation measures in accordance with Queensland Acid Sulphate Soil Technical Manual – Soil Management Guidelines (version 3.8), would be required.

6.3.3 Contamination

This section assesses the potential impacts related to contaminated land during construction and operation of the Project, including:

- disturbance of potentially contaminated material
- contamination from adjacent potentially contaminated sites
- disturbance of asbestos
- unforeseen contamination, including potential for the Project to cause contamination during construction and operation.

The impacts are considered in the following sections for specific construction worksites.

Disturbance of potentially contaminated material

For the purposes of this assessment, a land parcel which is listed on the EMR or which has been identified as an additional potentially contaminated land parcel, is referred to as a 'potentially contaminated site'.

Construction activities located at the surface or which involve excavation of soil have the potential to intercept contaminated material where works occur on land identified as a potentially contaminated site or, to a lesser extent, on land located adjacent to a potentially contaminated site. The disturbance of potentially contaminated soil and/ or groundwater by surface works could occur at 11 potentially contaminated sites across the Project. These are summarised in **Table 6-7** and are shown in **Figure 6-9** and **Figure 6-10**.

Table 6-7 Risk assessment of potentially contaminated properties directly impacted

Lot and plan	Description of Project works location	Potential for contaminant presence
Lot 420 SP116165, Lot 421 SP116165, Lot 195 SP198200	Southern Connection	Notifiable activity 'hazardous contaminant', higher risk of land contamination.
Lot 63 SP184386, Lot 4 SP149278, Lot 1291 CP899829	Woolloongabba Station	Notifiable activity 'railway yards' and 'hazardous contaminant', higher risk of land contamination.
Lot 37 SP169852, Lot 60 SP207215	Roma Street Station	Adjacent containment cell. Notifiable activity 'railway yards', higher risk of land contamination.
Lot 32 SP172136, Lot 34 SP172136, Lot 5 SP123915	Northern Connection	Notifiable activity 'railway yards' and 'hazardous contaminant', higher risk of land contamination.

If encountered, contaminated material would be managed in accordance with the Project's Emergency Response Procedures and Health, Safety and Environment Procedures (including a Construction Occupational Health and Safety Plan). Detailed mitigation measures are described in **Chapter 18 – Draft Outline EMP**.

LEGEND

- Existing rail station
- Existing rail line
- Watercourse

Slope

- Greater than 10%

- Study corridor

Project Infrastructure

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

Alignment

- Above ground
- Underground

Aerial Photo: Brisbane City Council 2012

BUS AND TRAIN PROJECT
ENVIRONMENTAL IMPACT STATEMENT

FIGURE 6-11

Erosion risks - south

N

0 0.25 0.5
Kilometres
1:15,000 (at A4)
Projection: GDA 1994 MGA56

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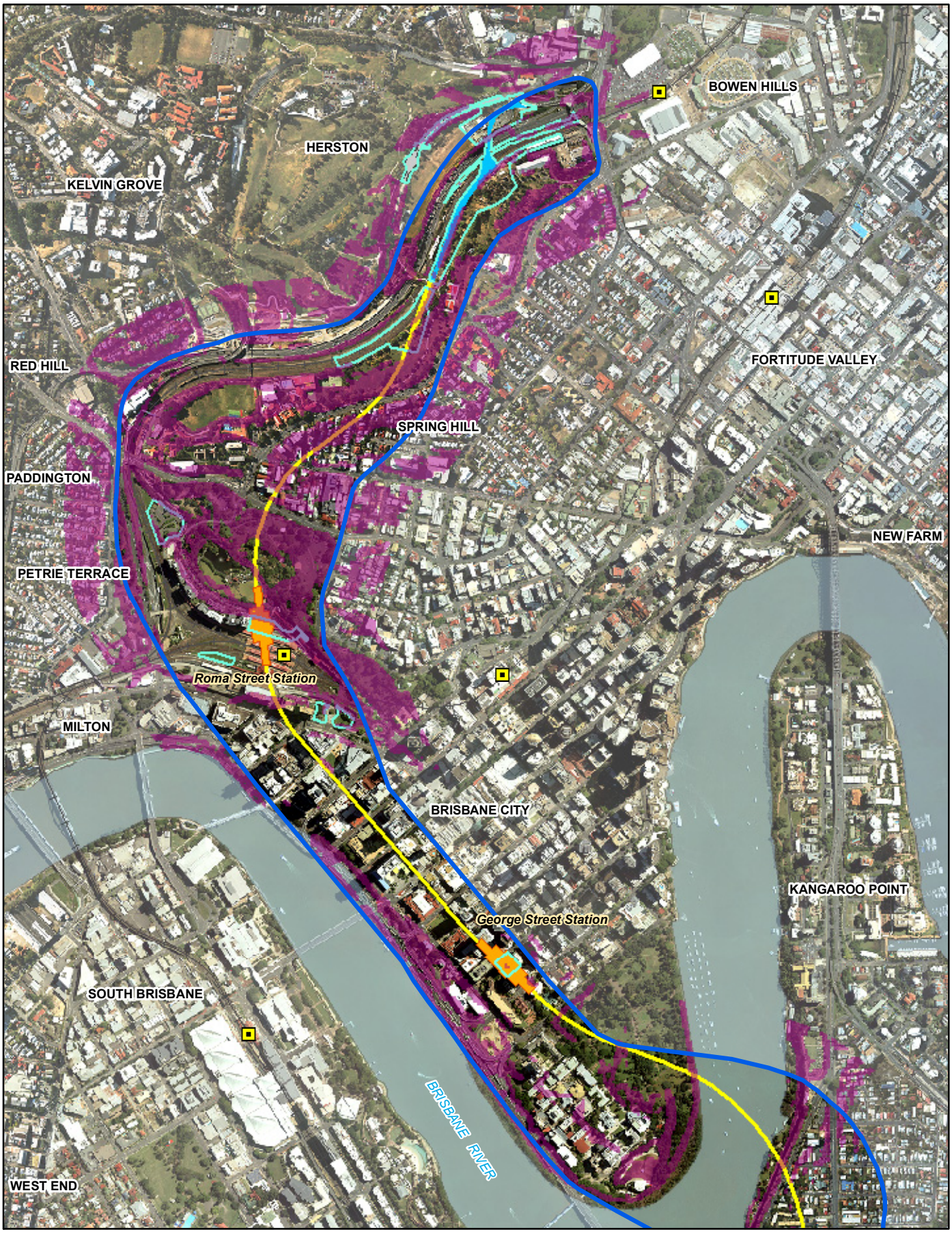

LEGEND

- Existing rail station
- Existing rail line
- Watercourse

Slope

- Greater than 10%

- Study corridor

Project Infrastructure

- Construction worksite
- Underground station
- Bus layover

Alignment

- Above ground
- Underground

BUS AND TRAIN PROJECT
ENVIRONMENTAL IMPACT STATEMENT

FIGURE 6-12

Erosion risks - north

N

0 0.25 0.5
Kilometres
1:15,000 (at A4)
Projection: GDA 1994 MGA56

Aerial Photo: Brisbane City Council 2012

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Contamination from adjacent potentially contaminated sites

In addition to those sites directly impacted as part of the construction worksites, impacts may occur as a result of contamination on adjacent sites. Adjacent sites are those that share a property boundary with the Project's construction worksites.

Ground gas refers to the air or vapour that occupy the spaces between soil particles in the ground and has the potential to pose a risk to human health or result in explosive atmospheres. Where contamination or putrescible (decaying) material in soil or groundwater produces gas or is of a volatile nature, potential exists for the vapour or gas to be noxious.

Based on former land use, contamination associated with Railway Yards (including areas within or adjacent to the Roma Street Parkland and the Woolloongabba GoPrint site) may have the potential to produce noxious or harmful gases. If left unmanaged, it could potentially pose an unacceptable risk to human health during both construction and operation phases of the Project. The potential for ground gas intrusion into subsurface structures would require investigation during the detailed design to ensure that suitable mitigation measures are integrated into Project design.

A conceptual hydrogeological and groundwater drawdown model has been prepared for the Project which identifies the area of land potentially subject to groundwater drawdown. This is described in **Chapter 9 – Hydrology**. Those sites considered to be of higher risk to the Project (refer to **Table 6-8**) include potentially contaminated sites where migration of contamination via groundwater and/ or ground gas is considered more likely.

Table 6-8 Risk assessment of potentially contaminated properties adjacent to construction worksites

Lot and plan	Description of adjacent Project works	Potential for contaminant presence
Lot 702 SP183568	Adjacent to Southern Connection	Notifiable activity Petroleum Product or Oil Storage, higher risk of land contamination.
Lot 61 SP188566	Adjacent to Woolloongabba Station	Notifiable activity Railway Yards, higher risk of land contamination.
Lot 18 RP209685, Lot 4 RP43986, Lot 3 RP43986, Lot 2 RP43986, Lot 2 RP640, Lot 1 RP43986	Adjacent to George Street Station	Notifiable activity Petroleum Product or Oil Storage, higher risk of land contamination.
Lot 1 SP207220	Adjacent to Roma Street Station	Adjacent containment cell. Notifiable activity Petroleum Product or Oil Storage, higher risk of land contamination.

Unforeseen contamination and prevention of contamination

The potential exists for unforeseen contamination to be encountered or for land contamination to occur during construction and operation, such as the accidental spillage or leakage of hazardous materials or waste products. In the event of an incident, environmental health and safety management controls would be implemented, including regulator notifications as required, and the residual risk would be expected to be low. Detailed mitigation measures are described in **Chapter 18 – Draft Outline EMP**.

Site specific impacts

Dutton Park

There is the potential for soil contamination to be intercepted at the southern construction worksites associated with rail operations in the vicinity of the site. Characterisation of soils prior to construction is required to derive specific management measures during construction and operation of the Project.

Asbestos containing materials has been identified in Asbestos Registers for Queensland Rail buildings or structures in this area. Prior to demolition, a licensed asbestos contractor would be required to audit the relevant structures. Asbestos discovered during the audit would be removed prior to commencing demolition. Any asbestos removal would be undertaken under strict controls as detailed in **section 6.4** and **Chapter 18 – Draft Outline EMP**.

Woolloongabba

There is the potential for soil contamination to be present in the vicinity of works at Woolloongabba.

Given the close proximity of the station to potentially contaminated sites, further investigation during detailed design is required to determine the risk of groundwater, or ground gas migration into subsurface infrastructure. Any unacceptable risk to human health identified by further quantitative risk assessment, should be addressed for both construction and operation during detailed design. Provision is also required for secondary impacts associated with the contamination, including increased perishability of polymer or rubber objects including liners, pipework and valves.

Given the fractured rock lithology within the Woolloongabba vicinity, it is possible that the proposed on-site contamination assessment will not capture all contamination likely to be disturbed by the Project. The extent of any contamination at the site may only become evident during construction. Site-specific measures would be required to mitigate any exposure risk to workers in the health and safety protocols.

The asbestos register for the GoPrint site at Woolloongabba indicates that asbestos is present in the building and printery infrastructure. Prior to demolition, a licensed asbestos contractor would be required to audit the relevant structures. Asbestos discovered during the audit would be removed prior to commencing demolition. Any asbestos removal would be undertaken under strict controls as detailed in **section 6.4** and **Chapter 18 – Draft Outline EMP**.

George Street

There is the potential for soil and groundwater contamination associated with uncontrolled fill materials and adjacent petroleum storage to be within the zone of groundwater drawdown at the George Street Station. Characterisation of soils and groundwater prior to construction is required to derive specific management measures during construction and operation of the Project.

The Hazardous Materials Removal Report prepared for 63 George Street (Parsons Brinkerhoff, 2006) indicates potential for asbestos to be present in areas unable to be accessed during previous asbestos removal works.

Prior to demolition, a licensed asbestos contractor would be required to audit the relevant areas of the structure not previously assessed. Asbestos discovered during the audit would be removed prior to commencing demolition. Any asbestos removal would be undertaken under strict controls as detailed in **section 6.4** and **Chapter 18 – Draft Outline EMP**.

Roma Street

There is the potential for soil and groundwater contamination to be present in the vicinity of works at Roma Street.

The location of the containment cell adjacent to the construction worksite should be accurately defined to confirm the Project does not impact its integrity. As the site is outside of the construction worksite, no direct impacts are anticipated. Based on the estimated levels of settlement in this area associated with the Project, the potential for such impacts on the containment cell is considered to be low.

Given the close proximity of the shaft and station to potentially contaminated sites (including the containment cell), further investigation during detailed design is required to determine the risk of groundwater, or ground gas migration into subsurface infrastructure. Any unacceptable risk to human health identified by further quantitative risk assessment, would be addressed for both construction and operation during detailed design. Provision is also required for secondary impacts associated with the contamination, including increased perishability of polymer or rubber objects including liners, pipework and valves.

Considering the fractured rock lithology within the Roma Street vicinity, it is possible that the proposed further on-site assessment would not capture all contamination likely to be disturbed by the Project. The true extent of any contamination at the site may only become evident during construction, and appropriate response measures would be required to mitigate any exposure risk to workers in the health and safety protocols onsite.

The presence of asbestos containing materials was not noted in the Asbestos Registers for Queensland Rail facilities at Platform 10 (Queensland Rail, 2013b). However, there were limitations in the assessment as some areas were not able to be assessed. Given the limitations there is still potential for asbestos to be present in this area.

Prior to demolition, a licensed asbestos contractor would be required to audit the relevant areas of the structures not previously assessed. Asbestos discovered during the audit would be removed prior to commencing demolition. Asbestos removal would be undertaken under strict controls as detailed in **section 6.4** and **Chapter 18 – Draft Outline EMP**.

Spring Hill

There is the potential for soil contamination to be intersected at the Northern Connection associated with rail operations in the vicinity of the site. Characterisation of soils prior to construction is required to derive specific management measures during construction and operation of the Project.

Asbestos containing materials have been noted in the Asbestos Registers for Queensland Rail facilities at this location (Queensland Rail, 2013c). Prior to demolition of the relevant buildings or structures, a licensed asbestos contractor would be required to audit the structure. Asbestos discovered during the audit would be removed prior to commencing demolition. Any asbestos removal would be undertaken under strict controls as detailed in **section 6.4** and **Chapter 18 – Draft Outline EMP**.

6.4 Impact management

6.4.1 Soils, geology and topography

Geotechnical investigation

Further geotechnical work is in progress and interpretive reporting from these investigative works is expected by late 2014. As an output from this ongoing investigation, it is anticipated that broader scope geotechnical work would be recommended to support the detailed design for the Project. This broader geotechnical survey scope is expected to include, as a minimum:

- additional ground investigation (drilling) of targeted ground and geological structures to support future detailed design, with a focus on: stations, cut and cover sections, the Brisbane River crossing, the Normanby Fault, areas of widely spaced investigation boreholes, likely significant geological contacts and faults
- further development of representative groundwater and rock head models for the Project
- a project level structural geological assessment of natural fractures, layers, foliation, shears and soft/ weak/ adverse ground
- assessment of settlement sensitive/ critical structures/ existing services
- numerical analysis of ground models for high risk structures (S1 sewer, George Street buildings, Brisbane Transit Centre, rail corridor at Park Road, retaining walls, roads, residential areas).

Settlement risk

Further comprehensive geotechnical and groundwater investigations would be completed to support detailed design, confirm subsurface conditions and verify the locations of potential settlement impacts, including:

- excavation induced settlement
- groundwater drawdown induced settlement
- local ground relaxation settlement.

Based on these investigations, specific mitigation measures would be identified and incorporated into the detailed design and construction planning for the Project. Detailed design and construction planning is to incorporate measures to limit settlement generally to 25mm or to 50mm in a worst case event, measured at any location within 50 m of the tunnel alignment centreline or the outer walls of an underground station or excavated structure.

If left unmitigated, ground subsidence has been identified as a potential risk during TBM excavation between the TBM launch shaft and Quarry Street. In order to mitigate this risk, the tunnelling methodology would incorporate pipe roofing through this section of the Project alignment as a pre-support to the anticipated shallow cover ahead of TBM excavation.

Pipe roofing is a means of pre-reinforcing the ground ahead of the tunnel face to ensure that the excavation can proceed safely until permanent support structures can be installed. The pipe roof would provide pre-support for the TBM excavation, increasing the stability of the overlying ground through improved load distribution in two ways:

1) Span longitudinally between the unexcavated rock in front of the face and the established segment of tunnel. The pipes will be in-filled with reinforced concrete as the roof is formed.
2) Form an arch in the transverse direction when ground mass around the pipes is grouted.

All buildings, structures, significant landscaping works and heritage landscape features within the areas where surface settlements and possible damage are predicted, would have pre and post construction dilapidation surveys completed. These surveys would be conducted in consultation with property owners, where appropriate. Surveys and other monitoring would be used to identify the effects of settlement, if any, as a consequence of the Project. Monitoring would be conducted from the commencement of underground construction works and dewatering.

If there is a concern that any subsequent ground settlement was caused by the Project, an independent consultant may be engaged to prepare a new building condition survey report and recommendations for repairing building damage established. The actual settlements would be compared to predicted settlements and further mitigating measures taken where required.

Erosion risk

A detailed Construction Erosion and Sediment Control Plan (Construction ESCP) would be developed for the Project in accordance with the guidelines for Best Practice Erosion and Sediment Control (International Erosion Control Association, 2008) and Clause 10.2 of TMR's Transport and Main Roads Technical Standard – MRTS51 Environmental Management (MRTS51), and would form a sub-plan under the overarching Environmental Management Plan. The ESCP would include all mitigation measures required to manage erosion risk for the Project (refer to **Chapter 18 – Draft Outline EMP**), addressing:

- water and wind erosion
- turbidity in freshwater, estuarine and marine environments
- land settlement
- soil mixing, inversion and compaction
- worksite reinstatement.

The Construction ESCP will be based on the information gathered during site-specific soil investigations at each of the worksites prior to construction. Information gathered through these investigations would include confirmation of soil landscapes, soil depth, presence of fill and soil chemical properties. Site-specific soil investigations would, in turn, inform an erosion risk assessment to quantify the erosion potential for each soil type expected to be disturbed during construction. The risk assessment would identify flow paths, suitable spoil stockpile locations, soil cover type, soil stability and high risk soils. This would be done to ensure that erosion and sediment control measures are implemented and adequate to the nature and scale of disturbance. These measures would also include construction worksite reinstatement measures once surface works are complete.

Proposed erosion control measures would be based upon the objective of reducing the risk of erosion during construction by:

- avoiding disturbance of vulnerable surface and subsurface soils
- minimising construction worksite clearing and the extent and duration of soil exposure
- identifying proposed spoil storage locations at construction worksites
- installing spoil enclosure sheds at construction worksites where activities associated with spoil management, handling and removal are to occur
- diverting clean waters around disturbed surfaces and spoil storage locations
- monitoring the effectiveness of installed control measures
- progressive stabilisation and revegetation of disturbed areas, using stored topsoil where practicable.

In addition to erosion control, sediment control devices such as sediment fences, check dams or other techniques would be implemented to slow water flow and enable sediment to settle from the water prior to migrating offsite.

Erosion and sediment control measures are to be maintained in good working order, with any damaged or ineffective measures repaired or replaced following rainfall events or otherwise as required. Additional monitoring and maintenance would be conducted in accordance with the measures specified in **Chapter 18 – Draft Outline EMP.**

Acid sulphate soils

To inform detailed design and construction planning, further ASS investigations would be undertaken, in combination with additional geotechnical survey and in accordance with the current Queensland Acid Sulphate Soils Investigation Team guidelines (Ahern, 1998). These investigations would focus on areas below five metres AHD, where proposed excavation or soil disturbance is to occur.

Should further investigations determine the presence of ASS, mitigation measures for managing ASS in the study corridor would require implementing management and monitoring practices in line with the principles outlined in Dear et al, (2004) Queensland Acid Sulphate Soil Technical Manual – Soil Management Guidelines' (version 3.8). An ASS Management Plan would form a sub-plan under the overarching Environmental Management Plan for the Project (refer to **Chapter 18 – Draft Outline EMP**) and would be implemented from the detailed design phase and extend through to the pre-construction and construction phases.

The ASS Management Plan would be prepared in consultation with the Department of Natural Resources and Mines (DNRM) and would include corrective actions for incident management and remediation, and requirements for validation and verification testing of soils and potentially affected waters prior to release from the construction worksite. Management strategies are to include, but not be limited to:

- neutralising the soils with alkaline material, such as lime
- hydraulic separation via sluicing and/ or hydrocloning
- strategic reburial below groundwater table
- stormwater/ groundwater collection, control and treatment measures.

Monitoring during the disturbance of ASS material would be conducted in accordance with the measures specified in **Chapter 18 – Draft Outline EMP.**

Fossil material

While the likelihood is low, if significant fossil material or finds are encountered during excavation, a suitably qualified specialist would be consulted to determine management or preservation measures as required.

6.4.2 Contamination

Disturbance of potentially contaminated soils

Eleven potentially contaminated sites are expected to be directly affected by the Project. The risk posed from disturbance of contaminated soil and/ or groundwater would be informed by undertaking Stage 1 and Stage 2 (as required) Detailed Site Investigations. Further detailed investigation would include consultation with the land owners, Brisbane City Council and/ or DEHP.

Should consultation not provide adequate information to define the potential risk, further site investigation would be required in accordance with the NEPM and the 'Queensland Guideline for Contaminated Land Professionals' (DEHP, 2012).

A detailed mitigation plan for the construction and operation phases of the Project would be developed following the acquisition of appropriate data. A draft outline of this plan is provided in **Chapter 18 – Draft Outline EMP**.

In accordance with the EP Act, a disposal permit would also be required for the removal and/ or disposal of contaminated soil from land which is recorded on the EMR or CLR to an off-site location.

Construction activities relating to the disturbance, excavation, removal and/ or disposal of contaminated soil and/ or groundwater would be conducted in a manner to prevent environmental harm. To achieve this, specific mitigation measures are to be developed and implemented prior to the commencement of site activities and would include:

- measures for managing generation of contaminated dust during earthworks, including monitoring at adjacent properties and at nearby sensitive receptors
- appropriate erosion and sediment controls and staging of site activities to minimise the extent of disturbed areas, and hence to minimise the potential run-off of contaminated soils
- measures to minimise the exposure of humans and the environment to potentially contaminated soils during excavation activities
- controls for material haulage, such as covering loads or wetting material to reduce airborne dust emissions
- documentation of all contaminated material during transport operations (including the descriptions of processes, personnel and organisations involved in the removal, transportation and placement of contaminated material)
- keep documented records of contaminated material movement and disposal
- appropriate workplace health and safety procedures, including use of personal protective equipment (PPE) and hygiene controls, and documentation of inspections and workplace health and safety compliance throughout construction and operation.

Off-site disposal of contaminated material would be to a licensed landfill facility under a DEHP issued Disposal Permit. Further discussion of waste management is included in **Chapter 15 – Waste**.

Disturbance/ migration of contaminated groundwater

Stage 1 and Stage 2 (as required) detailed site investigations would be undertaken to ascertain the risk posed from disturbance by the Project of potentially contaminated sites. This would include consultation with Brisbane City Council and/ or DEHP.

Where appropriate groundwater information for potentially contaminated sites is not available, targeted groundwater monitoring may be necessary to establish whether contamination is likely to be present in groundwater systems potentially impacted by the Project. The need for targeted groundwater monitoring would be determined based on the anticipated source and nature of contamination for each site. This monitoring would also assist in establishing mitigation measures for construction and operation, such as the need to treat groundwater drawn into the Project infrastructure prior to discharge.

A groundwater monitoring program is proposed to inform and support the construction and operation phases of the Project and is described in **Chapter 9 – Hydrology** and **Chapter 18 – Draft Outline EMP**. This monitoring program would also include triggers to identify mobilisation of contaminated groundwater both in-situ and at drawdown collection points.

Ground gas accumulation in underground infrastructure

Stage 1 and Stage 2 (as required) Detailed Site Investigations would be undertaken to ascertain the risk posed from disturbance by the Project of potentially contaminated sites, including ground gas that may have accumulated from such sites. In particular, these detailed investigations would focus on underground infrastructure to determine ground gas regimes and identify mitigation measures for construction and operation of the Project.

Where further investigations identify potential risks from ground gas, gas monitoring systems and alarms would be fitted in underground infrastructure during construction and operation to assess ambient gas concentrations, including oxygen, methane, carbon dioxide and carbon monoxide.

Where ground gas accumulation in underground work areas and/ or infrastructure is expected to occur, consider appropriate engineering controls to minimise the inflow of ground gas.

Disturbance of asbestos containing materials

An Asbestos Management Plan would be prepared for the Project prior to the commencement of demolition and construction works.

Where buildings or structures are to be partially or fully demolished for the Project, an asbestos audit is to be undertaken by a licensed asbestos contractor prior to commencing demolition. Existing asbestos registers for all buildings, where available, would be reviewed by licensed asbestos removal contractors as part of the Project's Asbestos Management Plan.

Where asbestos is suspected in previously filled areas, analytical testing is required to confirm the presence or absence of asbestos prior to intrusive works. If asbestos is present, management measures for asbestos containing materials would be implemented in accordance with the following:

- EP Act
- *Workplace Health and Safety Act 2011*
- *Workplace Health and Safety Regulation 2011*
- National Code of Practice for the Management and Control of Asbestos in Workplaces 2005
- National Code of Practice for the Safe Removal of Asbestos (2nd Edition) 2005.

Unforeseen contamination and prevention of contamination

Should land contamination be encountered or occur from construction activities, appropriate procedures and measures would be required for the notification, mitigation, investigation, remediation and validation of the contamination. These are documented in **Chapter 18 – Draft Outline EMP**.

During construction, mitigation measures that would be undertaken, should unforeseen contamination be encountered or land contamination occurs from construction activities, include:

- preparation of a Construction Occupational Health and Safety Plan (OH&S Plan), which includes measures to manage exposure of construction workers to potential contaminants in soil and/ or water e.g. through the wearing of PPE and the control of dust during construction

- preparation of a contaminated land management procedure for potentially contaminated sites prior to the commencement of construction, which includes:
  - identification of the likely forms of contamination that could occur (e.g. fuels, oils, paints)
  - procedures for the appropriate storage of hazardous materials in compliance with relevant standards
  - the prevention of land contamination during construction
  - the identification, investigation and management of unforeseen contamination
  - spill response and remediation
  - listing properties on the EMR in accordance with the EP Act
  - the management, remediation and disposal of contaminated soil and/ or spoil generated from properties listed on the EMR/ CLR
  - post construction management and/ or monitoring requirements
  - approval and disposal permits obtained from DEHP for the removal of contaminated soil in accordance with the EP Act, as required.

Specific measures for preventing and managing any spills and leaks of fuels or chemicals are contained within **Chapter 18 – Draft Outline EMP**. These include:

- the proper storage and handling of hazardous materials, such as chemicals, in accordance with relevant Australian Standards and Safety Data Sheets (SDS), to minimise the risk of environmental impact. This documentation, including schedules of potentially hazardous materials on worksites and their relevant SDSs, would be made readily available to all employees and contractors working on the Project
- site training for appropriate materials handling and environmental awareness to encourage good material handling practices, spill management and incident reporting
- siting all hazardous liquid stores above ground on an impervious base within a bund and secured. The base and bund walls would be impermeable to the material(s) stored
- storing smaller quantities of chemicals, fuels and oils in either self-bunded pallets, within a bunded area, or in a bunded container, while storing bulk quantities of diesel in self-bunded tanks or within an appropriately bunded area
- containing waste products such as oil/ water separator waste, sludges and residues within weatherproofed, sealed and bunded areas to prevent any leakages or spills potentially causing environmental harm to soils, surface water or groundwater
- locating spill kits in the vicinity of hazardous material storage areas and training site staff in their use
- securing fences and locking or manning access points to adequately protect construction worksites and storage areas from theft and/ or vandalism
- clearly marking the contents of tanks and displaying notices requiring that the valves and trigger guns be locked when not in use
- undertaking regular inspections of tanks, bunds and storage areas to ensure the integrity of all facilities.

The storage of hydrocarbons and/ or large quantities of chemicals associated with construction and operation of the Project may result in the site being listed on the EMR.

Further details of proposed management measures are provided in **Chapter 18 – Draft Outline EMP**.

6.4.3 Impact management summary

Table 6-9 provides a summary of the measures proposed to manage impacts to soils, geology, topography and contamination associated with the Project.

Table 6-9 Proposed management measures

Impact	Phase	Management measure
Erosion of surface soil and landform stability at construction worksites, particularly at areas of high erosion risk	Construction	• Develop a detailed ESCP for the Project in accordance with the guidelines for Best Practice Erosion and Sediment Control (International Erosion Control Association, 2008) and Clause 10.2 of MRTS51 • The ESCP would form a sub-plan under the overarching Construction EMP and would address: - water and wind erosion - turbidity in freshwater, estuarine and marine environments - land settlement - soil mixing, inversion and compaction - worksite reinstatement
Disturbance of acid sulphate soils during excavation at George Street	Construction	• Prepare an ASS Management Plan in consultation with DNRM and include corrective actions for incident management and remediation, and requirements for validation and verification testing of soils and potentially affected waters prior to release from the construction worksite • Management strategies are to include, but not be limited to: - neutralising the soils with alkaline material, such as lime - hydraulic separation via sluicing and/or hydrocloning - strategic reburial below groundwater table - stormwater/ groundwater collection, control and treatment measures • Conduct monitoring during the disturbance of ASS material in accordance with the following: - monitor daily for the presence of flocculation of iron in surface water drains, mortality of aquatic flora and/or fauna in adjacent waterways, visible corrosion of concrete structures - conduct weekly monitoring of receiving waters predicted to be influenced by drainage from a worksite or construction works involving ASS - conduct monthly groundwater and surface water monitoring in areas hydraulically connected to sites of ASS disturbance - capture, contain, analyse and treat (if necessary) all leachate and runoff from areas excavated below 5m AHD, ASS treatment pads and stockpile areas prior to offsite discharge in compliance with relevant approvals and surface water discharge criteria adopted for the Project

Impact	Phase	Management measure
Settlement impacts to properties during tunnelling	Construction	• Prepare pre and post construction dilapidation surveys for all buildings, structures, significant landscaping works and heritage landscape features within the areas where surface settlements and possible damage may occur • Identify the effects, if any, of settlement as a consequence of the Project, by reviewing the surveys in consultation with property owners, where appropriate • Conduct monitoring from the commencement of underground construction works and dewatering • In the event of settlement, engage an independent consultant to prepare a new building condition survey report and recommendations for repairing building damage established. Actual settlements would be compared to predicted settlements and further mitigating measures taken where required
Disturbance of contaminated soil during excavation at construction worksites	Construction	• Where required, obtain a disposal permit for the removal and/ or disposal of contaminated soil from land which is recorded on the EMR or CLR to an off-site location • Conduct construction activities relating to the disturbance, excavation, removal and/ or disposal of contaminated soil and/ or groundwater in accordance with specific mitigation measures including: - monitor the generation of contaminated dust during earthworks - implement appropriate erosion and sediment controls and staging of site activities to minimise the extent of disturbed areas and the potential run-off of contaminated soils - minimise the exposure of humans and the environment to potentially contaminated soils during excavation activities - implement controls for material haulage, such as covering loads or wetting material, to reduce airborne dust emissions - document all contaminated material during transport operations (including the descriptions of processes, personnel and organisations involved in the removal, transportation and placement of contaminated material) - keep documented records of contaminated material movement and disposal - implement appropriate workplace health and safety procedures, including use of PPE and hygiene controls, and documentation of inspections and workplace health and safety compliance throughout construction and operation
Disturbance of asbestos during demolition or excavation at construction worksites	Construction	• Prepare an Asbestos Management Plan for the Project prior to the commencement of demolition and construction works • Undertake an asbestos audit by a licensed asbestos contractor, where buildings or structures are to be partially or fully demolished for the Project, including a review of applicable registers, prior to commencing demolition

Impact	Phase	Management measure
		• Undertake analytical testing where asbestos is suspected in previously filled areas, to confirm the presence or absence of asbestos prior to intrusive works. If asbestos is present, manage asbestos containing materials in accordance with the relevant legislation and Codes of Practice
Unforseen contamination or encountering of contaminated sites at construction worksites	Construction	• Prepare a Construction OH&S Plan to manage exposure of construction workers to potential contaminants in soil and/ or water e.g. through the wearing of PPE and the control of dust during construction • Prepare a contaminated land management procedure for potentially contaminated sites that includes: - identification of the likely forms of contamination that could occur (e.g. fuels, oils, paints) - procedures for the appropriate storage of hazardous materials in compliance with relevant standards - the prevention of land contamination during construction - the identification, investigation and management of unforeseen contamination - spill response and remediation - listing properties on the EMR in accordance with the EP Act - the management, remediation and disposal of contaminated soil and/ or spoil generated from properties listed on the EMR/ CLR - post construction management and/ or monitoring requirements - approval and disposal permits obtained from DEHP for the removal of contaminated soil in accordance with the EP Act, as required.
Contamination of land through spills and leaks at worksites	Construction	Prevent and manage any spills and leaks of fuels or chemicals by: • storage and handling of hazardous materials, such as chemicals, in accordance with relevant Australian Standards and SDS • provide site training for appropriate materials handling and environmental awareness to encourage good material handling practices, spill management and incident reporting • site all hazardous liquid stores above ground on an impervious base within a bund and secured. The base and bund walls would be impermeable to the material(s) stored • storage of smaller quantities of chemicals, fuels and oils in either self-bunded pallets, within a bunded area, or in a bunded container, while storing bulk quantities of diesel in self-bunded tanks or within an appropriately bunded area • contain waste products such as oil/ water separator waste, sludges and residues within weatherproofed, sealed and bunded areas to prevent any leakages or spills potentially causing environmental harm to soils, surface water or groundwater

Impact	Phase	Management measure
		• provide spill kits in the vicinity of hazardous material storage areas and training site staff in their use • secure fences and locking or manning access points to adequately protect worksites and storage areas from theft and/ or vandalism • clearly mark the contents of tanks and displaying notices requiring that the valves and trigger guns be locked when not in use • undertake regular inspections of tanks, bunds and storage areas to ensure the integrity of all facilities.

6.5 Summary

6.5.1 Soils and topography

The key elements for the topography, geology and soils assessment for the Project are:

- The highest point within the area is on Wickham terrace in Spring Hill (55m AHD) and the lowest point is within the Brisbane River channel (<0m AHD). It is unlikely that there would be significant changes to topographical features as a result of construction activities as many of the surface structures would be located within the vicinity of existing structures.
- The major geological formations within the study corridor comprise of the Palaeozoic 'Brisbane Metamorphics', consisting of the Neranleigh – Fernvale Beds to the north of the Brisbane River and the Triassic sediments of the Aspley formation dominating the study corridor to the south of the Brisbane River. The potential risk of impacts due to settlement is considered to be low.
- Eight main soil types/ landscapes were encountered in the study corridor, including predominantly Beenleigh, with smaller parts of the Logan, Moggill Creek, Toowong and Brisbane River soil types on the northern side of the Brisbane River, and predominantly Chermside, with smaller parts of the Woongoolba and Woodridge soils types on the southern side of the Brisbane River.
- Areas of high erosion risk and steep areas, e.g. greater than 10 per cent gradient, are a potential risk to surface soil and landform stability during construction and are identified at the Southern Connection, Woolloongabba Station and Northern Connection and would require detailed specific soil investigations to quantify the risks associated with accelerated erosion and for developing soil erosion prevention techniques and on-site management plans. Sediment control and mitigation measures to address the risk of accelerated erosion would be developed as ESCPs during the detailed design phase of the Project and incorporated into the EMPs prepared for construction and operation phases of the Project.
- ASS is likely to be absent at the Southern Connection, Woolloongabba Station, Roma Street Station and the Northern Connection. At George Street Station, there is low probability of the presence of ASS within or directly adjacent to areas to be disturbed as a result of the Project.
- Should the presence of ASS be confirmed during the detailed geotechnical investigation, management and monitoring practices in line with the principles outlined in Dear et al, (2004) Queensland Acid Sulphate Soil Technical Manual – Soil Management Guidelines (version 3.8) would be implemented.

6.5.2 Settlement

Settlement in tunnelling projects may arise due to many factors including groundwater drawdown and local ground relaxation effects around excavations and underground openings. The potential for damage to structures as a result of settlement is dependent on the structure type and the differential settlement across the structure. Generally where differential settlement is less than 1 in 1000, property impacts would be negligible.

The potential for settlement impacts to property as a result of the Project are generally negligible to very slight. Greater potential exists surrounding the cut and cover tunnel sections, however, generally impacts are limited to the railway corridors. Pre and post construction dilapidation surveys of all structures predicted to be affected by settlement would be undertaken. These surveys would be conducted in consultation with property owners, where appropriate. Surveys and other monitoring would be used to identify the effects of settlement, if any, as a consequence of the Project

6.5.3 Contamination

The potential for land contamination within the study corridor has been investigated to identify properties which may require further investigation or management as part of the Project works.

An EMR search covering up to 1km beyond the study corridor was conducted and 1,987 listed land parcels were identified. These included:

- 1,067 land parcels were identified with notifiable activities which are considered to be of higher risk
- 920 land parcels were identified with notifiable activities which are considered to be of lower risk
- 45 land parcels are managed under a SMP.

A total of 337 additional properties were identified which were not listed on the EMR but may potentially contain contamination.

A total of 20 land parcels have been identified within the Project's surface works and on adjacent land parcels as containing potential soil and/ or groundwater contamination. These would require further investigation as part of the Project detailed design.

There is a potential that the Project may have the following impacts:

- disturbance of potentially contaminated soils
- disturbance of unexpected contamination
- contamination from potentially contaminated sites adjacent to construction worksites
- migration of potential groundwater contamination
- ground gas accumulation in subsurface structures
- disturbance of asbestos containing materials.

Areas identified as being of key interest for the Project in relation to contaminated land include:

- Railway corridor (including both proposed portals), which is likely to be contaminated from past management practices involving the use of pesticides (including arsenic) and other solvents and oils and the presence of uncertified fill material.
- Roma Street Parkland, which is the site of the former Roma Street goods and freight yards. A known containment cell is present on land adjacent to the construction worksite, and residual soil/ groundwater across the property may contain residual contamination.

- Woolloongabba Station, which was a former railway yard. The property may contain residual soil/ groundwater contamination.
- Asbestos may be present in buildings, structures and possibly fill materials across areas impacted by surface works. Prior to demolition, a licensed asbestos contractor would be required to audit the relevant structures. Asbestos discovered during the audit would be removed prior to commencing demolition.

To assess the impacts of each potentially contaminated site, detailed investigations and consideration of any existing SMPs would be undertaken where required prior to detailed design. Detailed design would incorporate the findings of contamination assessments and any recommended management measures for contaminated soils, groundwater or ground gases.

Off-site disposal of contaminated material would be to a licensed landfill facility. In accordance with the EP Act, a disposal permit would also be required for the removal and/ or disposal of contaminated soil from land which is recorded on the EMR or CLR.

Specific mitigation which would be developed and implemented prior to the commencement of site construction activities. A draft outline of this plan is provided in **Chapter 18 – Draft Outline EMP**.