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M4-M5 Link

Environmental Impact Statement

August 2017

Main Volume Chapters 9 to 15

Volume 1B

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9 Air quality

9.1 Introduction

This chapter describes the methodology used to assess the impacts of the M4-M5 Link project (the project) on regional, local and in-tunnel air quality, the results of that assessment and proposed mitigation measures to avoid or reduce the impacts. **Appendix I** (Technical working paper: Air quality) provides greater detail of the monitoring and modelling methodologies and results.

The Secretary of the NSW Department of Planning and Environment (DP&E) has issued environmental assessment requirements for the project. These are referred to as Secretary's Environmental Assessment Requirements (SEARs). **Table 9-1** sets outs these requirements and the associated desired performance outcome that relates to air quality, and identifies where this has been addressed in this environmental impact statement (EIS).

Table 9-1 SEARs – air quality

Desired performance outcome	SEARs	Where addressed in the EIS
2. Air quality The project is designed, constructed and operated in a manner that minimises air quality impacts (including nuisance dust and odour) to minimise risks to human health and the environment to the greatest extent practicable.	1. The Proponent must undertake an air quality assessment (AQIA) for construction and operation of the project in accordance with the current guidelines.	The full AQIA is reported in **Appendix I** (Technical working paper: Air quality) and summarised in this chapter.
	2. The Proponent must ensure the AQIA also includes the following: (a) demonstrated ability to comply with the relevant regulatory framework, specifically the *Protection of the Environment Operations Act 1997* and the Protection of the Environment Regulation 2010;	Refer to **sections 9.6** and **section 9.7** and **Appendix I** (Technical working paper: Air quality).
	(b) the identification of all potential sources of air pollution and an assessment of potential emissions of PM_{10}, $PM_{2.5}$, CO and NO_2 and other nitrogen oxides and volatile organic compounds (eg BTEX);	Refer to **sections 9.6** and **9.7** and **Annexure A** of **Appendix I** (Technical working paper: Air quality).
	(c) consider the impacts from the dispersal of these air pollutants on the ambient air quality along the proposal route, proposed ventilation outlets and portal, surface roads, ramps and interchanges and the alternative surface road network;	Refer to **sections 9.6** and **9.7** and **Appendix I** (Technical working paper: Air quality).
	(d) assessment of worst case scenarios for in-tunnel and ambient air quality, including a range of potential ventilation scenarios and range of traffic scenarios, including the worst case design maximum traffic flow scenario (variable speed) and worst case breakdown scenario, and discussions of the likely occurrence of each;	Refer to **section 9.7.1** and Annexure L (Ventilation Report) of **Appendix I** (Technical working paper: Air quality).

Desired performance outcome	SEARs	Where addressed in the EIS
	(e) details of the proposed tunnel design and mitigation measures to address – in-tunnel air quality and the air quality in the vicinity of portals and any mechanical ventilation systems (ie ventilation outlets and air inlets) including details of proposed air quality monitoring (including frequency and criteria);	Refer to **Chapter 4** (Project development and alternatives) and **Chapter 5** (Project description) and **Appendix I** (Technical working paper: Air quality).
	(f) a demonstration of how the project and ventilation design ensures that concentrations of air emissions meet NSW, national and international best practice for in-tunnel and ambient air quality, and taking into consideration the approved criteria for the M4 East project and the In-Tunnel Air Quality (Nitrogen Dioxide) Policy;	The NSW criteria applied to the project design and assessment and a comparison with international practice is in **section 9.2.3** and tunnel design is described in **Chapter 5** (Project description).
	(g) consideration of any advice from the Advisory Committee on Tunnel Air Quality on the project, particularly in relation to assessment methodology;	**Section 9.2.1** outlines the consultation with the Advisory Committee on Tunnel Air Quality.
	(h) details of any emergency ventilation systems, such as air intake/exhaust outlets, including protocols for the operation of these systems in emergency situations, potential emissions of air pollutants and their dispersal, and safety procedures;	The ventilation facilities, including emergency systems and their operation, are described in **Chapter 5** (Project description).
	(i) details of in-tunnel air quality control measures considered, including air filtration, and justification of the proposed measures;	The in-tunnel air quality control measures and their justification are described in **section 0** and Annexure L of **Appendix I** (Technical working paper: Air quality).
	(j) details of the proposed mitigation measures to prevent the generation and emission of dust (particulate matter and TSP) and air pollutants (including odours) during the construction of the proposal, particularly in relation to ancillary facilities (such as concrete batching plants), the use of mobile plant, stockpiles and the processing and movement of spoil; and	The proposed mitigation measures to reduce the impact of dust from construction activities are described in **section 9.10.1**.

Desired performance outcome	SEARs	Where addressed in the EIS
	(k) a cumulative assessment of the in-tunnel, local and regional air quality due to the operation of and potential continuous travel through the M4 East and New M5 Motorways and surface roads.	Refer to **section 9.8** and **Appendix I** (Technical working paper: Air quality). An analysis of the potential cumulative impacts is provided in **section 9.7.1** and **Chapter 26** (Cumulative impacts).

9.2 Assessment approach

9.2.1 Overview

The assessment considers the potential air quality impacts during construction and operation of the project. Consideration is also given to the potential cumulative impacts of the project with the other component projects of the WestConnex program of works and related projects that are in proximity to the project and likely to be operational within 10 years of the opening of the project. The assessment includes detailed analysis of the predicted air quality inside the mainline tunnels, including entry and exit ramps, during the operation of the project.

The design and assessment of the project has benefited from data from the design and operation of existing Sydney tunnels. In particular this has enabled evaluation of emissions models for both in-tunnel and external emissions modelling.

Recent air quality assessments for surface roads and tunnels in Australia and New Zealand were reviewed in order to identify the methodologies, tools and findings that could inform the M4-M5 Link assessment. These assessments are presented in Annexure D of **Appendix I** (Technical working paper: Air quality). The findings include details of the pollutants considered, the sources of emission factors, the dispersion models applied, and the approaches used to assess construction impacts.

The following NSW Government agencies and bodies were consulted during the development and preparation of the air quality assessment for the project:

- NSW Environment Protection Authority (NSW EPA)
- NSW Health
- The NSW Government Advisory Committee on Tunnel Air Quality (ACTAQ).

The impacts of construction on air quality from dust and diesel vehicle emissions are assessed using a risk-based approach, based on the likely construction methods and machinery.

The in-tunnel and ambient air quality assessment was undertaken against criteria, or levels of pollutants, that have been adopted by the NSW Government. The *Protection of the Environment Operations Act 1997* (NSW) (POEO Act) provides the legislative authority for the NSW EPA to regulate air emissions in NSW. SEARs for the project refer to the POEO Act and the Protection of the Environment Operations (Clean Air) Regulation 2010 (NSW). Although the Regulation specifies in-stack concentration limits (stacks being the ventilation outlets), these are designed primarily for industrial activities and the limit values are much higher than those imposed for road tunnels in Sydney. For example, Schedule 4 of the Protection of the Environment Operations (Clean Air) Regulation 2010 (NSW), which specifies standards of in-stack concentration for general activities and plant. These standards have values of at least 50 milligrams per cubic metre (mg/m^3) for total particles, at least 350 mg/m^3 for oxides of nitrogen (NO_X), and at least 125 mg/m^3 for carbon monoxide (CO). The project was assessed against the air quality criteria listed in the *Approved Methods for the Modelling and Assessment of Air Pollutants in New South Wales* (NSW EPA 2016) (NSW EPA Approved Methods) (**section 9.2.3**).

Validated computer models have been used to predict:

- In-tunnel air quality
- Changes in ambient air quality arising from the project and other planned infrastructure projects, so that changes in local and regional air quality can be assessed.

The models incorporate meteorology, local topography, the emissions from the future vehicle fleet and the physical characteristics of the motorway, including the tunnel portals and ventilation outlets, and the broader road network.

9.2.2 Terminology

The concentration of a pollutant at a given location includes contributions from various sources.

The following terms have been used in this assessment to describe the concentration of a pollutant at a specific location or receptor:

- **Background concentration** describes all contributing sources of a pollutant concentration other than road traffic. It includes, for example, contributions from natural sources, industry and domestic activity
- **Surface road concentration** describes the contribution of pollutants from the surface road network. It includes not only the contribution of the nearest road at the receptor, but also the net contribution of the rest of the modelled road network at the receptor
- **Ventilation outlet concentration** describes the contribution of pollutants from tunnel ventilation outlets
- **Total concentration** is the sum of the sources defined above: background, surface road and ventilation outlet concentrations. It may relate to conditions with or without the project under assessment
- **The change in concentration** due to the project is the difference between the total concentration with the project and the total concentration without the project, and may be either an increase or a decrease, depending on factors such as the redistribution of traffic on the network as a result of the project.

9.2.3 Air quality criteria

Two types of criteria were used to assess the air quality for the operation of the project. These are ambient or outdoor air quality criteria and in-tunnel criteria. Compliance with ambient air quality standards is an essential consideration during road project design and operation. An ambient air quality standard defines a metric (measure) relating to the concentration of an air pollutant in the ambient air. Standards are usually designed to protect human health, including sensitive people such as children, the elderly and people suffering from respiratory disease. The standards may also relate to other adverse effects such as damage to buildings and vegetation.

The form of an air quality standard is typically a concentration limit for a given averaging period (eg annual mean, 24-hour mean), which may be stated as a ‘not-to-be-exceeded’ value or with some exceedances permitted. Several different averaging periods may be used for the same pollutant to address long-term and short-term exposure.

Air pollutants are often divided into ‘criteria’ pollutants and ‘air toxics’. Criteria pollutants tend to be ubiquitous, ie found everywhere, and emitted in relatively large quantities, and their health effects relatively well known. Air toxics are gaseous or particulate organic pollutants that are present in the air in low concentrations, but are defined on the basis that they are, for example, highly toxic or last a long time in the environment so as to be a hazard to humans, plants or animal life.

NSW EPA Approved Methods

The Australian states and territories manage emissions and air quality. In NSW the statutory methods used for assessing air pollution from stationary sources are listed in the NSW EPA Approved Methods (NSW EPA 2016).

Air quality was assessed in relation to the criteria listed in **Table 9-2**. These criteria include the latest (2016) update of the NSW EPA Approved Methods for particulate matter. The NSW EPA Approved Methods specify air quality criteria for many other substances, including air toxics. The SEARs for the project require an evaluation of volatile organic compounds including the group known as BTEX compounds ie benzene, toluene, ethylbenzene, and xylenes.

Table 9-2 Air quality criteria applicable to the project assessment

Pollutant/metric	Concentration	Averaging period	Source
Criteria pollutants			
CO	30 mg/m^3	1 hour	NSW EPA (2016)
	10 mg/m^3	8 hours (rolling)	NSW EPA (2016)
Nitrogen dioxide (NO_2)	246 µg/m^3	1 hour	NSW EPA (2016)
	62 µg/m^3	1 year	NSW EPA (2016)
Particulate matter less than or equal to 10 micrometre	50 µg/m^3	24 hours	NSW EPA (2016)
	25 µg/m^3	1 year	NSW EPA (2016)
Particulate matter less than or equal to 2.5 micrometre diameter ($PM_{2.5}$)	25 µg/m^3	24 hours	NSW EPA (2016)
	20 µg/m^3 (goal by 2025)	*24 hours*	NEPC[(a)] (2016)
	8 µg/m^3	1 year	NSW EPA (2016)
	7 µg/m^3 (goal by 2025)	*1 year*	NEPC (2016)
Air toxics			
Benzene	0.029 mg/m^3	1 hour	NSW EPA (2016)
PAHs (as b(a)p)[(b)]	0.0004 mg/m^3	1 hour	NSW EPA (2016)
Formaldehyde	0.02 mg/m^3	1 hour	NSW EPA (2016)
1,3-butadiene	0.04 mg/m^3	1 hour	NSW EPA (2016)

Notes:

(a) National Environment Protection Council

(b) Polycyclic aromatic hydrocarbon as benzo(a)pyrene

The application of the assessment criteria is described in the NSW EPA Approved Methods. Further details of the application of the criteria pollutants are presented in section 5.5.3 of **Appendix I** (Technical working paper: Air quality).

National ambient air quality standards (AAQNEPM)

In 1998, Australia adopted a National Environment Protection (Ambient Air Quality) Measure (AAQNEPM), with the goal of ensuring compliance with air quality standards within 10 years of commencement, in order to attain 'ambient air quality that allows for the adequate protection of human health and wellbeing'. The AAQNEPM was extended in 2003 to include advisory reporting standards for $PM_{2.5}$. The standards for particles were further amended in February 2016 with the main changes being as follows (NEPC 2016):

- The advisory reporting standards for $PM_{2.5}$ were converted to formal standards
- A new annual average PM_{10} standard of 25 micrograms per cubic metre (µg/m^3) was established
- An aim to move to annual average and 24 hour $PM_{2.5}$ standards of seven µg/m^3 and 20 µg/m^3 by 2025 was included
- A nationally consistent approach to reporting population exposure to $PM_{2.5}$ was initiated
- The existing five-day allowed exceedance of the 24 hour $PM_{2.5}$ and PM_{10} standards was replaced with an exceptional event rule.

It should be noted that the AAQNEPM is a national monitoring and reporting protocol. The AAQNEPM standards are applicable to urban background monitoring sites, which are broadly representative of population exposure.

The use of any AAQNEPM air quality criteria in relation to the assessment of projects and developments is outside the scope of the AAQNEPM itself, and is decided by the state and territory jurisdictions. The criteria for air quality assessments for projects/developments in NSW are contained in the NSW EPA Approved Methods.

Review of international ambient air quality criteria

For the criteria pollutants included in the assessment, the impact assessment criteria in the NSW EPA Approved Methods (2016) and the AAQNEPM from February 2016 are compared with the World Health Organization (WHO) guidelines and the standards in other countries/organisations in **Table 9-3**. The comparison found:

- For CO, the NSW standards are similar to those in most other countries and organisations
- The NSW standards for NO_2 are more stringent than Canada and the United States Environmental Protection Agency (US EPA), but less stringent than California (USA). The standards in the European Union are numerically lower but the European Union experiences higher background NO_2 levels than NSW
- In the case of PM_{10}, the NSW standard for the 24 hour mean is lower than or equivalent to the standards in force elsewhere, whereas the annual mean standard is in the middle of the range of values for other locations
- The NSW annual average standard for $PM_{2.5}$ is numerically lower than international standards and there is a much lower background concentration in NSW than in the northern hemisphere.

There are differences in implementation of standards regarding where they apply and how many exceedances are permitted. For example, 35 exceedances per year of the 24-hour PM_{10} standard are permitted in the European Union.

Table 9-3 Comparison of international health-related ambient air quality standards and criteria[(a)]

Country/Region/ Organisation	CO			NO_2			PM_{10}		$PM_{2.5}$	
	15 min. (mg/m³)	1 hour (mg/m³)	8 hours (mg/m³)	1 hour (µg/m³)	1 day (µg/m³)	1 year (µg/m³)	24 hours (µg/m³)	1 year (µg/m³)	24 hours (µg/m³)	1 year (µg/m³)
NSW EPA Approved Methods	100(0)[(a)]	30(0)	10(0)	246(0)	-	62	50(0)	25	-25	-8
AAQNEPM	-	-	10(1)[(b)]	246(1)[(b)]	-	62	50(0)	25	25(0)/20(0)[(c)]	8/7[(c)]
WHO	100(0)	30(0)	10(0)	200	-	40	50[(d)]	20	25[(d)]	10
Canada	-	-	-	-	-	-	120[(e,f)]	-[(e)]	28/27[(g)]	10/8.8[(g)]
European Union	-	-	10(0)	200(18)	-	40	50(35)	40	-	25[(h)]
Japan	-	-	22(0)	-	75-115	-	-	-	-	-
New Zealand	-	30[(i)]	10(1)	200(9)	100[(i)]	-	50(1)	20[(i)]	25[(i)]	-
UK	-	-	10(0)[(j)]	200(18)	-	40	50(35)	40	-	25
UK (Scotland)	-	-	10(0)[(k)]	200(18)	-	40	50(7)	18	-	12
United States (USEPA)	-	39(1)	10(1)	190[(l)]	-	100	150(1)	-	35[(m,n)]	12[(m)]
United States (California)	-	22(0)	10(0)	344(0)	-	57	50	20	-	12

Notes:

(a) Numbers in brackets shows allowed exceedances per year for short-term standards. Non-health standards (eg for vegetation) have been excluded
(b) One day per year
(c) Goal by 2025
(d) Stated as 99th percentile
(e) Although there is no national standard, some provinces have standards
(f) As a goal
(g) By 2015/2020
(h) The 25 µg/m³ value is initially a target, but became a limit in 2015. There is also an indicative 'Stage 2' limit of 20 µg/m³ for 2020
(i) By 2020
(j) Maximum daily running eight-hour mean
(k) Running eight-hour mean
(l) 98th percentile, averaged over three years
(m) Averaged over three years
(n) Stated as 98th percentile

In-tunnel air quality

The air quality criteria used to assess and manage air quality in tunnels have changed in recent years as a result of significant changes in vehicle emissions. Traditionally, CO was the key criterion used to protect the health of tunnel users. Following reductions in CO in vehicle emissions, there is relatively more NO_2 in tunnel air than in the past. NO_2 is a respiratory irritant with identified health effects at levels that may be encountered in road tunnels. An extensive review of the scientific literature commissioned by NSW Health found some evidence of health effects from short-term exposure to NO_2 concentrations between 0.2 and 0.5 ppm. No health effects were identified from short-term (20–30 minutes) exposure at NO_2 levels below 0.2 ppm in this review.

For the operating years of the project, NO_2 would be the pollutant that determines the required airflow and drives the design of the tunnel ventilation system for in-tunnel pollution. DP&E issued a report in January 2015 that included discussion on this topic for the NorthConnex project. The Secretary's Environmental Assessment Report for the NorthConnex project states:

'The Department considers that nitrogen dioxide (NO_2) is now the key pollutant of concern for in-tunnel air quality. While carbon monoxide has historically been the basis for in-tunnel criteria in NSW and internationally, improvements in modern vehicle technology mean that NorthConnex will comply with existing health based carbon monoxide standards. By contrast, vehicle emissions of NO_2 have fallen less quickly, and uptake of diesel vehicles (which produce more NO_2 than petrol based vehicles) has risen … Accordingly, it is recommended that the Proponent's design criteria for NO_2 of 0.5 ppm (averaged over 15 minutes) be applied as an average across the tunnel under all operating conditions.'

In February 2016, the ACTAQ issued a document entitled *In-tunnel Air Quality (Nitrogen Dioxide) Policy* (ACTAQ 2016). That document further consolidated the approach taken earlier for the NorthConnex, M4 East and New M5 projects. The policy wording requires tunnels to be *'designed and operated so that the tunnel average nitrogen dioxide (NO_2) concentration is less than 0.5 ppm as a rolling 15-minute average'*. This criterion compares favourably to the international in-tunnel guidelines which range between 0.4 and 1.0 ppm. Examples of in-tunnel NO_2 values for ventilation control from other projects across several countries are summarised in **Table 9-4**.

For M4-M5 Link and the associated integrated analysis of all WestConnex tunnels, the 'tunnel average' has been interpreted as a 'route average', being the 'length-weighted average pollutant concentration over a portal-to-portal route through the system'. Tunnel average NO_2 has been assessed for every possible route through the system and the calculation of this is outlined in section 7.3 of Annexure L of **Appendix I** (Technical working paper: Air quality). The routes assessed the length of all WestConnex tunnels from the western end of the M4 East to the western end of the New M5 and all connections to and from the Rozelle interchange including the Iron Cove Link. The routes assessed are shown in Tables 7-8 and 7-9 in Annexure L of **Appendix I** (Technical working paper: Air quality).

Table 9-4 Comparative in-tunnel NO_2 limits (from ACTAQ In-tunnel Air Quality Policy, NSW Government 2014)

Jurisdiction/project	In-tunnel NO_2 criteria	Design or compliance	Averaging period
NSW/NorthConnex	0.5 ppm tunnel average	Design and compliance	15-minutes
Brisbane City Council/Clem 7 (2007/LegacyWay (2010) tunnels	1 ppm average	Design and compliance	None given
Permanent International Association of Road Congresses (PIARC)	1 ppm tunnel average	Design only	None given
New Zealand	1 ppm	Design only	15-minutes
Hong Kong	1 ppm	Design only	5-minutes

Jurisdiction/project	In-tunnel NO_2 criteria	Design or compliance	Averaging period
Norway	0.75 ppm tunnel midpoint (equivalent to tunnel average)	Design and compliance	15-minutes
France	0.4 ppm	Design	15-minutes

Visibility and particulate matter

Visibility is an important consideration in the design of a road tunnel ventilation system. The visibility is required to be greater than the minimum vehicle stopping distance at the design speed (PIARC 2012). Visibility is reduced by the scattering and absorption of light by particles suspended in the air. The measurement of visibility in a tunnel (using an opacity meter) is based on the concept that a light beam reduces in intensity as it passes through air containing particles or other pollutants.

The amount of light scattering, or absorption, in road tunnels is principally dependent on the composition, diameter and density of the particles in the air. Particles that affect visibility are generally in a size range of 0.4 to 1.0 micrometres (µm). A coefficient of light extinction is used as an indicator of the particulate matter concentration in the tunnel. It is the inverse of visibility. The operational extinction coefficient limit of 0.005 m^{-1} may result in tunnel emissions being visible under congested conditions, but not at sufficient levels to produce hazy conditions (PIARC 2012). The criteria against which the in-tunnel air quality was assessed are shown in **Table 9-5**.

Table 9-5 In-tunnel air quality criteria

Pollutant	Concentration Limit	Unit	Averaging period
In-tunnel average along length of tunnel			
CO	87	ppm	Rolling 15-minute
CO	50	ppm	Rolling 30-minute
NO_2	0.5	ppm	Rolling 15-minute
In-tunnel single point maxima			
CO	200	ppm	Rolling 3-minute
Visibility	0.005	(m^{-1})[(a)]	Rolling 15-minute

Note:

(a) m^{-1} = reciprocal metre: Standard unit of measurement for extinction coefficient

9.2.4 Tunnel ventilation outlets

For tunnels in Sydney, limits are also imposed on the discharges from the ventilation outlets. The limits specified for the NorthConnex, M4 East and New M5 projects are shown in **Table 9-6**. The SEARs for the M4-M5 Link refer to the POEO Act and the Protection of the Environment Operations (Clean Air) Regulation 2010 (NSW).

Table 9-6 Concentration limits for the NorthConnex, M4 East and New M5 ventilation outlets

Pollutant	Maximum value (mg/m^3)	Averaging period	Reference conditions
Solid particles	1.1	1 hour, or the minimum sampling period specified in the relevant test method, whichever is the greater	Dry, 273 K, 101.3 kPa
NO_2 or NO or both, as NO_2 equivalent)	20	1 hour	Dry, 273 K, 101.3 kPa

Pollutant	Maximum value (mg/m^3)	Averaging period	Reference conditions
NO_2	2.0	1 hour	Dry, 273 K, 101.3 kPa
CO	40	Rolling 1 hour	Dry, 273 K, 101.3 kPa
VOC[(b)] (as propane)	4.0[(a)]	Rolling 1 hour	Dry, 273 K, 101.3 kPa

Note:

(a) Stated as 1.0 in the conditions of approval for NorthConnex

(b) Volatile organic compounds

9.2.5 Tunnel portal emission restrictions

A key operating restriction for road tunnels over one kilometre long in Sydney, and indeed in most Australian road tunnels, is the requirement for there to be no emissions of air pollutants from the portals. To avoid portal emissions the polluted air from within a tunnel must be expelled from one or more elevated ventilation outlets along its length. There are some circumstances when portal emissions may be permitted, such as emergency situations and during major maintenance periods.

9.2.6 Pollutants and metrics not assessed

The following pollutants and metrics were not considered to be relevant to the ambient air quality assessment of the project (nor to road transport projects in general):

- Sulfur dioxide (SO_2) – although SO_2 is emitted from road vehicles, SO_2 emissions are directly proportional to the sulfur content of the fuel, and given that petrol and diesel in NSW now contain less than 50 ppm and 10 ppm of sulfur respectively, the emissions of SO_2 are very low. Sulfur dioxide is therefore not a major concern in terms of transport related air quality. Nevertheless, although SO_2 was not included in the ambient air quality modelling for the project, information on emissions and existing air quality has been compiled and provided for completeness in **Appendix I** (Technical working paper: Air quality)
- Lead (Pb) – the removal of lead from petrol means that it is no longer considered to be an air quality consideration in transport-related air quality other than in relation to specific industrial activities, such as smelting
- Total suspended particulates (TSP) – for road transport, TSP can be considered to be equivalent to PM_{10}, and therefore within the controlling standard. While this is certainly the case for exhaust particles, it is possible that some non-exhaust particles are greater than 10 µm in diameter. However, non-exhaust PM is poorly quantified at present
- Ozone (O_3) – because of its secondary and regional nature, ozone cannot practicably be considered in a local air quality assessment
- Hydrogen fluoride (HF) – the standards for HF relate to sensitive vegetation rather than human health, and HF is not a pollutant that is relevant to road vehicle operation.

Ultrafine particles

There are currently no standards for assessment of ‘ultrafine’ particles (UFPs). These are particles with a diameter of less than 0.1 µm. While there is some evidence that particles in this size range are associated with adverse health effects in **Appendix K** (Technical working paper: Human health risk assessment), it is not currently practical to incorporate them into an environmental impact assessment. There are several reasons for this, including the rapid transformation of such particles in the atmosphere, the need to treat UFPs in terms of number rather than mass, the lack of robust emission factors, the lack of robust concentration response functions, the lack of ambient background measurements, and the absence of air quality standards for this particle type.

In relation to concentration response functions, the WHO Regional Office for Europe (2013) has stated the following:

'… the richest set of studies provides quantitative information for $PM_{2.5}$. For ultrafine particle numbers, no general risk functions have been published yet, and there are far fewer studies available. Therefore, at this time, a health impact assessment for ultrafine particles is not recommended.'

As UFPs are a subset of $PM_{2.5}$, any potential health effects from UFPs are included in the dose-response functions for $PM_{2.5}$. For the purpose of the project assessment it has therefore been assumed that the effects of UFPs on health are included in the assessment of $PM_{2.5}$.

9.2.7 Modelling scenarios

Ambient air quality

Two types of scenario were considered for ambient air quality:

- Expected traffic scenarios
- Regulatory worst case scenarios.

Expected traffic scenarios

The seven expected traffic scenarios included in the operational air quality assessment are summarised in **Table 9-7**. The scenarios took into account future changes over time in the composition and performance of the vehicle fleet, as well as predicted traffic volumes, the distribution of traffic on the network and vehicle speeds, as represented in the WestConnex Road Traffic Model version 2.3 (WRTM v2.3). The results from the modelling of these scenarios were also used in the health risk assessment for the project. The NorthConnex project is also included in the WRTM traffic assumptions for traffic forecasts for the years 2023 and 2033.

Table 9-7 Expected traffic scenarios for the operational assessment

Scenario code	Scenario description	Inclusions									
		Existing network	WestConnex projects					Other projects			
			M4 Widening	M4 East	New M5	M4-M5 Link[(a)]	KGRIU[(b)]	Sydney Gateway	WHT[(c)]	Beaches Link	F6 Extension
2015-BY	2015 – Base Year (existing conditions)	✓	-	-	-	-	-	-	-	-	-
2023-DM	2023 – Do Minimum (no M4-M5 Link)	✓	✓	✓	✓	-	✓	-	-	-	-
2023-DS	2023 – Do Something (with M4-M5 Link)	✓	✓	✓	✓	✓	✓	-	-	-	-
2023-DSC	2023 – Do Something Cumulative (with M4-M5 Link and <u>some</u> other projects)	✓	✓	✓	✓	✓	✓	✓	✓	-	-
2033-DM	2033 – Do Minimum (no M4-M5 Link)	✓	✓	✓	✓	-	✓	-	-	-	-
2033-DS	2033 – Do Something (with M4-M5 Link)	✓	✓	✓	✓	✓	✓	-	-	-	-
2033-DSC	2033 – Do Something Cumulative (with M4-M5 Link and <u>all</u> other projects)	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

Notes:

(a) Includes Rozelle interchange and Iron Cove Link

(b) KGRIU = King Georges Road Interchange Upgrade

(c) WHT = Western Harbour Tunnel (a component of the Western Harbour Tunnel and Beaches Link project)

The traffic demand scenarios for the project were represented by the following model years:

- 2012, which was adopted as the existing traffic case to match the year of WRTM calibration. This represented the current road network with no new projects or upgrades. However, for the purpose of the air quality assessment, a 2015 base year was used (see below)
- 2023, which was adopted as the primary forecasting year for the project (ie opening year)
- 2033, which was adopted as the case for 10 years after the opening year, and was considered to allow for full ramp-up of traffic demand as travellers respond to the provision of the fully completed WestConnex, as well as changes in the emission behaviour of the fleet with time.

The expected traffic scenarios are:

- 2015 Base Year (BY): This represented the current road network with no new projects or upgrades (including WestConnex), and was used to establish existing conditions. The main purpose of including a base year was to enable the dispersion modelling methodology to be verified against real-world air pollution monitoring data. The base year also provided a current baseline which helped to define underlying trends in projected emissions and air quality, and gave a sense of scale to the project impacts (ie compared with how emissions and air quality would be predicted to change anyway without the project)
- 2023 Do Minimum (2023-DM): In this scenario it is assumed that the following projects would be completed and open to traffic:
  - M4 Widening
  - M4 East
  - New M5
  - KGRIU.

The M4-M5 Link and other projects (proposed future Sydney Gateway, Western Harbour Tunnel and Beaches Link and F6 Extension projects) are not built. It is called ‘Do Minimum’ rather than ‘Do Nothing’ as it assumes that ongoing improvements would be made to the broader transport network, including some new infrastructure and intersection improvements to improve capacity and cater for traffic growth:

- 2023 Do Something (2023-DS): As for 2023 Do Minimum, but with the M4-M5 Link also completed and open to traffic
- 2023 Do Something Cumulative (2023-DSC): As for 2023 Do Minimum, but with the M4-M5 Link and some other projects (proposed future Sydney Gateway and Western Harbour Tunnel projects) also completed and open to traffic
- 2033 Do Minimum (2033-DM): As for 2023 Do Minimum, but for 10 years after project opening
- 2033 Do Something (2033-DS): As for 2033 Do Minimum, but with the M4-M5 Link also completed and open to traffic
- 2033 Do Something Cumulative (2033-DSC): As for 2033 Do Minimum, but with the M4-M5 Link and all other projects (proposed future Sydney Gateway, Western Harbour Tunnel and Beaches Link and F6 Extension projects) also completed and open to traffic.

Regulatory worst case (RWC) scenarios

The objective of these scenarios was to demonstrate that compliance with the concentration limits for the tunnel ventilation outlets would deliver acceptable ambient air quality. The scenarios assessed emissions from the ventilation outlets only, with concentrations fixed at the limits, ie the maximum pollutant concentrations permitted. This represented the theoretical maximum changes in air quality for all potential traffic operations in the tunnel, including unconstrained and worst case traffic conditions (including heavy congestion) from an emissions perspective, as well as vehicle breakdown situations. The results of the analysis demonstrate the air quality performance of the project if it operates continuously at the limits which is very unlikely. In reality, ventilation outlet concentrations would vary over a daily cycle due to changing traffic volumes and tunnel fan operation. Further information, including the modelled results of the RWC scenarios is provided in **Appendix I** (Technical working paper: Air quality).

In-tunnel air quality

The traffic scenarios for in-tunnel assessment use the same traffic data and assessment years as those used for the ambient air quality assessment except that additional scenarios for traffic travelling at different speeds through the tunnel are also modelled. The in-tunnel scenarios are:

- Expected traffic – these scenarios represent the expected 24 hour operation of the tunnel ventilation system under day-to-day conditions of expected traffic demand. Vehicle emissions are based on the design fleet in the corresponding year
- Regulatory demand traffic – (maximum traffic flow scenarios) – these were included to demonstrate that the ventilation system would meet the air quality criteria under maximum traffic flow for 24 hours, seven days a week
- Worst case operations – traffic speeds between 20 and 80 kilometres per hour were modelled. These scenarios were assessed on the basis that they would represent a worst case in terms of emissions over the shorter term. These were used to determine the level of ventilation required and therefore the design of the ventilation system needed to ensure that all in-tunnel and ventilation outlet limits would be met. Examples of worst case operations are:
  - Congestion (travel speed down to an average of 20 kilometres per hour)
  - Breakdown or minor incident
  - Accident closing a tube
  - Free-flowing traffic at maximum capacity.

9.2.8 Accuracy and conservatism

There is generally a desire for an appropriate level of conservatism in air quality assessments. The reasons for this include:

- Allowing for uncertainty: an assessment on the scale undertaken for this project is a complex, multi-step process that involves a range of assumptions, inputs, models and post-processing procedures. There is an inherent uncertainty in methods used to estimate emissions and concentrations, and there are clearly limits to how accurately any impacts in future years can be predicted. For these reasons, conservatism is built into predictions to ensure that a margin of safety is applied to minimise the risk that any potential impacts are underestimated
- Providing flexibility: it is undesirable to define the potential environmental impacts of a project too narrowly in the early stages of the development process. A conservative approach provides flexibility, allowing for ongoing design refinements within an approved environmental envelope. Conversely, excessive conservatism in an assessment risks overstating potential air quality impacts and associated human health risks. An overly conservative approach may create, or contribute to, unnecessary concerns within the local community and among other stakeholders about the impacts of the project. It may lead to additional or more stringent conditions of approval than necessary, including requirements for the mitigation, monitoring and management of air quality. Overstatement of vehicle contributions to local air quality may also lead to overstating the benefit where vehicle emissions are reduced by the project (AECOM 2014b).

Air quality assessments therefore need to strike a balance between these potentially conflicting requirements. The operational air quality assessment for the project has been conducted, as far as possible, with the intention of providing accurate and realistic estimates of pollutant emissions and concentrations. The general approach has been to use inputs, models and procedures that are as accurate as possible, except where the context dictates that a degree of conservatism is sensible.

However, the scale of the conservatism can be difficult to define, and this can sometimes result in assumptions being overly conservative. By demonstrating that a deliberate overestimate of impacts is acceptable, it can be confidently predicted that the actual impacts that are likely to be experienced in reality would also lie within acceptable limits (AECOM 2014b). A number of key assumptions with implications for conservatism are discussed in **Appendix I** (Technical working paper: Air quality).

9.3 Construction assessment methodology

The main air pollution and amenity considerations at demolition/construction sites are:

- Annoyance due to dust deposition (eg soiling of surfaces at residences) and visible dust plumes
- Elevated PM_{10} concentrations due to on-site dust generating activities
- Increased concentrations of airborne particles and NO_2 due to exhaust emissions from on-site diesel-powered vehicles and construction equipment. Exhaust emissions from on-site plant and site traffic are unlikely to have a significant impact on local air quality, and in the majority of cases they would not need to be quantitatively assessed.

Construction activities can be categorised into four types to reflect their potential impacts. The potential for dust emissions has been assessed for each likely activity in each category:

- **Demolition** is any activity that involves the removal of existing structures
- **Earthworks** covers the processes of soil stripping, ground levelling, excavation and landscaping. Earthworks primarily involve excavating material, haulage, tipping and stockpiling
- **Construction** is any activity that involves the provision of new structures, or modification or refurbishment of existing structures. 'Structures' include buildings, ventilation outlets and roads
- **Track-out** involves the transport of dust and dirt from the construction/demolition site onto the public road network on construction vehicles. These materials may then be deposited and re-suspended by vehicles using the network.

There are other potential impacts of demolition and construction, such as the release of heavy metals, asbestos fibres, silica dust or other pollutants during the demolition of certain buildings such as former chemical works, or the removal of contaminated soils. Specific regulatory procedures govern the actions taken to minimise the risk of harm from release and removal of these materials.

The risk of dust impacts from a demolition/construction site causing loss of amenity and/or health or ecological impacts is related to the following:

- The nature and duration of the activities being undertaken
- The size of the site
- The meteorological conditions (wind speed, direction and rainfall). Adverse impacts are more likely to occur downwind of the site and during drier periods
- The proximity of receptors to the activities
- The sensitivity of the receptors to dust
- The adequacy of the mitigation measures applied to reduce or eliminate dust.

It is difficult to reliably quantify dust emissions from construction activities. Due to the variability of the weather it is impossible to predict what the weather conditions would be when specific construction activities are undertaken. Any effects of construction on airborne particle concentrations would also generally be temporary and relatively short-lived. It is therefore usual to provide a more qualitative type of assessment of potential construction dust impacts.

Construction activities would occur at several sites within the project footprint, as described in **Chapter 6** (Construction work), **section 9.6.2** and **Table 9-13**. Many of these activities would be transitory (ie not permanent). The majority of the project footprint would be underground; however, surface works would be required to support tunnelling activities and to construct surface infrastructure.

The guidance published by the Institute of Air Quality Management (IAQM 2014) was used for the assessment of air quality during construction (**Appendix I** (Technical working paper: Air quality)). The IAQM guidance has been adapted for use in NSW, taking into account factors such as the assessment criteria for ambient PM_{10} concentrations. The potential construction air quality impacts were assessed based on the proposed works, plant and equipment, and the potential emission sources and levels.

The assessment of construction dust using the IAQM procedure is outlined in **Figure 9-1**.

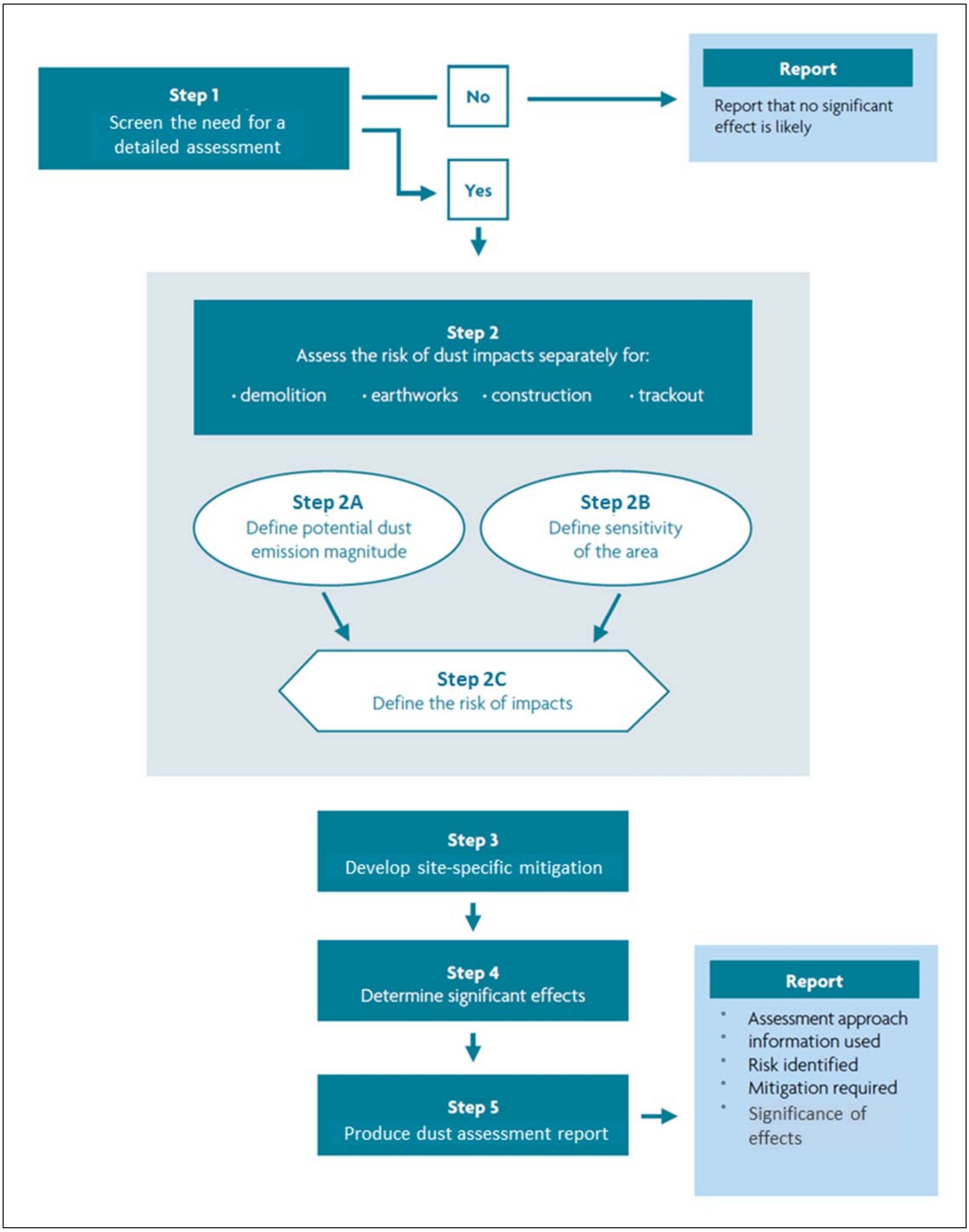

Figure 9-1 Steps in an assessment of construction dust (IAQM 2014)

9.4 Operational assessment methodology

The assessment of operational air quality impacts took into account the emissions from motor vehicles on both surface roads and tunnel roads.

9.4.1 In-tunnel air quality assessment

The project ventilation system is designed for coordinated operation with adjacent tunnel projects (ie the WestConnex M4 East and New M5 projects and the proposed future Western Harbour Tunnel and Beaches Link project), with complete or partial air exchange at project boundaries when necessary to ensure in-tunnel air quality is maintained throughout the tunnel network.

The ventilation system is designed to have complete exchange of tunnel air between the proposed future Western Harbour Tunnel and Beaches Link project and the M4-M5 Link project at the Rozelle ventilation facility. The proposed future Western Harbour Tunnel and Beaches Link project is modelled only for the expected traffic cases, and for the purpose of estimating the emissions captured at the project interface ventilation plant at Rozelle.

In-tunnel traffic, air flows, pollution levels, and temperatures for the project were modelled using the IDA Tunnel software[1]. The criteria, scenarios, data and detailed method that were used in the tunnel ventilation simulations, and the detailed results of the simulations, are provided in full in Annexure L of **Appendix I** (Technical working paper: Air quality).

Route average NO_2 calculations

All possible travel routes through the M4-M5 Link and the adjoining WestConnex tunnels were identified for each direction of travel and assessed against the in-tunnel criterion for NO_2 as an average along any route through the tunnel network. The details of the mathematical formulae and models used are provided in section 7.3 in Annexure L of **Appendix I** (Technical working paper: Air quality). Tables 7.8 and 7.9 in Annexure L of **Appendix I** (Technical working paper: Air quality) list the 28 routes assessed in the M4 Motorway to M5 Motorway direction and the 31 routes assessed in the M5 Motorway to M4 Motorway direction.

For routes that would ultimately incorporate the proposed future Western Harbour Tunnel, the route average NO_2 has been calculated as beginning or ending at the respective interface with the M4-M5 Link. As each portion of the entire route would meet the air quality criterion on its own, the average of the entire route from origin portal to destination portal would meet, or be better than, the air quality criterion. Similarly, routes including the proposed future F6 Extension have been assessed on the basis of starting or ending at the proposed entry and exit portals near President Avenue at Rockdale and so the F6 Extension ventilation system would be required to be achieve the same criterion.

9.4.2 Ambient air quality assessment

The operational ambient air quality assessment was based on the GRAMM/GRAL modelling system. This system consists of two main modules: a prognostic wind field model (GRAMM) and a dispersion model (GRAL). The elements of the system are shown in **Figure 9-2** and summarised below. Full details of the methodology are presented in **Appendix I** (Technical working paper: Air quality).

The GRAL dispersion model is a three-dimensional model used to predict pollutant concentrations. It is suitable for regulatory applications and can use a full year of meteorological data. It predicts pollutant concentrations under low wind speed conditions (less than one metre per second) more accurately than Gaussian models (eg CALINE). It is specifically designed for the simultaneous modelling of surface roads, point sources (tunnel ventilation outlets) and tunnel portals (where relevant).

[1] http://www.equa.se/en/tunnel/ida-tunnel/road-tunnels.

GRAL models pollution dispersion in complex local terrain and topography, including the presence of buildings in urban areas. It has been validated in a wide range of studies featuring complex and flat terrain, and with different meteorological conditions such as high and low wind velocities, and stable or unstable atmospheric conditions (refer to Annexure J of **Appendix I** (Technical working paper: Air quality) and is not inherently conservative (see discussion of conservatism in **section 9.2.8**).

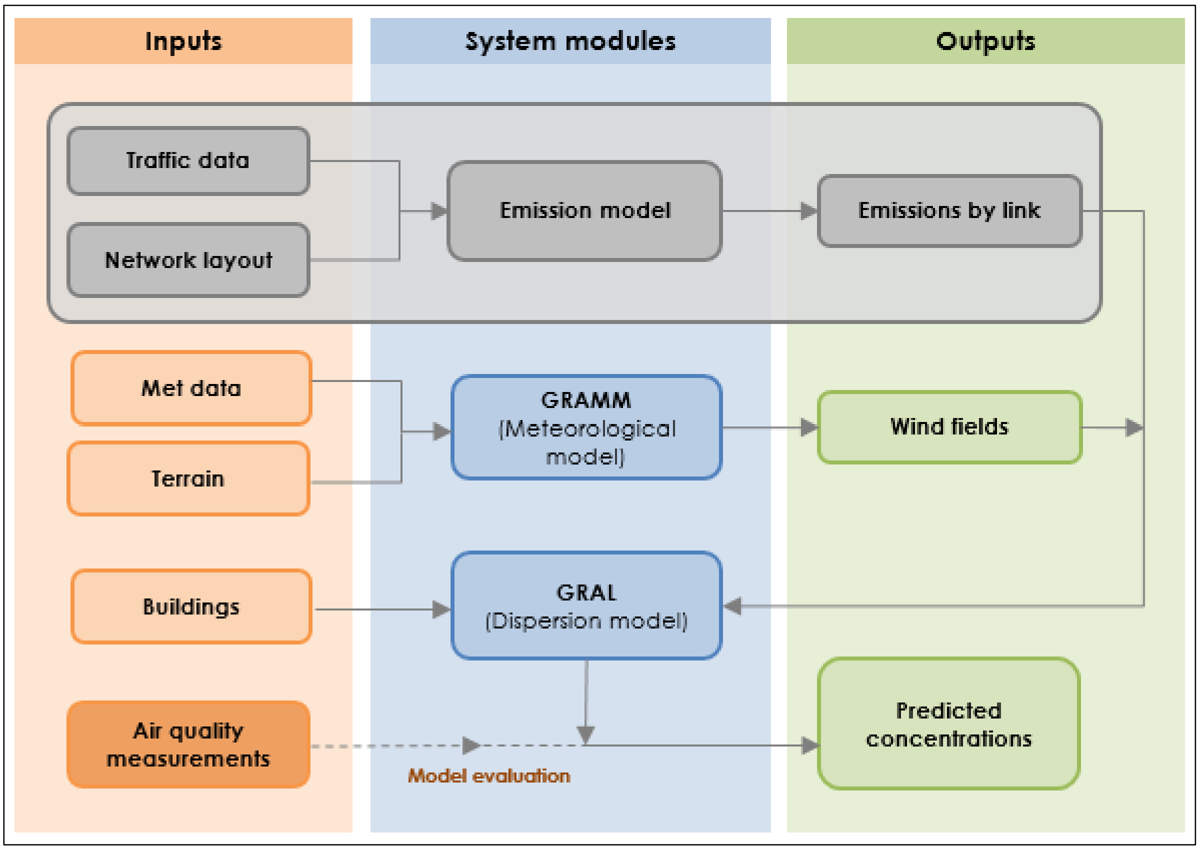

Figure 9-2 Overview of the GRAMM/GRAL modelling system

The GRAMM/GRAL system has been used in the assessment of major projects including the Waterview Connection tunnels near Auckland, New Zealand, and more recently for the assessment of the WestConnex M4 East and New M5 projects. The model set up for this project has been tailored to suit the needs of both the project and the regulatory requirements in NSW in relation to air quality. The GRAL model is described in more detail in **Appendix I** (Technical working paper: Air quality).

The overall performance of the GRAMM-GRAL system was evaluated by comparing the predicted and measured concentrations at multiple NSW Office of Environment and Heritage (OEH), NSW Roads and Maritime Services (Roads and Maritime) and Sydney Motorway Corporation (SMC) air quality monitoring stations in 2015. The model predictions were based upon the WRTM data for the 2015 Base Year scenario. The method and results of the evaluation are given in Annexure J of **Appendix I** (Technical working paper: Air quality).

Sensitivity tests

Sensitivity tests were conducted to investigate the effects of varying the key assumptions in the ambient air quality assessment. These included:

- The influence of ventilation outlet temperature
- The influence of ventilation outlet height
- The inclusion of buildings near tunnel ventilation outlets.

These tests were based on a sub-area of the New M5 GRAL domain of about three kilometres by three kilometres around the project's western ventilation outlet. Only the ventilation outlet contribution, and annual mean $PM_{2.5}$ and maximum 24 hour $PM_{2.5}$, were included in the sensitivity tests. A sub-set of sensitive receivers was evaluated. The predicted concentrations were indicative as the aim of the sensitivity tests was to assess the proportional sensitivity of the model to specific input parameters.

As the outcomes of the tests from both the M4 East and New M5 projects were very similar, the tests were not repeated for this project, and it was assumed that the previous outcomes would apply to the M4-M5 Link project.

Definition of modelling domains

The modelling domains for the project are shown in **Figure 9-3**. The following terms are used in this report to describe the different geographical areas of the assessment:

- The GRAMM domain (also referred to as the 'study area') is shown by the red boundary in **Figure 9-3**. This was used for the modelling of meteorology, and covers a substantial part of Sydney, extending 23 kilometres in the east−west (x) direction and 23 kilometres in the north−south (y) direction
- The WestConnex GRAL domain for dispersion modelling is shown by the black boundary in **Figure 9-3**. This extended 12 kilometres in the east−west (x) direction and 12 kilometres in the north−south (y) direction. The domain extended well beyond the project itself to allow for the traffic interactions between the project, other WestConnex projects (M4 Widening, KGRIU, M4 East, and New M5) and related projects (proposed future Sydney Gateway, Western Harbour Tunnel and Beaches Link and F6 Extension projects). Having a relatively large GRAL domain also increased the number of meteorological and air quality monitoring stations that could be included for model evaluation purposes.

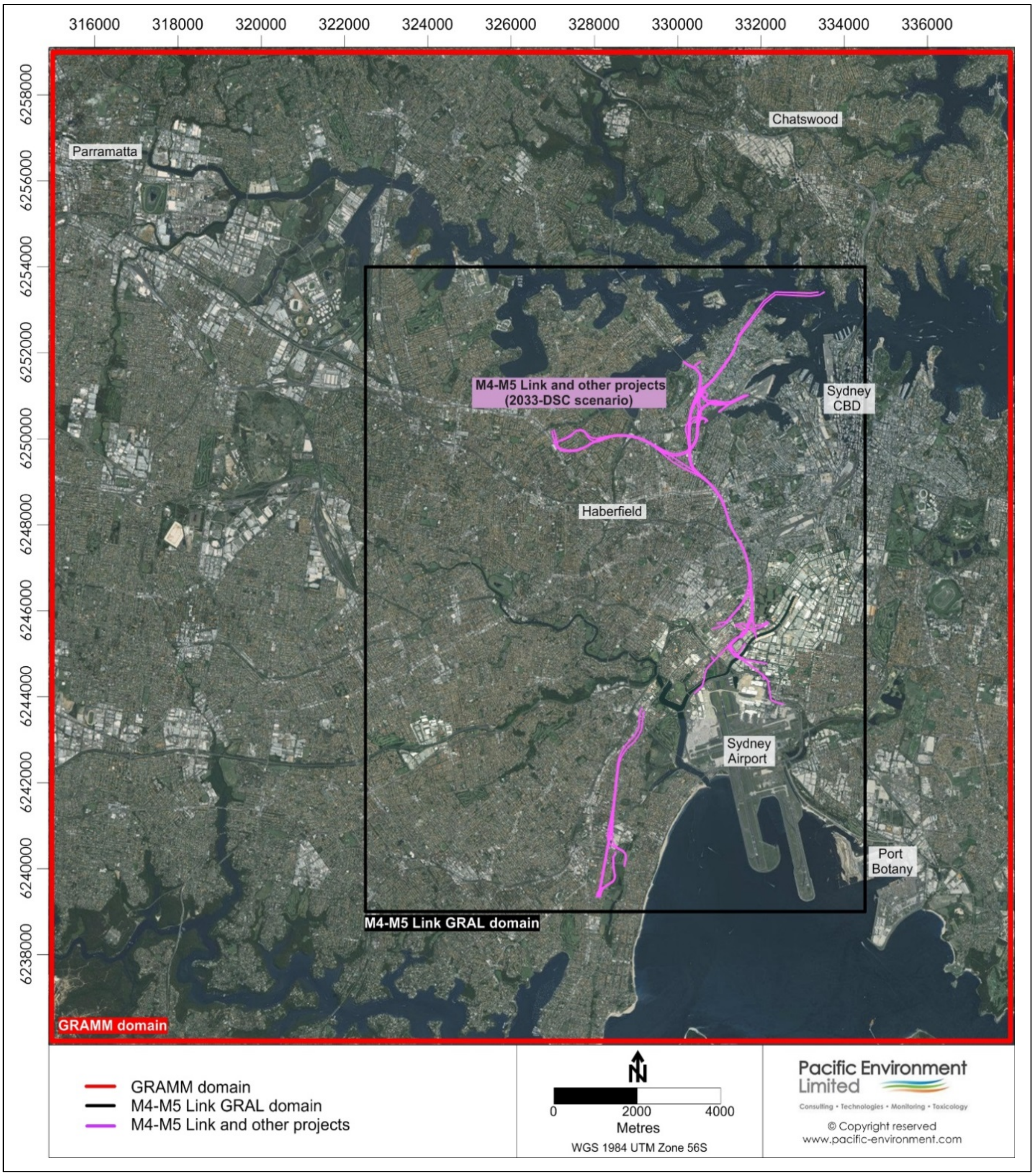

Figure 9-3 Modelling domains for GRAMM and GRAL (grid system MGA94)

Determination of components of assessment

The various pollutant concentrations were determined as follows:

- Background concentrations were based on measurements from air quality monitoring stations at urban background locations in the study area, but well away from roads (as defined in Australian Standard AS/NZS 3580.1.1:2007 – Methods for sampling and analysis of ambient air – Guide to siting air monitoring equipment). The approaches used to determine long-term and short-term background concentrations are explained in Annexure F of **Appendix I** (Technical working paper: Air quality). Background concentrations were assumed to remain unchanged in future years

- Separate estimates were made for the surface road concentrations and ventilation outlet concentrations using the GRAL dispersion model
- For all pollutants except NO_2, the project increment was equal to the difference between the road concentration (surface roads and ventilation outlets), with and without, the project. A different method was required for NO_2 to account for the change in atmospheric chemistry in the roadside environment (refer to Annexure G of **Appendix I** (Technical working paper: Air quality)).

Discrete receptors

Receptors are defined by NSW EPA as anywhere people work or reside, or may work or reside, including residential areas, hospitals, hotels, shopping centres, playgrounds and recreational centres. Due to its location in a highly built-up area, the project modelling domain contains a large number of sensitive receptors. Many of these sensitive receptors are located immediately adjacent to the existing major road network.

Receptors locations are identified on a geographical information system (GIS) and a remote sensing method termed LIDAR (light detection and ranging) was used to identify structures within the air quality modelling domain to represent buildings. Not all the structures identified by LIDAR are inhabitable buildings, so that for example, fuel tanks and containers are included in the dots on the map that represent discrete receptors. For this reason, where any pollutant levels of concern are identified, these locations were examined to determine whether or not they represent real world exposure of people.

Two types of discrete receptor locations were defined for use in the assessment:

- 'Community receptors': These were taken to be representative of particularly sensitive locations such as schools, childcare centres and hospitals within a specified zone around 500–600 metres either side of the project footprint, and generally near significantly affected roadways. For these receptors, a more detailed method was used to calculate the total concentration of each pollutant. In total, 40 community receptors were included in the assessment and these are listed in **Table 9-8**
- 'Residential, workplace and recreational (RWR) receptors': These were all discrete receptor locations along the project footprint, and were generally residential and commercial land uses. For these receptors a simpler[2] statistical approach was used to combine a concentration statistic for the modelled roads and outlets (eg maximum 24 hour mean PM_{10}) with an appropriate background statistic. In total, 86,375 RWR receptors were included in the assessment (this included the 40 community receptors). The RWR receptors are discrete points at ground level – where people are likely to be present for some period of the day – classified according to the land use identified at that location. The RWR receptors do not identify the number of residential (or other) properties at the location; the residential land use at an RWR receptor location may range from a single-storey dwelling to a multi-storey, multi-dwelling building. The RWR receptors are not designed for the assessment of changes in total population exposure. The Technical working paper: Human health risk assessment (**Appendix K**) combines the air quality information with the highest resolution population data from the Australian Bureau of Statistics to calculate key health indicators that reflect varying population density across the study area.

Figure 9-4 shows the locations of the various discrete receptors.

[2] The simplification only related to short-term metrics. Annual mean concentrations were equally valid for both types of receptor.

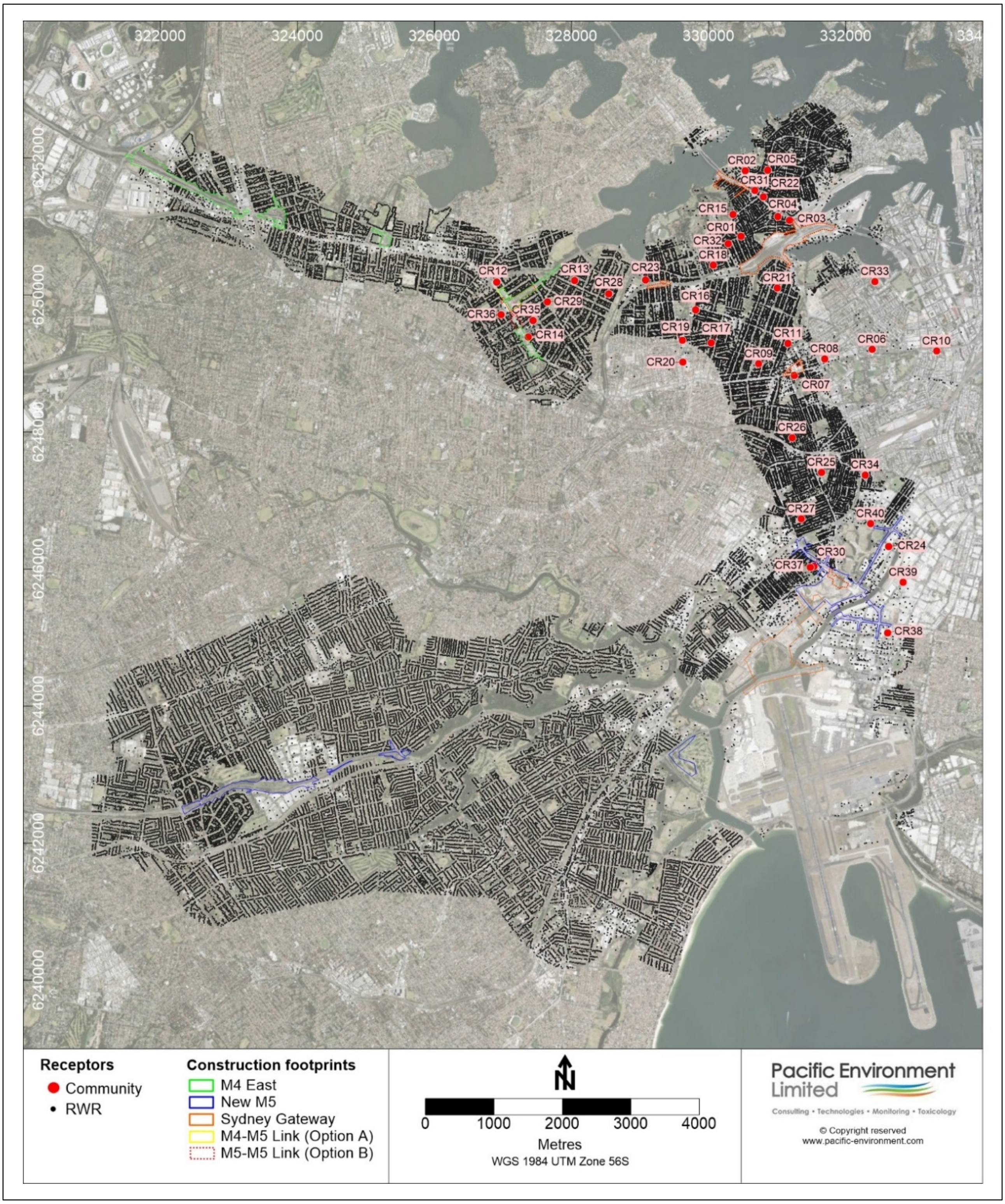

Figure 9-4 Modelled discrete receptor locations

The numbers of RWR receptors are listed by category in **Table 9-9**. Forty particularly sensitive receptors along the project corridor were identified as community receptors. These were included in the RWR categories and assessment but were subject to more detailed assessment than the other. RWR receptors. The community receptors included, for example, aged care facilities and schools. Further discussion of the assessment of the receptors is in **Appendix I** (Technical working paper – Air quality).

The list of RWR receptors was based upon the receptors defined for the three separate WestConnex project corridors (M4 Widening, M4 East, KGRIU, New M5 and M4-M5 Link) and the F6 Extension. Receptors locations in proximity to the indicative Sydney Gateway and F6 Extension designs were included to enable an assessment of the cumulative impacts of these projects. The following were excluded:

- Any receptors outside the GRAL domain for the M4-M5 Link
- Any receptor locations that would be removed for construction of surface roads and facilities
- Any receptors that were duplicated across projects.

Table 9-8 Full list of community receptors (grid system MGA94)

Receptor code	Receptor name	Address	Suburb
CR01	The Jimmy Little Community Centre	19 Cecily Street	Lilyfield
CR02	Balmain Cove Early Learning Centre	35 Terry Street	Rozelle
CR03	Rosebud Cottage Child Care Centre	5 Quirk Street	Rozelle
CR04	Sydney Community College	2A Gordon Street	Rozelle
CR05	Rozelle Total Health	579 Darling Street	Rozelle
CR06	Laurel Tree House Child Care Centre	61 Arundel Street	Glebe
CR07	Bridge Road School	127 Parramatta Road	Camperdown
CR08	NHMRC Clinical Trials Centre	92-94 Parramatta Road	Camperdown
CR09	Annandale Public School	25 Johnston Street	Annandale
CR10	The University of Notre Dame Australia	Broadway	Chippendale
CR11	Laverty Pathology	34C Taylor Street	Annandale
CR12	Little VIPs Child Care Centre	113 Dobroyd Parade	Haberfield
CR13	Dobroyd Point Public School	89 Waratah Street	Haberfield
CR14	Peek A Boo Early Learning Centre	183 Parramatta Road	Haberfield
CR15	Rozelle Child Care Centre	450 Balmain Road	Lilyfield
CR16	Sydney Secondary College Leichhardt Campus	210 Balmain Road	Leichhardt
CR17	Rose Cottage Child Care Centre	1 Coleridge Street	Leichhardt
CR18	Inner Sydney Montessori	10 Trevor Street	Lilyfield
CR19	Leichhardt Little Stars Nursery & Early Learning Centre	10 Wetherill Street	Leichhardt
CR20	Leichhardt Montessori Academy	67 Norton Street	Leichhardt
CR21	St Basil's Sister Dorothea Village	252 Johnston Street	Annandale
CR22	St Thomas Child Care Centre	668 Darling Street	Rozelle
CR23	Billy Kids Lilyfield Early Learning Centre	64 Charles Street	Lilyfield
CR24	Little Learning School	95 Burrows Road	Alexandria

Receptor code	Receptor name	Address	Suburb
CR25	Newtown Public School Combined Out of School Hours Care	Norfolk Street	Newtown
CR26	The Athena School	28 Oxford Street	Newtown
CR27	Camdenville Public School	Laura Street	Newtown
CR28	St Joan of Arc Home for the Aged	7 Tillock Street	Haberfield
CR29	Inner West Education Centre	207 Ramsay Street	Haberfield
CR30	St Peters Community Pre-school	Church Street	St Peters
CR31	Rozelle Public School	663 Darling Street	Rozelle
CR32	Lilyfield Early Learning Centre	2/6 Justin Street	Lilyfield
CR33	Sydney Secondary College Blackwattle Bay	Taylor Street	Glebe
CR34	Erskineville Public School	13 Swanson Street	Erskineville
CR35	Haberfield Public School	Bland Street	Haberfield
CR36	The Infants Home	17 Henry Street	Ashfield
CR37	St Peters Public School	Church Street	St Peters
CR38	Active Kids Mascot	18 Church Avenue	Mascot
CR39	Alexandria Early Learning Centre	3/100 Collins Street	Alexandria
CR40	Sydney Park Childcare Centre	177 Mitchell Road	Alexandria

Table 9-9 Summary of RWR receptor types

Receptor type	Number	% of total
Aged care	20	0.02%
Childcare/pre-school	130	0.15%
Commercial	2,765	3.20%
Community	1,941	2.25%
Further education	18	0.02%
Hospital	4	0.00%
Hotel	30	0.03%
Industrial	2,093	2.42%
Medical practice	125	0.14%
Mixed use	514	0.60%
Park/sport/recreation	1,018	1.18%
Place of worship	106	0.12%
Residential	75,157	87.01%
School	206	0.24%
Other[(a)]	2,248	2.60%
Total	**86,375**	**100.00%[(b)]**

Note:

(a) 'Other' includes car parks, garages, veterinary practices, construction sites, certain zoning categories (DM – Deferred Matter; G – Special Purposes Zone – Infrastructure; SP1 – Special Activities; SP2 – Infrastructure) and any other unidentified types

(b) Total of receptor types does not add up to exactly 100 per cent due to rounding

Elevated receptors

The main emphasis in the assessment was on ground-level concentrations (as specified in the NSW EPA Approved Methods). However, at a number of locations in the GRAL domain there are multi-storey residential and commercial buildings. The potential impacts of the project at these elevated points are likely to be different to the impacts at ground level, and therefore these were assessed separately.

Building heights were not available for all locations in the GRAL domain but height information was available for a sample of around 94,000 buildings. The locations and heights of the buildings in the sample are shown in **Figure 9-5**, and the overall frequency distribution is shown in **Figure 9-6**.

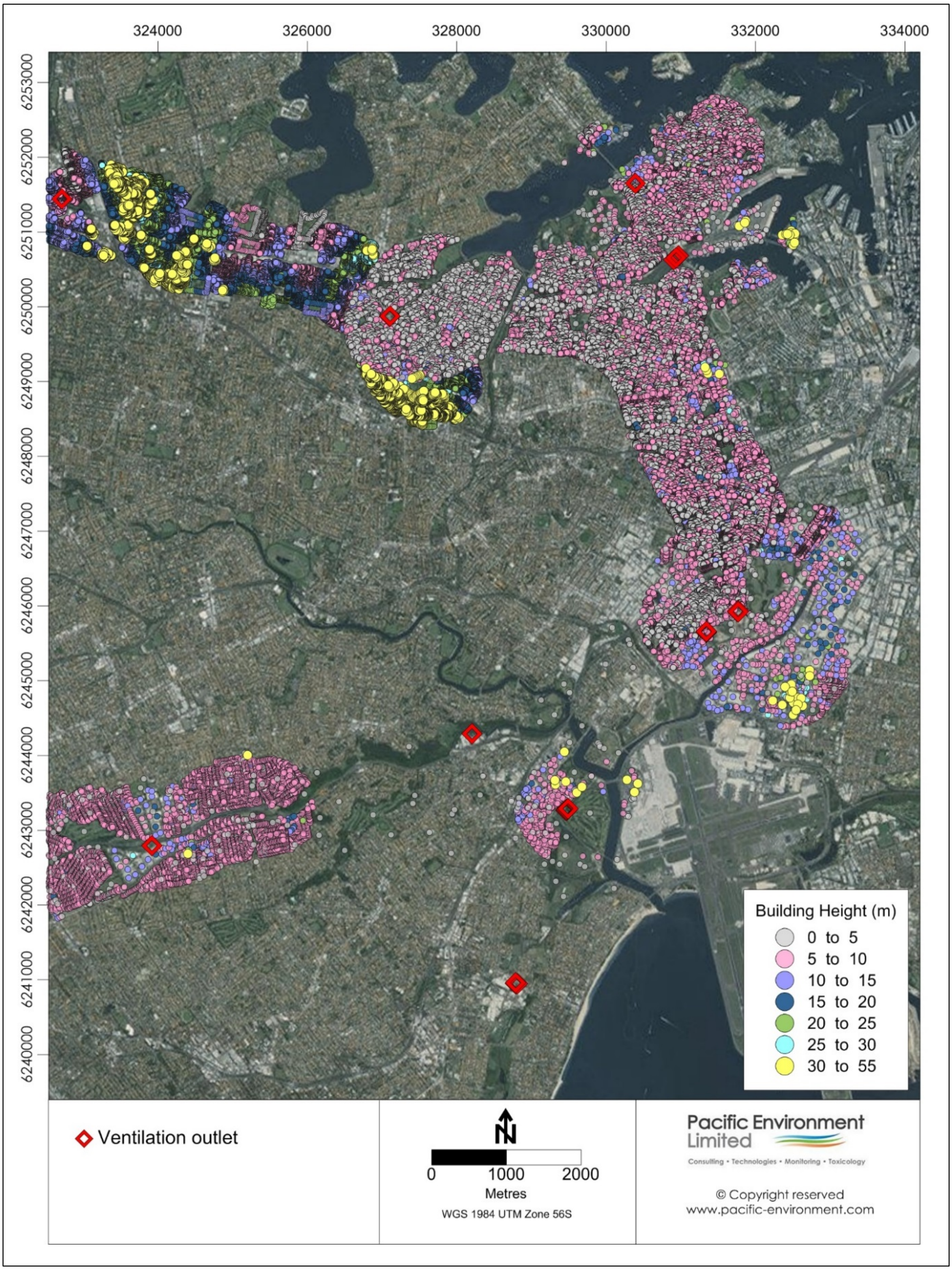

Figure 9-5 Sample of building heights in the GRAL domain (grid system MGA94)

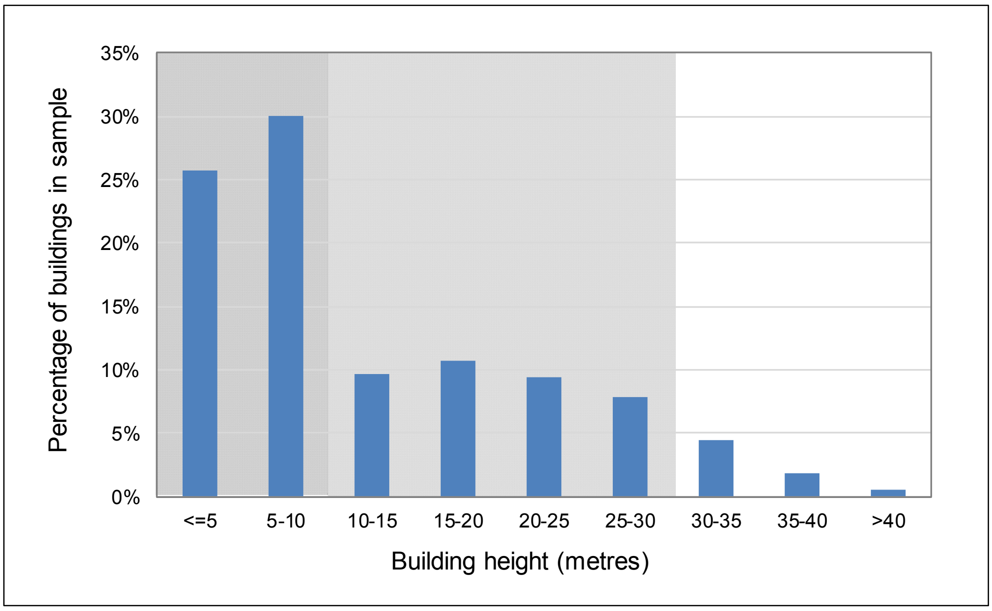

Figure 9-6 Frequency distribution of building heights

More than half (55 per cent) of the buildings had a height of less than 10 metres, and more than 93 per cent had a height of less than 30 metres. A very small proportion (less than 0.5 per cent) of buildings had a height of more than 40 metres. None of the buildings within at least 50 metres of the M4-M5 Link had a height of more than 30 metres, although there were some buildings in the general area of the New M5 Arncliffe ventilation outlet that were taller than 30 metres. Based on this assessment, two elevated receptor heights were selected to cover both existing buildings and future developments: 10 metres and 30 metres. For both heights a full modelling run across the GRAL domain was conducted to identify areas where planning controls may be needed to guide future high-rise developments.

This part of the assessment did not cover all pollutants and averaging periods. The focus was on the changes in annual average and maximum 24-hour $PM_{2.5}$ concentrations in the 2033-DSC scenario. Background concentrations were not taken into account, as these could not be quantified at elevated locations.

The GRAL model was used to predict $PM_{2.5}$ concentrations associated with both surface roads and tunnel ventilation outlets. The following cases were assessed:

- 2033-DM at a height of 10 metres
- 2033-DM at a height of 30 metres
- 2033-DSC at a height of 10 metres
- 2033-DSC at a height of 30 metres
- Changes in annual and maximum 24 hour $PM_{2.5}$ (2033-DSC minus 2033-DM) at a height of 10 metres
- Changes in annual and maximum 24 hour $PM_{2.5}$ (2033-DSC minus 2033-DM) at a height of 30 metres.

Ventilation outlets

Method

Emissions were determined for 14 different tunnel ventilation outlets. All ventilation outlets for tunnels in the domain were included, with the exception of the outlet for the Cross City Tunnel. The Cross City

Tunnel outlet was excluded because it is very close to the eastern boundary[3] of the domain, has relatively low volumes of traffic and therefore low emissions, and because of the distance between the outlet and the receptors included in the assessment the Cross City Tunnel outlet would not have a material impact on the results of the assessment.

Locations and height

The locations and heights (above ground level) of the ventilation outlets included in the assessment are given in **Table 9-10** and shown in **Figure 9-7**. The ventilation outlets for the proposed future F6 Extension are subject to further stages of the project development process by the NSW Government. The locations and height shown here are therefore indicative.

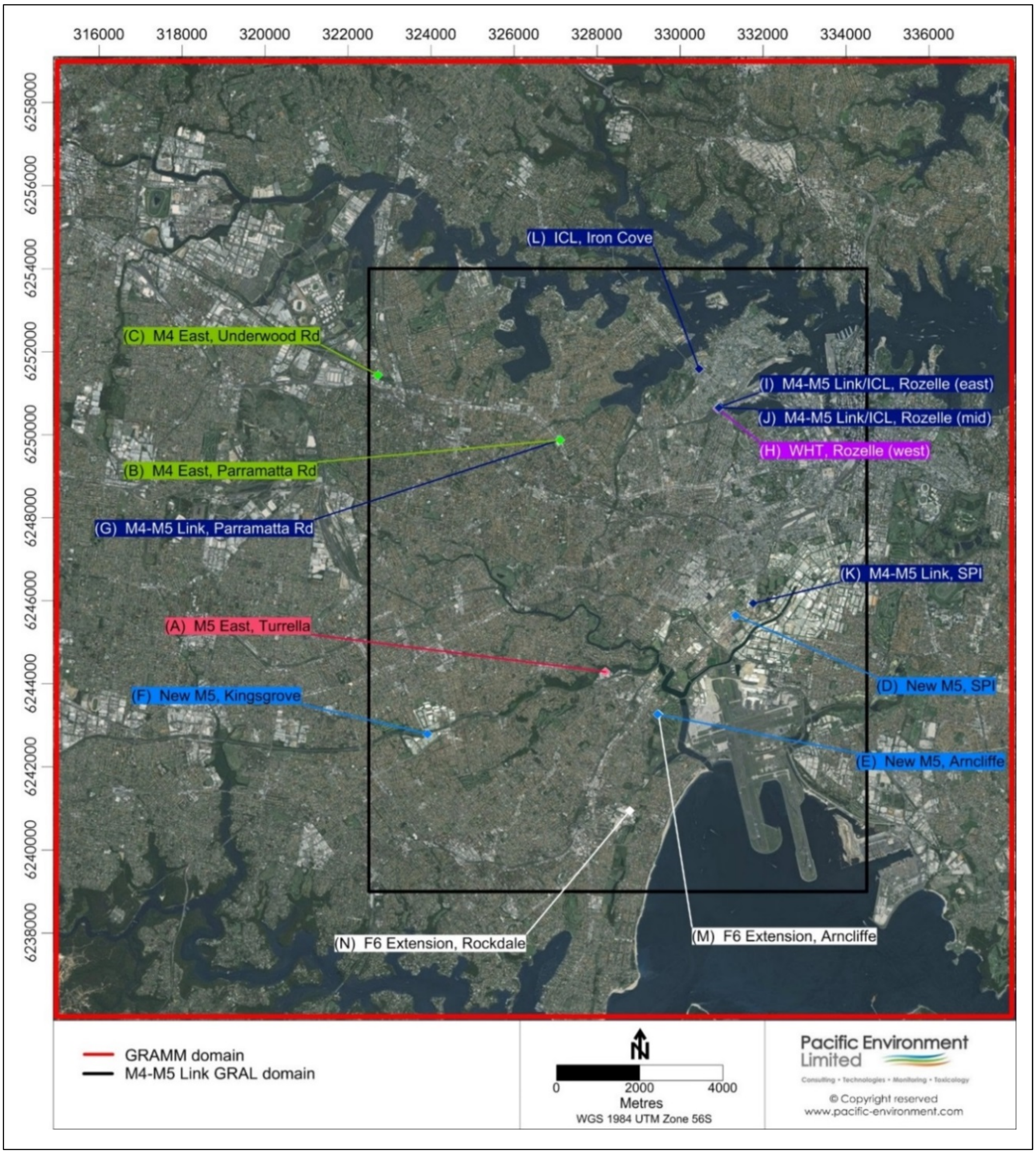

Figure 9-7 Locations of all tunnel ventilation outlets included in the assessment (grid system MGA94)

3 Although the M4 East outlet at Underwood Road is also close to the edge of the domain shown in the report, the 'real' model domain was actually extended to the west to include this outlet with a suitable buffer (the domain shown in the report is therefore a cropped version of the actual modelled domain).

Table 9-10 Ventilation outlets: locations and heights

Ventilation outlet	Tunnel project	Location	Traffic direction	Ventilation outlet(s)	Outlet location (MGA94)		Ground elevation (m)	Outlet height above existing ground elevation (m)
					X	Y	$Z^{(a)}$	
A	M5 East	Turrella	EB/WB	TUR-1	328204	6244290	7.2	35.0
B	M4 East	Parramatta Road, Haberfield	EB	PAR-1	327100	6249870	12.4	25.0
C	M4 East	Underwood Road Homebush	WB	UND-1	322714	6251442	12.6	38.1
D	New M5	St Peters interchange	EB	SPI-1	331340	6245650	10.5	20.0
				SPI-2	331346	6245655	10.5	20.0
				SPI-3	331334	6245656	10.4	20.0
				SPI-4	331340	6245662	10.4	20.0
E	New M5	Arncliffe	EB	ARN-1	329459	6243267	9.0	35.0
				ARN-2	329470	6243275	9.0	35.0
				ARN-3	329463	6243261	9.1	35.0
				ARN-4	329474	6243269	9.1	35.0
F	New M5	Kingsgrove	WB	KIN-1	323916	6242795	13.0	30.0
G	M4-M5 Link	Parramatta Road, Haberfield	WB	PAR-2	327108	6249875	12.1	25.0
H	Western Harbour Tunnel (WHT)	Rozelle ventilation facility (west)	SB	ROZ-1	330906	6250633	4.2	35.0
I	M4-M5 Link/Iron Cove Link (ICL)	Rozelle ventilation facility(east)	Various	ROZ-2	330972	6250679	5.0	35.0

Ventilation outlet	Tunnel project	Location	Traffic direction	Ventilation outlet(s)	Outlet location (MGA94)		Ground elevation (m)	Outlet height above existing ground elevation (m)
					X	Y	Z[(a)]	
J	M4-M5 Link/ICL	Rozelle ventilation facility (mid)	Various	ROZ-3	330939	6250656	4.5	35.0
K	M4-M5 Link	Campbell Road ventilation facility St Peters	SB	SPI-5	331765	6245940	9.0	22.0
				SPI-6	331775	6245933	8.9	22.0
				SPI-7	331775	6245925	8.9	22.0
				SPI-8	331765	6245918	9.0	22.0
L	ICL	Iron Cove ventilation facility Rozelle near Terry Street	NB	ICL-1	330391	6251650	23.2	20.0
M	F6 Extension	Arncliffe as part of the New M5 ventilation facility	NB	ARN-5	329479	6243276	9.0	35.0
				ARN-6	329475	6243281	8.9	35.0
				ARN-7	329485	6243291	8.9	35.0
				ARN-8	329489	6243286	9.0	35.0
N	F6 Extension	Rockdale, near President Avenue	SB	ROC-1	328788	6240950	9.5	35.0
				ROC-2	328802	6240952	9.7	35.0
				ROC-3	328813	6240947	9.8	35.0
				ROC-4	328791	6240960	9.6	35.0

Note:

(a) Taken from GRAMM terrain file

9.5 Existing environment

This section describes the existing environment and conditions in the GRAMM domain, and covers the following aspects:

- Terrain
- Land use
- Climate
- Meteorology
- Air pollutant emissions, with an emphasis on road traffic
- In-tunnel air quality
- Ambient air quality.

The meteorological inputs and background pollutant concentrations required for the operational air-quality assessment are described in more detail in **Appendix I** (Technical working paper: Air quality)**.**

Pollutant concentrations can fluctuate a great deal on short timescales, and substantial concentration gradients can occur in the vicinity of sources such as busy roads. Meteorological conditions and local topography are also very important; cold nights and clear skies can create temperature inversions, trapping air pollution near ground level, and local topography can increase the frequency and strength of these inversions. In the case of particulate matter, dust storms, natural bush fires and planned burning activities are often associated with the highest concentrations (State of the Environment Committee 2011).

9.5.1 Terrain and land use

The topography of the land in an area plays an important role in the dispersion of air pollutants. It steers winds, generates turbulence and large scale eddies, and generates drainage flows at night and upslope flows during the day.

Terrain data for Sydney was obtained from the Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) website. The terrain within the WestConnex GRAMM domain is shown on **Figure 9-8** and is predominantly flat, but increases in elevation to the north of the Five Dock Bay area towards the Hills District and to the south towards the Sutherland Shire and adjoining parkland.

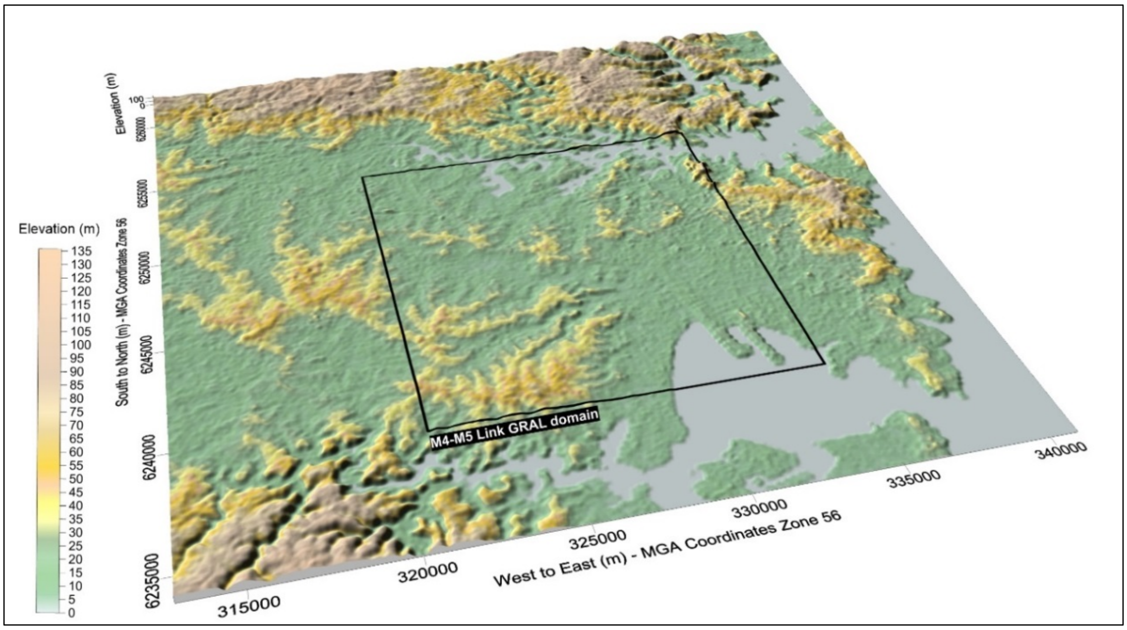

Figure 9-8 Terrain in the GRAMM domain (grid system MGA94)

The terrain along the project corridor varies from an elevation of around 10 metres Australian Height Datum (AHD) at the western end of the M4-M5 Link to an elevation of around 14 metres AHD at the Rozelle interchange and 10 metres at St Peters, at the southern end. The uniformity of the terrain, and the lack of major geographical obstacles to wind flow, should support good dispersion and airflow throughout the study area.

Land use within the GRAL domain consists primarily of urban areas, with pockets of recreational reserves and waterbodies towards the eastern end and around the airport.

9.5.2 Climate

Table 9-11 presents the long-term average temperature and rainfall data for the Bureau of Meteorology (BoM) weather station at Canterbury Racecourse (site number 066194), which is located near to the centre of the GRAMM domain and broadly representative of the area. The annual average daily maximum and minimum temperatures are 23.0°C and 12.3°C, respectively. On average, January is the hottest month with an average daily maximum temperature of 27.6°C. July is the coldest month, with average daily minimum temperature of 5.8°C. The wettest month is April, with 111 millimetres falling over eight rain days. The average annual rainfall is 971 millimetres over an average of 85 rain days per year.

Table 9-11 Long-term average climate summary for Canterbury Racecourse (AWS)

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Mean daily maximum temperature (ºC)												
27.6	27.2	26.0	23.4	20.6	18.1	17.5	19.0	21.9	23.5	24.8	26.3	23.0
Mean daily minimum temperature (ºC)												
18.3	18.3	16.5	12.8	9.3	7.1	5.8	6.5	9.5	12.1	14.9	16.7	12.3
Mean monthly rainfall (mm)												
85.2	99.1	74.6	111.0	81.1	108.2	59.5	66.8	46.8	59.0	78.7	64.8	970.9
Mean rain days per month (number)												
8.0	7.6	7.6	7.8	6.9	8.8	6.6	5.3	5.1	6.1	8.1	6.8	84.7

Source: BoM (2017) Climate averages for Station: 066194; Commenced: 1995 – last record January 2017; Latitude: 33.91°S; Longitude: 151.11 °E

9.5.3 Meteorology

Several meteorological stations in the study area were considered, and their locations are shown in **Figure 9-9**. Data relevant to the dispersion modelling such as wind speed, wind direction, temperature and cloud cover were obtained for the following:

- OEH meteorological stations:
  - Chullora
  - Earlwood
  - Rozelle
- BoM meteorological stations:
  - Canterbury Racecourse Automatic Weather Station (AWS) (Station No. 066194)
  - Fort Denison (Station No. 066022)
  - Sydney Airport AMO (Station No. 066037)
  - Sydney Olympic Park AWS (Archery Centre) (Station No. 066212).

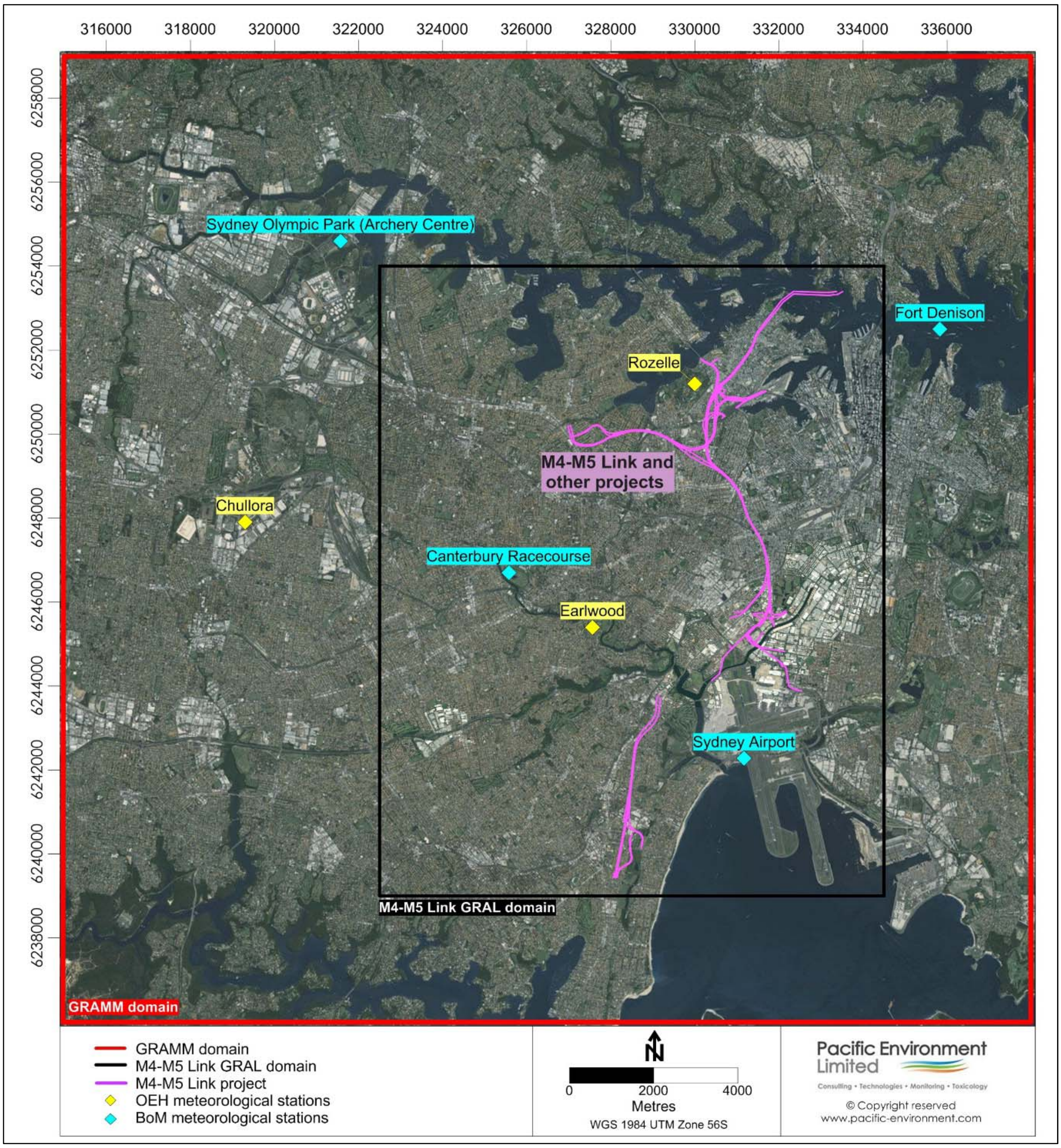

Figure 9-9 Meteorological stations in the model domains (grid system MGA94)

A detailed analysis of the meteorological data from the weather stations within the GRAMM domain is presented in Annexure H. Based on this analysis and other considerations, the measurements from the BoM Canterbury Racecourse station in 2015 were chosen as the reference meteorological data for modelling. The rationale for this selection is summarised in Annexure H of **Appendix I** (Technical working paper: Air quality).

At Canterbury Racecourse the wind speed and wind direction patterns over the seven-year period between 2009 and 2015 were quite consistent; the annual average wind speed ranged from 3.2 metres per second to 3.3 metres per second, and the annual percentage of calms (wind speeds <0.5 metres per second) ranged from 8.0 to 9.4 per cent (between 8.6 and 8.8 per cent in the three most recent three years).

9.5.4 Emissions

Exhaust emissions of some pollutants from road transport have decreased as the vehicle emission legislation has tightened, and are predicted to decrease further in the future (Bureau of Infrastructure, Transport and Regional Economics (BITRE) 2010). The most detailed and comprehensive source of information on current and future emissions in the Sydney area is the emissions inventory[4] that is compiled periodically by NSW EPA. The base year of the latest published inventory is 2008 (NSW EPA 2012a), and projections are available for future years to 2036.

The contribution of road transport to air pollution in Sydney can be illustrated by reference to sectoral emissions. The data for emissions, produced by human activity (anthropogenic) and biological sources (biogenic) in Sydney, as well as a detailed breakdown of emissions from road transport, were extracted from the inventory by NSW EPA[5] and are presented here. Emissions were considered for the most recent historical year (2011) and for the future years.

Figure 9-10 shows that road transport was the single largest sectoral contributor to emissions of CO (44 per cent) and NO_X (57 per cent) in Sydney during 2011. It was also responsible for a proportion of emissions of VOCs (17 per cent), PM_{10} (10 per cent) and $PM_{2.5}$ (12 per cent). The main contributors to VOCs were domestic-commercial activity and biogenic sources.

The most significant sources of PM_{10} and $PM_{2.5}$ emissions were the domestic-commercial sector and industry. The contribution to PM from the domestic sector in Sydney was due largely to wood burning for heating in winter. Emissions from natural sources, such as bushfires, dust storms and salt spray, also contributed significantly to PM concentrations.

Road transport contributed only two per cent of total SO_2 emissions in Sydney, reflecting the removal of sulfur from road transport fuels in recent years. SO_2 emissions in Sydney were dominated by the off-road mobile sector and industry.

The projections of sectoral emissions in **Figure 9-11** show that the road transport contribution to emissions of CO, VOCs and NO_X has decreased over several decades (BITRE 2010) and is projected to continue to decrease substantially between 2011 and 2036 due to improvements in emission control technology. For PM_{10}, $PM_{2.5}$ and SO_2 the road transport contributions are also expected to decrease, but their smaller contributions to these pollutants mean that these decreases would have only a minor impact on total emissions.

The breakdown of emissions in 2011 from the road transport sector by process and vehicle type is presented in **Figure 9-12**. Petrol passenger vehicles (mainly cars) accounted for a large proportion of the vehicle kilometres travelled (VKT) in Sydney[6].

Exhaust emissions from these vehicles were responsible for 62 per cent of CO from road transport in Sydney in 2011, 45 per cent of NO_X, and 76 per cent of SO_2. They were a minor source of PM_{10} (four per cent) and $PM_{2.5}$ (nine per cent). Non-exhaust particulates, eg particles from brake lining wear and tyre wear were the largest source of road transport PM_{10} (60 per cent) and $PM_{2.5}$ (46 per cent). This is a larger proportion than in most European countries, as there are relatively few diesel cars in Australia. There are currently no controls for non-exhaust particles (and no legislation), and emissions would increase in line with projected traffic growth. Heavy duty diesel vehicles are disproportionate contributors of NO_X and PM emissions due to their inherent combustion characteristics, high operating mass (and hence high fuel usage) and level of emission control technology (NSW EPA 2012b). Evaporation is the main source of VOCs.

The projections of road transport emissions are broken down by process and vehicle group in **Figure 9-13**. There are projected to be substantial reductions in emissions of CO, VOCs, and NO_X between 2011 and 2036. There would be smaller changes in emissions of PM_{10} and $PM_{2.5}$ on account of the growing contribution of non-exhaust particles from the expected increase in vehicle activity. SO_2

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[4] An emissions inventory defines the amount (in tonnes per year) of pollution that is emitted from each source in a given area.

[5] The data were provided for the project Economic Analysis to Inform the National Plan for Clean Air (Particles), undertaken by Pacific Environment on behalf of the NEPC Service Corporation.

[6] Diesel passenger vehicles have represented only a very small proportion of the total passenger vehicle fleet. However, the improved performance of light duty diesel vehicles over the last 10 years, together with superior fuel economy, has boosted sales and the market share is increasing (NSW EPA 2012b).

emissions are proportional to fuel sulfur content, and this is assumed to remain constant in the inventory.

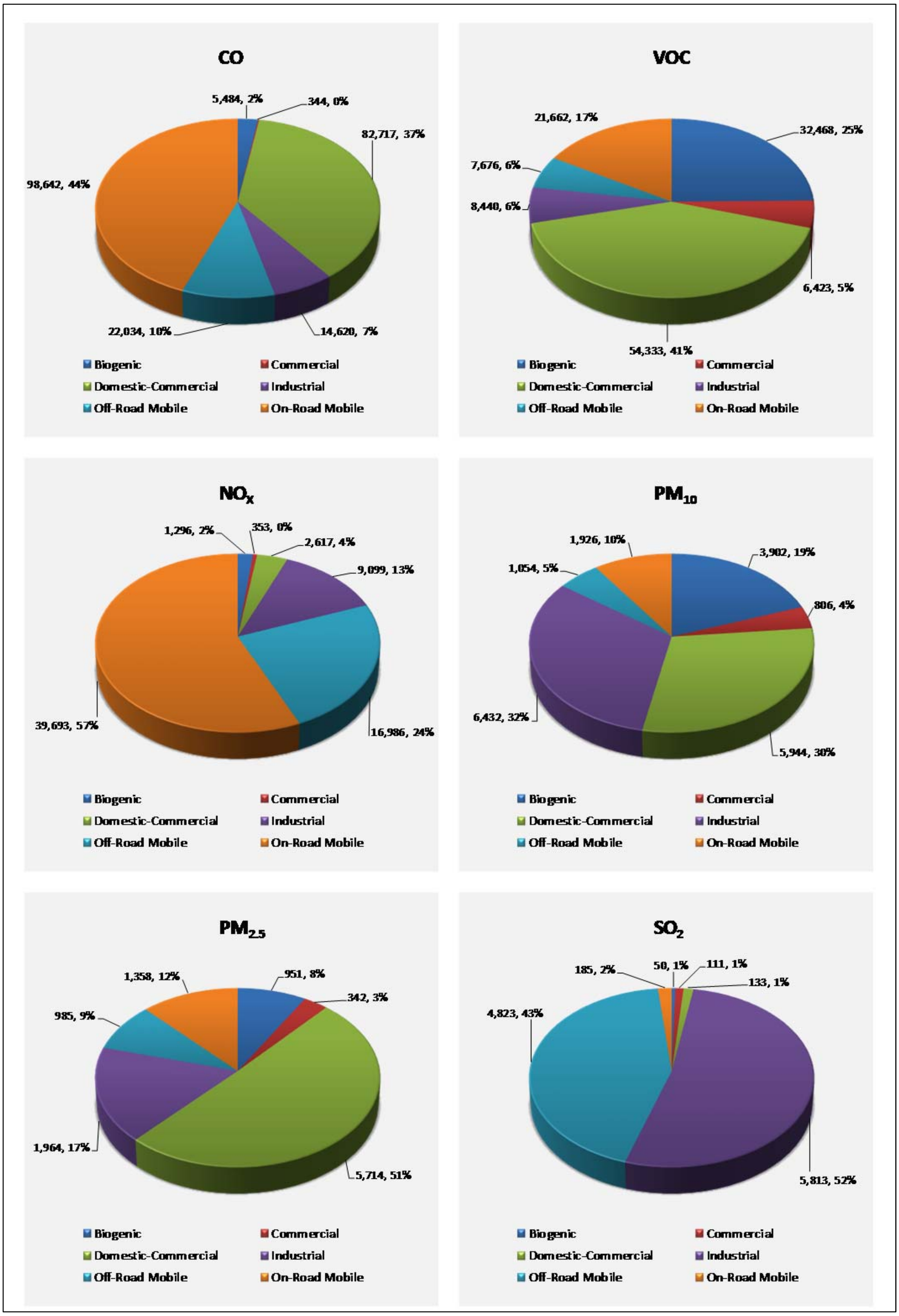

Figure 9-10 Sectoral emissions in Sydney 2011 (tonnes per year and percentage of total)

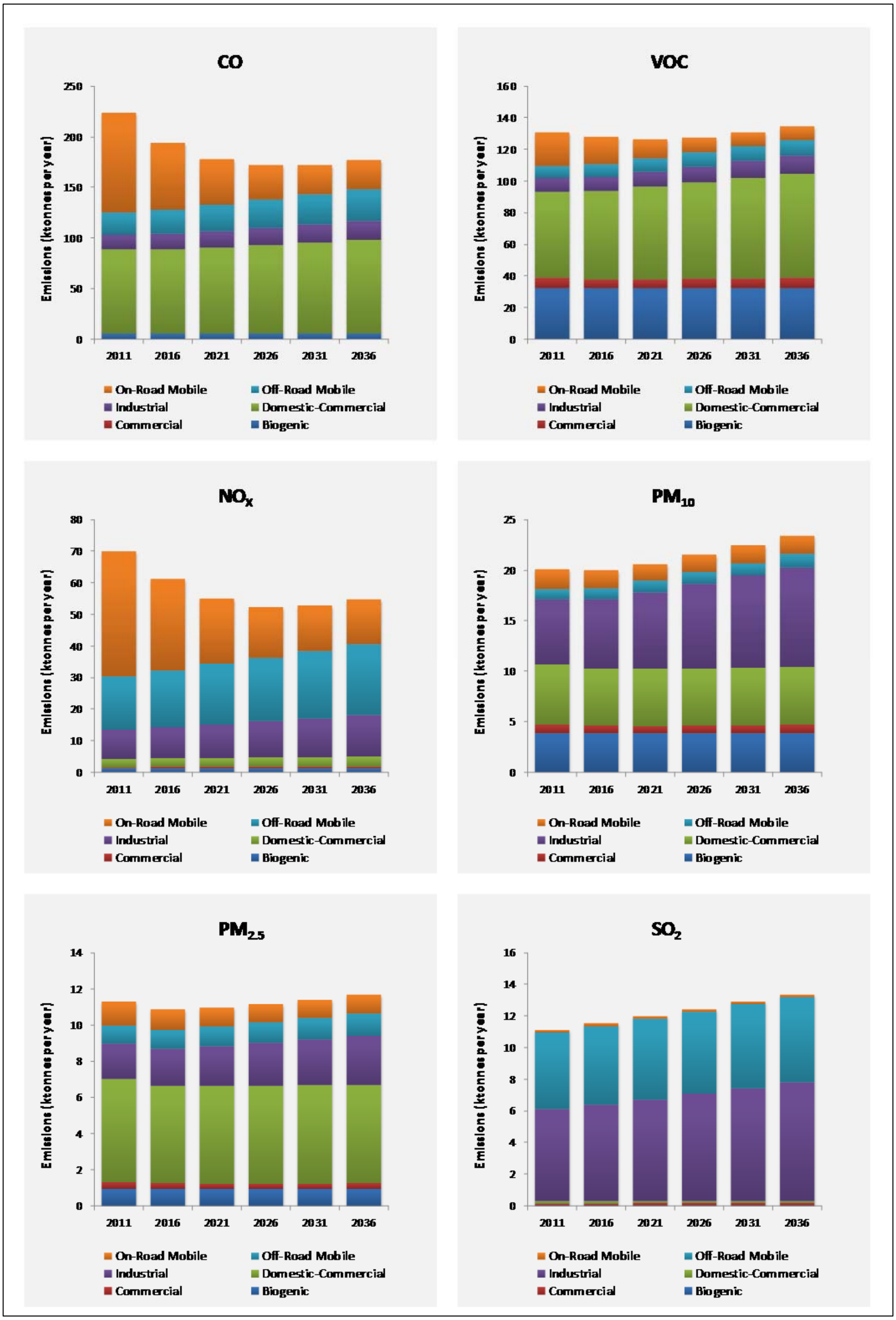

Figure 9-11 Future projections of sectoral emissions – Sydney 2011–2036

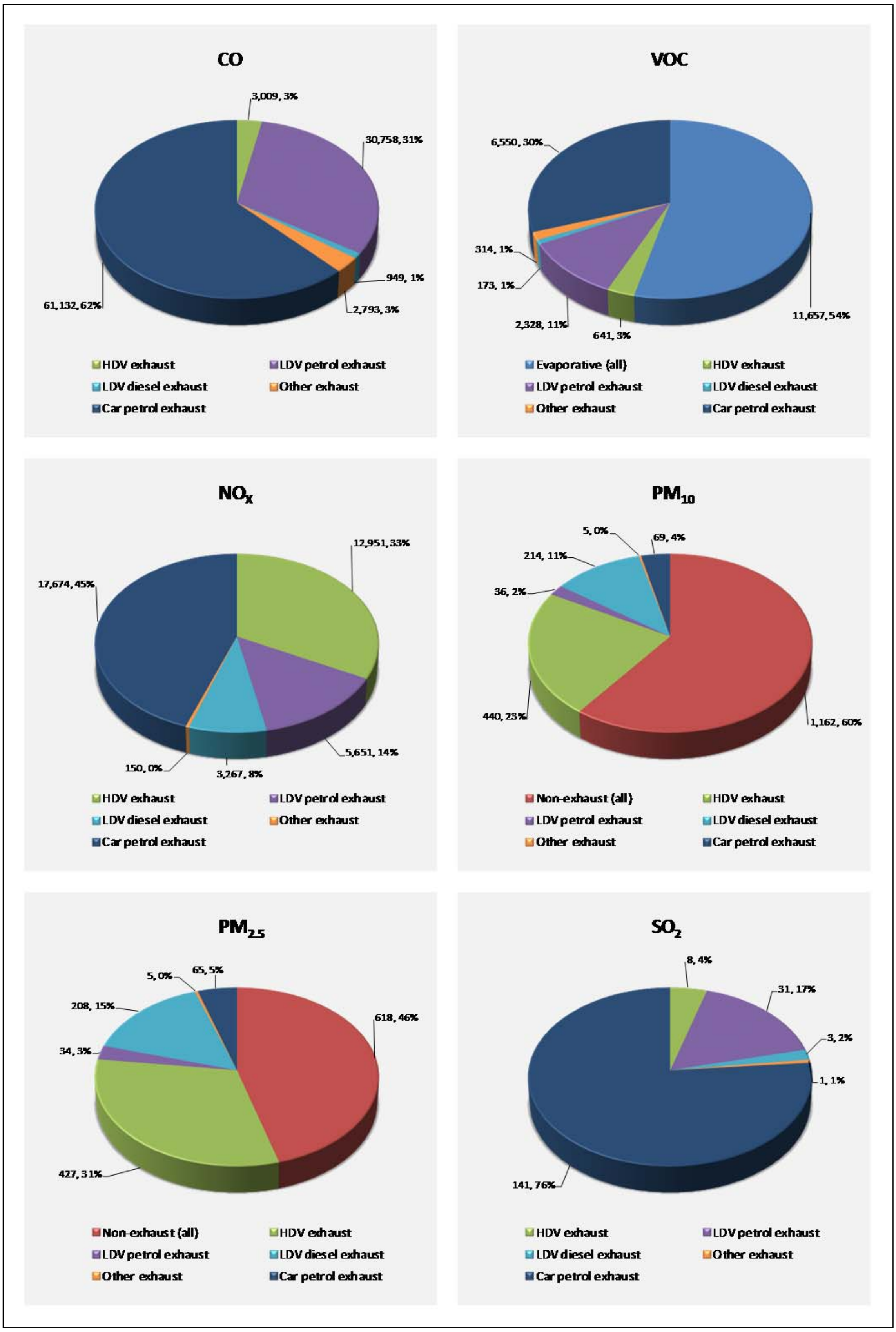

Figure 9-12 Breakdown of road transport emissions – Sydney, 2011 (tonnes per year and percentage of total)

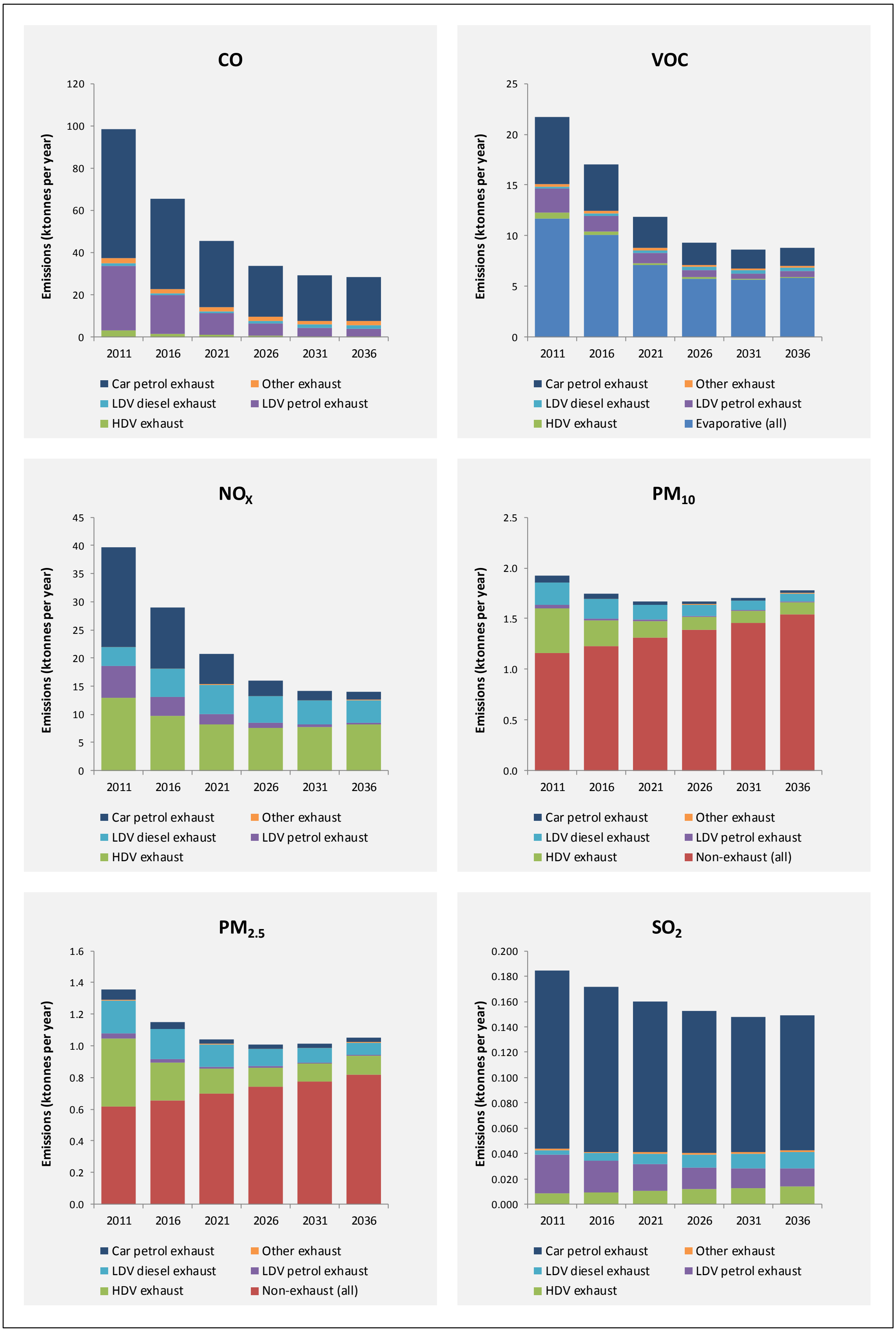

Figure 9-13 Future projections of road transport emissions – Sydney 2011–2036

9.5.5 In-tunnel air quality

Air quality is monitored continuously in all Sydney's major road tunnels. Monitors are installed along the length of each tunnel. These typically measure CO and visibility, and are specially designed for use in road tunnels, where access for routine essential maintenance is restricted by the need to minimise traffic disruption.

The instruments typically only have a coarse resolution. More precise instrumentation has been installed in the ventilation outlets of some tunnels, with measurements including PM_{10}, $PM_{2.5}$, NO_X and NO_2. Some of the data are available on the websites of the tunnel operators[7,8], and measurements from some of the tunnels have been used to support the air quality assessment found in Annexure L of **Appendix I** (Technical working paper: Air quality).

9.5.6 Ambient air quality

In order to understand the likely and potential impacts of the project on air quality, a good understanding of the existing air quality in Sydney is essential. The following sections provide a brief overview of air quality in Sydney and a summary of an extensive analysis of the data from monitoring stations in the study area.

General characteristics of Sydney air quality

A thorough analysis of the air quality monitoring data that were available for the study area was undertaken and is provided in Annexure F of **Appendix I** (Technical working paper: Air quality). The analysis was based mainly on measurements conducted during the 12 year period between 2004 and 2015, the principal aim being to establish background pollutant concentrations for use in the M4-M5 Link assessment. The analysis dealt with temporal and spatial patterns in the data, and contributed to the general understanding of air quality in Sydney.

Air quality in the Sydney region has improved over the last few decades. The improvements have been attributed to initiatives to reduce emissions from industry, motor vehicles, businesses and residences.

Historically, elevated levels of CO were generally only encountered near busy roads, but concentrations have fallen as a result of improvements in motor vehicle technology. Since the introduction of unleaded petrol and catalytic converters in 1985, peak CO concentrations in central Sydney have plummeted, and the last exceedance of the air quality standard for CO in NSW was recorded in 1998 (NSW Department of Environment, Climate Change and Water (DECCW) 2009; 2010).

While levels of NO_2, SO_2 and CO continue to be below national standards, across Sydney, levels of ozone and particles (PM_{10} and $PM_{2.5}$) can still exceed the standards on occasion.

Ozone and PM levels are affected by:

- The annual variability in the weather
- Natural events such as bushfires and dust storms, as well as hazard reduction burns
- The location and intensity of local emission sources, such as wood heaters, transport and industry (OEH 2015).

9.5.7 Data from monitoring sites in the study area

A detailed analysis of the historical trends in Sydney's air quality (2004–2015), and the current situation, is provided in Annexure F of **Appendix I** (Technical working paper: Air quality). The analysis

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7 http://www.lanecovemotorways.com.au/downloads.htm.

8 http://www.crosscity.com.au/AirQuality.htm.

was based upon hourly data from the following long-term monitoring stations operated by OEH and Roads and Maritime:

- OEH stations (urban background):
  - Chullora, Earlwood, Randwick, Rozelle, Lindfield, Liverpool, Prospect
- Roads and Maritime stations (M5 East urban background):
  - Community based monitoring stations, T1, U1, X1
- Roads and Maritime stations (M5 East roadside):
  - F1, M1.

Consideration was also given to the shorter-term data from other Roads and Maritime air quality monitoring stations.

The results for specific air quality metrics during the period 2004–2015 can be summarised as follows:

- Maximum one hour and rolling eight hour mean CO
  - All values were well below the air quality criteria of 30 mg/m^3 (one hour) and 10 mg/m^3 (eight hour), and quite stable at all sites between 2004 and 2015. In 2015 the maximum one hour concentrations were typically between around two and three mg/m^3, and the maximum eight hour concentrations were around two mg/m^3
  - There were general downward trends in maximum concentrations, and these were statistically significant at most sites
- Annual mean NO_2
  - Concentrations at all sites were well below the air quality criterion of 62 µg/m^3, and ranged between around 15 and 25 µg/m^3 (depending on the site) in recent years. Values at the OEH sites exhibited a systematic, and generally significant, downward trend overall. However, in recent years the concentrations at some sites appear to have stabilised
  - The long-term average NO_2 concentrations at the Roads and Maritime roadside sites (F1 and M1) were 35–37 µg/m^3, ie around 10–20 µg/m^3 higher than those at the background sites. Even so, the concentrations at roadside were also well below the criterion
- Maximum one hour NO_2
  - Although variable from year to year, maximum NO_2 concentrations have been quite stable in the longer term. The values across all sites typically range between 80 and 120 µg/m^3, and continue to be well below the criterion of 246 µg/m^3
  - The maximum one hour mean NO_2 concentrations at the Roads and Maritime roadside sites in 2015 were 123 µg/m^3. These values were similar to the highest maximum values for the background sites
- Annual mean PM_{10}
  - Concentrations at the OEH sites showed a downward trend, and this was statistically significant at several sites. In recent years the annual mean concentration at these sites has been between 17 µg/m^3 and 20 µg/m^3, except at Lindfield where the concentration is substantially lower (around 14 µg/m^3). The concentrations at the Roads and Maritime background sites appear to have stabilised at around 15 µg/m^3. These values can be compared with air quality criterion of 30 µg/m^3 and the standard of 25 µg/m^3 in the recently updated AAQNEPM
- Maximum 24 hour PM_{10}
  - Maximum 24 hour PM_{10} concentrations exhibited a slight downward trend overall, but there was a large amount of variation from year to year. In 2015 the concentrations at the various sites were clustered around 40 µg/m^3

- Annual mean $PM_{2.5}$
  - $PM_{2.5}$ is only measured at three OEH sites in the study area. Concentrations at the two OEH sites closest to WestConnex – Chullora and Earlwood – showed a similar pattern, with a systematic reduction between 2004 and 2012 being followed by a substantial increase in 2013. The reason for the increase was the change in the measurement method from Tapered Element Oscillating Microbalance (TEOM) to Beta Attenuation Monitor (BAM) endorsed by the NSW EPA. The change in measurement method has resulted in an increase baseline measurement of PM. The increases meant that background $PM_{2.5}$ concentrations in the study area during 2015 were already very close to or above the standard in the AAQNEPM of eight µg/m^3, and above the long-term goal of seven µg/m^3
- Maximum 24 hour $PM_{2.5}$
  - There has been no systematic trend in the maximum 24 hour $PM_{2.5}$ concentration. As with the annual mean $PM_{2.5}$ concentration, the maximum one hour concentrations were very close to or above the standard in the AAQNEPM of 25 µg/m^3, and were generally above the long-term goal of 20 µg/m^3.

The data from these stations were also used to define appropriate background concentrations of pollutants for the project assessment.

9.5.8 Project-specific air quality monitoring

A network of air quality monitoring stations was established to support the WestConnex M4 East, New M5 and M4-M5 Link projects. Some of the stations are located at urban background sites and others are located so as to characterise population exposure near busy roads.

The WestConnex network has been designed to:

- Supplement the existing OEH and Roads and Maritime stations in Sydney
- Establish the representativeness of the data from these stations that were used to characterise air quality in the WestConnex modelling domain
- Provide a time series of air quality data in the vicinity of the project.

The data collected at the WestConnex sites between August 2014 and February 2017 have been compared with the corresponding data from the OEH and Roads and Maritime sites, and the results are summarised in **Appendix I** (Technical working paper: Air quality) and details presented in Annexure F of **Appendix I** (Technical working paper: Air quality). Only the OEH sites closest to the M4-M5 Link project (ie Chullora, Earlwood, Randwick and Rozelle) were included in this evaluation. All the Roads and Maritime M5 East sites were included.

9.5.9 Assumed background concentrations

Various approaches have been used in previous air quality assessments to define long-term (annual mean) and short-term (eg one hour, 24 hour) background concentrations. Background concentrations for 2015 were developed using the data from the OEH sites at Chullora, Earlwood, Randwick and Rozelle sites, the Roads and Maritime M5 East background sites, and the M4 East St Lukes Park site. The detailed methods for calculating the background concentration are provided in Annexure F of **Appendix I** (Technical working paper: Air quality).

Summary

The characteristics of the assumed background concentrations, and the forms of the concentrations, are provided in **Table 9-12**.

Table 9-12 Characteristics of assumed background concentrations (2015)

Pollutant / metric	Averaging period	Form	Units	Statistical descriptors		
				Mean	Max	98th %ile
CO	1 hour	Synthetic profile	mg/m^3	0.48	3.37	1.41
	8 hours (rolling)	Synthetic profile	mg/m^3	0.46	2.27	1.21
NO_X	Annual	Map	µg/m^3	Spatially varying	-	-
	1 hour	Synthetic profile	µg/m^3	65.9	769.6	301.4
PM_{10}	Annual	Map	µg/m^3	Spatially varying	-	-
	24 hours	Synthetic profile	µg/m^3	20.0	46.2	35.8
$PM_{2.5}$	Annual	Single value	µg/m^3	8.0	-	-
	24 hours	Synthetic profile	µg/m^3	9.5	25.1	19.9

9.6 Assessment of potential construction impacts

9.6.1 Overview

This section deals with the potential impacts of the construction phase of the project. The construction activities for the project are described in **section 9.3**.

The section:

- Identifies the project footprint and construction scenarios
- Identifies the risk associated with the various construction activities
- Discusses the significance of the identified risks.

9.6.2 Construction surface works and scenarios

The impacts associated with surface works and construction sites are described below. The above ground construction activities would take place at several separate locations (see **Table 9-13**). The concept design considers two possible combinations for construction ancillary facilities around Haberfield and Ashfield. These are described and assessed in this EIS (Option A and Option B). The construction ancillary facilities that comprise these options have been grouped together and are denoted by the suffix *a* (for Option A) or *b* (for Option B) eg C1a is Wattle Street civil and tunnel site. The preferred combination of construction ancillary facilities would be determined during detailed design and would meet the environmental performance outcomes stated in the EIS and the Submissions and Preferred Infrastructure Report, satisfy criteria that would be identified in any relevant conditions of approval and manage environmental risks.

Table 9-13 M4-M5 Link construction ancillary facilities

Construction ancillary facility	Description	Indicative construction period
C1a	Wattle Street civil and tunnel site	Q3 2019 – Q4 2022
C2a	Haberfield civil and tunnel site	Q3 2019 – Q4 2022
C3a	Northcote Street civil site	Q4 2019 – Q4 2022
C1b	Parramatta Road West civil and tunnel site	Q4 2018 – Q2 2022
C2b	Haberfield civil site	Q3 2019 – Q3 2022
C3b	Parramatta Road East civil site	Q4 2018 – Q3 2022
C4	Darley Road civil and tunnel site	Q3 2018 – Q4 2022
C5	Rozelle civil and tunnel site	Q4 2018 – Q3 2023
C6	The Crescent civil site	Q1 2019 – Q4 2021
C7	Victoria Road civil site	Q1 2019 – Q4 2022

Construction ancillary facility	Description	Indicative construction period
C8	Iron Cove Link civil site	Q4 2018 – Q3 2023
C9	Pyrmont Bridge Road tunnel site	Q3 2018 – Q4 2022
C10	Campbell Road civil and tunnel site	Q4 2018 – Q4 2022

The construction activities in several of the construction ancillary facilities are expected to take place concurrently and in close proximity to one another. Therefore, for the assessment the construction ancillary facilities were combined according to the seven 'worst case' scenarios listed in **Table 9-14**.

Table 9-14 M4-M5 Link construction scenarios

Scenario	Construction ancillary facilities included
S1	C1a to C3a
S2	C1b to C3b
S3	C4
S4	C5, C6 and C7
S5	C8
S6	C9
S7	C10

The number of receptors in each distance band from construction sites was estimated from land use zoning of the site. The exact number of 'human receptors' is not required by the IAQM guidance, which recommends that judgement is used to determine the approximate number of receptors within each distance band. For receptors that are not dwellings, judgement was used to determine the number of human receptors. The results of the screening assessment of receptors in proximity to the various construction sites are shown in **Figure 9-14**.

In the case of the M4-M5 Link, the following numbers of receptors per building were assumed:

- Commercial:
  - B1 – Neighbourhood Centre = five
  - B2 – Local Centre = five
- Mixed use:
  - B4 – Mixed Use = three
- Commercial:
  - B6 – Enterprise Corridor = five
  - B7 – Business Park = 20
- Community:
  - Community centre = 20
  - Childcare = 30
  - School = 500
- Industrial:
  - IN1 – General Industrial = 10
  - IN2 – Light Industrial = 10

- Residential:
  - R1 – General Residential = three
  - R2 – Low Density Residential = three
  - R3 – Medium Density Residential = five
  - R4 – High Density Residential = 50.

Table 9-15 shows the results of the risk categorisation for the construction activities that would be carried out in each construction scenario.

Table 9-15 Criteria for assessing the potential scale of emissions

Type of activity	Site category		
	Large	Medium	Small
Demolition	Building volume >50,000 m^3, potentially dusty construction material (eg concrete), on-site crushing and screening, demolition activities >20 m above ground level.	Building volume 20,000–50,000 m^3, potentially dusty construction material, demolition activities 10-20 m above ground level.	Building volume <20,000 m^3, construction material with low potential for dust release (eg metal cladding, timber), demolition activities <10 m above ground and during wetter months.
Earthworks	Site area >10,000 m^2, potentially dusty soil type (eg clay, which would be prone to suspension when dry due to small particle size), >10 heavy earth moving vehicles active at any one time, formation of bunds >8 m in height, total material moved >100,000 tonnes.	Site area 2,500–10,000 m^2, moderately dusty soil type (eg silt), 5–10 heavy earth moving vehicles active at any one time, formation of bunds 4–8 m in height, total material moved 20,000–100,000 tonnes.	Site area <2,500 m^2, soil type with large grain size (eg sand), <5 heavy earth moving vehicles active at any one time, formation of bunds <4 m in height, total material moved <20,000 tonnes, earthworks during wetter months.
Construction	Total building volume >100,000 m^3, piling, on site concrete batching; sandblasting.	Building volume 25,000–100,000 m^3, potentially dusty construction material (eg concrete), piling, on site concrete batching.	Total building volume <25,000 m^3, construction material with low potential for dust release (eg metal cladding or timber).
Track-out	>50 HDV (>3.5 t) outward movements in any one day, potentially dusty surface material (eg high clay content), unpaved road length >100 m.	10–50 HDV (>3.5 t) outward movements in any one day, moderately dusty surface material (e.g. high clay content), unpaved road length 50–100 m.	<10 HDV (>3.5 t) outward movements in any one day, surface material with low potential for dust release, unpaved road length <50 m.

Table 9-16 Results of risk categorisation of construction scenario for each type of activity

Type of activity	Site category by scenario						
	Scenario 1 (C1a-3a)	Scenario 2 (C1b-3b)	Scenario 3 (C4)	Scenario 4 (C5, 6, 7)	Scenario 5 (C8)	Scenario 6 (C9)	Scenario 7 (C10)
Demolition	Small	Large	Large	Large	Medium	Large	Small
Earthworks	Small	Medium	Medium	Large	Large	Large	Large
Construction	Medium	Medium	Medium	Large	Large	Large	Large
Track-out	Large	Large	Large	Large	Medium	Large	Large

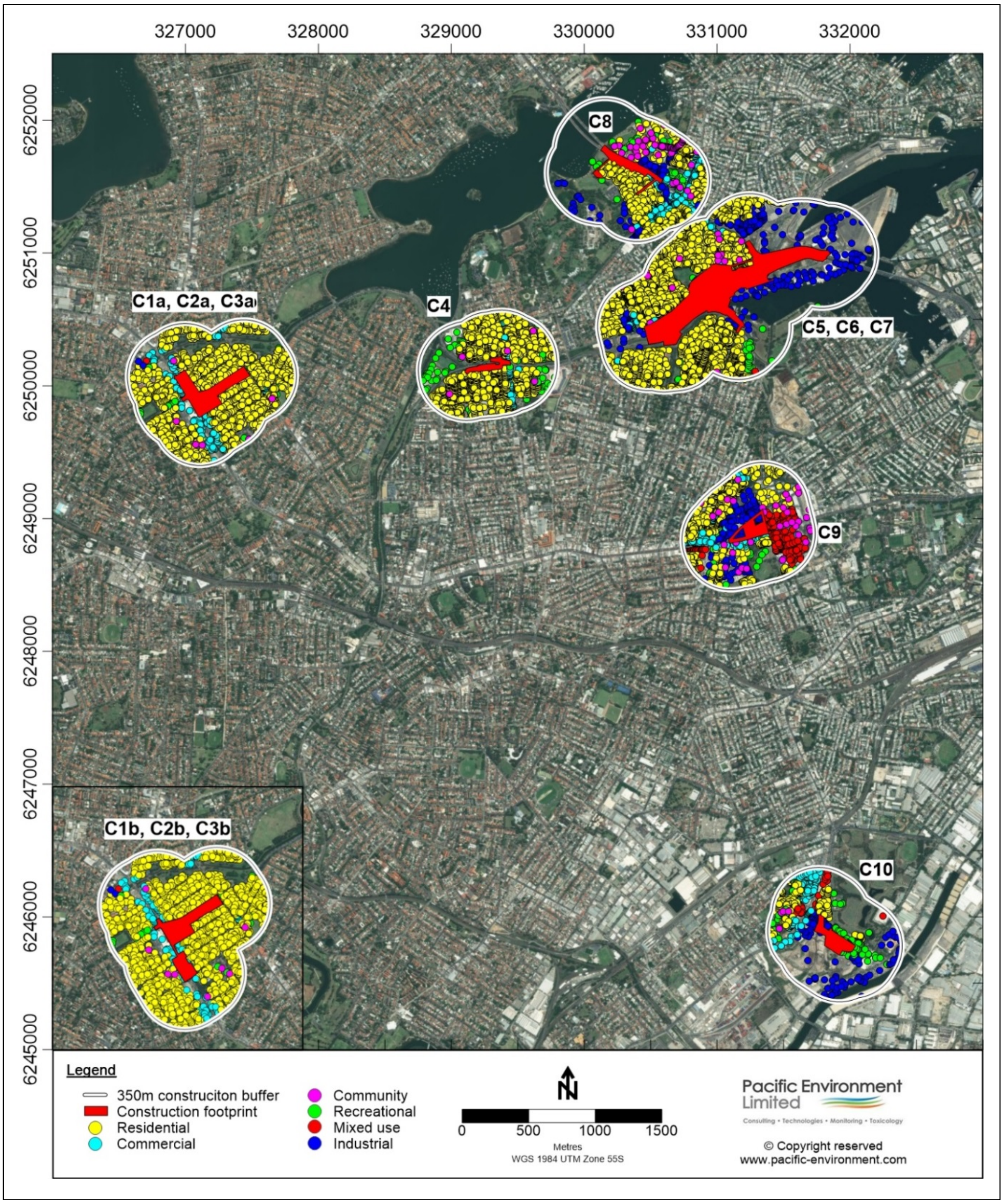


Figure 9-14 Screening assessment – receptors near the project footprint

Sensitivity of area to dust soiling effects on people and property

The criteria for determining the sensitivity of an area to dust soiling impacts are shown in **Table 9-17**. The sensitivity of people to the health effects of PM_{10} is based on exposure to elevated concentrations over a 24 hour period. High-sensitivity receptors relate to locations where members of the public are exposed over a time period that is relevant to the air quality criterion for PM_{10} (in the case of the 24 hour criterion a relevant location would be one where individuals may be exposed for eight hours or more in a day). The main example of this would be a residential property. All non-residential sensitive receptor locations were considered as having equal sensitivity to residential locations for the purposes of this assessment. In view of the types of receptor shown in **Figure 9-14**, being predominantly residences in addition to community centres, and in consideration of the IAQM guidance, the receptor sensitivity was assumed to be ‘high’.

Table 9-17 Criteria for sensitivity of area to dust soiling impacts

Receptor sensitivity	Number of receptors	Distance from source (m)			
		<20	<50	<100	<350
High	>100	High	High	Medium	Low
	10–100	High	Medium	Low	Low
	1–10	Medium	Low	Low	Low
Medium	>1	Medium	Low	Low	Low
Low	>1	Low	Low	Low	Low

Table 9-18 Results of sensitivity to dust soiling effects

Scenario	Activity	Receptor sensitivity	Number of receptors by distance from				Sensitivity of area
			<20	20-50	50-100	100-350	
Scenario 1 (C1a–C3a)	Demolition	High	694	436	819	4,341	High
	Earthworks	High	694	436	819	4,341	High
	Construction	High	694	436	819	4,341	High
	Track-out	High	694	436	N/A	N/A	High
Scenario 2 (C1b–C3b)	Demolition	High	945	571	922	5,150	High
	Earthworks	High	945	571	922	5,150	High
	Construction	High	945	571	922	5,150	High
	Track-out	High	945	571	N/A	N/A	High
Scenario 3 (C4)	Demolition	High	60	83	357	5,166	High
	Earthworks	High	60	83	357	5,166	High
	Construction	High	60	83	357	5,166	High
	Track-out	High	60	83	N/A	N/A	High
Scenario 4 (C5, C6, C7)	Demolition	High	960	679	1,691	10,272	High
	Earthworks	High	960	679	1,691	10,272	High
	Construction	High	960	679	1,691	10,272	High
	Track-out	High	960	679	N/A	N/A	High
Scenario 5 (C8)	Demolition	High	551	766	1,415	5,390	High
	Earthworks	High	551	766	1,415	5,390	High
	Construction	High	551	766	1,415	5,390	High
	Track-out	High	551	766	N/A	N/A	High
Scenario 6 (C9)	Demolition	High	663	974	775	5,070	High
	Earthworks	High	663	974	775	5,070	High
	Construction	High	663	974	775	5,070	High
	Track-out	High	663	974	N/A	N/A	High
Scenario 7 (C10)	Demolition	High	779	620	384	4,119	High
	Earthworks	High	779	620	384	4,119	High
	Construction	High	779	620	384	4,119	High
	Track-out	High	779	620	N/A	N/A	High

Sensitivity of area to human health impacts

The criteria for determining the sensitivity of an area to human health impacts caused by construction dust are shown in **Table 9-19**. Air quality monitoring data from Rozelle were used to establish an annual average PM_{10} concentration of between 16 µg/m^3 and 18 µg/m^3 for 2010 to 2016 (refer to Annexure F of **Appendix I** (Technical working paper: Air quality)). Based on the IAQM guidance the receptor sensitivity was assumed to be ‘high’. The numbers of receptors for each scenario and activity, and the resulting outcomes, are shown in **Table 9-20**. The sensitivity for all areas and all activities was determined to be ‘medium’.

Table 9-19 Criteria for sensitivity of area to health impacts

Receptor sensitivity	Annual mean PM_{10} conc. (µg/m3) (a)	Number of receptors	Distance from source (m)				
			<20	<50	<100	<200	<350
High	>24	>100	High	High	High	Medium	Low
		10–100	High	High	Medium	Low	Low
		1–10	High	Medium	Low	Low	Low
	21–24	>100	High	High	Medium	Low	Low
		10–100	High	Medium	Low	Low	Low
		1–10	High	Medium	Low	Low	Low
	18–21	>100	High	Medium	Low	Low	Low
		10–100	High	Medium	Low	Low	Low
		1–10	Medium	Low	Low	Low	Low
	<18	>100	Medium	Low	Low	Low	Low
		10–100	Low	Low	Low	Low	Low
		1–10	Low	Low	Low	Low	Low
Medium	-	>10	High	Medium	Low	Low	Low
		1–10	Medium	Low	Low	Low	Low
Low	-	>1	Low	Low	Low	Low	Low

Note:

(a) Scaled for Sydney, according to the ratio of NSW and UK annual mean standards (30 µg/m^3 and 40 µg/m^3 respectively)

Table 9-20 Results for sensitivity of area to health impacts

Scenario	Activity	Receptor sensitivity	Annual mean PM10	Number of receptors by distance from source (m)					Sensitivity of area
				<20	20-50	50-100	100-200	200-350	
Scenario 1 (C1a–C3a)	Demolition	High	<18	694	436	819	1,407	2,934	Medium
	Earthworks	High	<18	694	436	819	1,407	2,934	Medium
	Construction	High	<18	694	436	819	1,407	2,934	Medium
	Track-out	High	<18	694	436	N/A	N/A	N/A	Medium
Scenario 2 (C1b–C3b)	Demolition	High	<18	945	571	922	2,135	3,015	Medium
	Earthworks	High	<18	945	571	922	2,135	3,015	Medium
	Construction	High	<18	945	571	922	2,135	3,015	Medium
	Track-out	High	<18	945	571	N/A	N/A	N/A	Medium
Scenario 3 (C4)	Demolition	High	<18	60	83	357	1,930	3,236	Medium
	Earthworks	High	<18	60	83	357	1,930	3,236	Medium
	Construction	High	<18	60	83	357	1,930	3,236	Medium
	Track-out	High	<18	60	83	N/A	N/A	N/A	Medium

Scenario	Activity	Receptor sensitivity	Annual mean	Number of receptors by distance from source (m)					Sensitivity of area
C7)	Track-out	High	<18	960	679	N/A	N/A	N/A	Medium
Scenario 5 (C8)	Demolition	High	<18	984	646	1,619	4,190	5,961	Medium
	Earthworks	High	<18	984	646	1,619	4,190	5,961	Medium
	Construction	High	<18	984	646	1,619	4,190	5,961	Medium
	Track-out	High	<18	984	646	N/A	N/A	N/A	Medium
Scenario 6 (C9)	Demolition	High	<18	663	974	775	1,432	3,638	Medium
	Earthworks	High	<18	663	974	775	1,432	3,638	Medium
	Construction	High	<18	663	974	775	1,432	3,638	Medium
	Track-out	High	<18	663	974	N/A	N/A	N/A	Medium
Scenario 7 (C10)	Demolition	High	<18	779	620	384	683	3,436	Medium
	Earthworks	High	<18	779	620	384	683	3,436	Medium
	Construction	High	<18	779	620	384	683	3,436	Medium
	Track-out	High	<18	779	620	N/A	N/A	N/A	Medium

Sensitivity of area to ecological impacts

The criteria for determining the sensitivity of an area to ecological impacts of construction dust are shown in **Table 9-21**. Based on the IAQM guidance, the receptor sensitivity was assumed to be ‘medium’ for ecologically sensitive areas such as threatened flora and fauna, and ‘low’ for areas that were classed as ‘forest reserve’. Scenarios 3, 4, 5 and 7 all contained areas within 50 metres that had the potential for ecological significance. The results for the respective scenarios are shown in **Table 9-22.** All activities in Scenarios 4 and 5 were determined to have a ‘medium’ sensitivity to ecological impacts. All activities in Scenario 7 were determined to have a low sensitivity.

Table 9-21 Criteria for sensitivity of area to ecological impacts

Receptor sensitivity	Distance from source (m)	
	<20	20–50
High	High	Medium
Medium	Medium	Low
Low	Low	Low

Table 9-22 Results of sensitivity to ecological impacts

Scenario	Activity	Receptor sensitivity	Distance from source (m)	Sensitivity of area
Scenario 3 (C4)	Demolition	Low	<20	Low
	Earthworks	Low	<20	Low
	Construction	Low	<20	Low
	Track-out	Low	<20	Low
Scenario 4 (C5, C6, C7)	Demolition	Medium	<20	Medium
	Earthworks	Medium	<20	Medium
	Construction	Medium	<20	Medium
	Track-out	Medium	<20	Medium
Scenario 5 (C8)	Demolition	Medium	<20	Medium
	Earthworks	Medium	<20	Medium
	Construction	Medium	<20	Medium
	Track-out	Medium	<20	Medium
Scenario 7 (C10)	Demolition	Low	20–50	Low
	Earthworks	Low	20–50	Low
	Construction	Low	20–50	Low
	Track-out	Low	20–50	Low

The results for the risk assessment are provided in **Table 9-23**, combining the scale of the activity and the sensitivity of the area. As the level of risk varies in accordance with scenario and activity, those activities that were determined to be of high risk have been identified as follows:

- Scenario 1 (C1a–C3a): Track-out for dust soiling
- Scenario 2 (C1b–C3b): Track-out for dust soiling
- Scenario 3 (C4): Demolition and track-out for dust soiling
- Scenario 4 (C5, C6, C7): All activities for dust soiling, and demolition for human health and ecologically sensitive receptors
- Scenario 5 (C8): Earthworks and construction for dust soiling
- Scenario 6 (C9): All activities for dust soiling, and demolition for human health
- Scenario 7 (C10): Earthworks, construction and track-out for dust soiling.

9.6.3 Mitigation

Mitigation measures were determined for each of the four potential activities in **Table 9-16**. This was based on the risk of dust impacts identified. For each activity, the highest risk category was used. The suggested mitigation measures are discussed in **section 9.10.1**.

Table 9-23 Summary of risk assessment for the construction of the project

Scenario	Activity	Step 2A: Potential for dust emissions	Step 2B: Sensitivity of area			Step 2C: Risk of dust impacts		
			Dust soiling	Human health	Ecological	Dust soiling	Human health	Ecological
Scenario 1 (C1a–C3a)	Demolition	Small	High	Medium	N/A[(a)]	Medium	Low	N/A
	Earthworks	Small	High	Medium	N/A	Low	Low	N/A
	Construction	Medium	High	Medium	N/A	Medium	Medium	N/A
	Track-out	Large	High	Medium	N/A	High	Medium	N/A
Scenario 2 (C1b–C3b)	Demolition	Small	High	Medium	N/A	Medium	Low	N/A
	Earthworks	Small	High	Medium	N/A	Low	Low	N/A
	Construction	Medium	High	Medium	N/A	Medium	Medium	N/A
	Track-out	Large	High	Medium	N/A	High	Medium	N/A
Scenario 3 (C4)	Demolition	Large	High	Low	Low	High	Medium	Medium
	Earthworks	Medium	High	Low	Low	Medium	Low	Low
	Construction	Medium	High	Low	Low	Medium	Low	Low
	Track-out	Large	High	Low	Low	High	Low	Low
Scenario 4 (C5,C6, C7)	Demolition	Large	High	Medium	Medium	High	High	High
	Earthworks	Large	High	Medium	Medium	High	Medium	Medium
	Construction	Large	High	Medium	Medium	High	Medium	Medium
	Track-out	Large	High	Medium	Medium	High	Medium	Medium
Scenario 5 (C8)	Demolition	Medium	High	Medium	Medium	Medium	Medium	Medium
	Earthworks	Large	High	Medium	Medium	High	Medium	Medium
	Construction	Large	High	Medium	Medium	High	Medium	Medium
	Track-out	Medium	High	Medium	Medium	Medium	Low	Low

Scenario	Activity	Step 2A: Potential	Step 2B: Sensitivity of area			Step 2C: Risk of dust impacts		
Scenario 6 (C9)	Demolition	Large	High	Medium	N/A	High	High	N/A
	Earthworks	Large	High	Medium	N/A	High	Medium	N/A
	Construction	Large	High	Medium	N/A	High	Medium	N/A
	Track-out	Large	High	Medium	N/A	High	Medium	N/A
Scenario 7 (C10)	Demolition	Small	High	Medium	Low	Medium	Low	Negligible
	Earthworks	Large	High	Medium	Low	High	Medium	Low
	Construction	Large	High	Medium	Low	High	Medium	Low
	Track-out	Large	High	Medium	Low	High	Medium	Low

Note:

(a) N/A = not applicable

9.6.4 Significance of risks

Once the risk of dust impacts was determined, and the appropriate dust mitigation measures identified, the final step is to determine whether there are significant residual effects arising from the construction phase of a proposed development. For almost all construction activity, the aim should be to prevent significant effects on receptors through the use of effective mitigation. Experience shows that this is normally possible. Hence the residual effect would normally be ‘not significant’ (IAQM 2014).

However, even with a rigorous Dust Management Plan in place, it is not possible to guarantee that the dust mitigation measures would be effective all the time. There is the risk that nearby residences, commercial buildings, hotel, cafés and schools in the immediate vicinity of the construction zone, might experience some occasional dust soiling impacts. This does not mean that impacts are likely, or that if they did occur, that they would be frequent or persistent. Overall construction dust is unlikely to represent a serious ongoing problem. Any effects would be temporary and relatively short-lived, and would only arise during dry weather with the wind blowing towards a receptor, at a time when dust is being generated and mitigation measures are not being fully effective. The likely scale of this would not normally be considered sufficient to change the conclusion that with mitigation the effects would be ‘not significant’.

The construction of the proposed future Western Harbour Tunnel and Beaches Link project at the Rozelle Rail Yards has been included in this assessment. The CBD and South East Light Rail Rozelle maintenance depot works would be completed prior to commencement of the project.

9.7 Assessment of potential operational impacts

9.7.1 In-tunnel air quality

The three pollutants assessed for in-tunnel air quality were NO_2, CO and visibility, which is expressed as a coefficient of extinction (of light). The coefficient of extinction is proportional to the $PM_{2.5}$ concentration (refer to **section 9.2.3**) as light is scattered or ‘extinguished’ by particulate matter in the tunnel air. It is not a direct measure of particulate matter from vehicle exhausts.

The information presented in Annexure L of **Appendix I** (Technical working paper: Air quality) has confirmed that the tunnel ventilation system would be able to maintain in-tunnel air quality well within operational limits for all scenarios assessed, including congestion and incidents within the tunnel. The project is proposed to be delivered in two stages:

- **Stage 1** – construction of the mainline tunnels and stub tunnels to the Rozelle interchange at the Inner West subsurface interchange

- **Stage 2** – construction of the Rozelle interchange and Iron Cove Link including:
  - Connections to the stub tunnels for the mainline tunnels (built during Stage 1)
  - Connections to the surface road network
  - Civil construction of tunnels, entry and exit ramps and infrastructure (a ventilation outlet and ancillary facilities) to provide connections to the proposed future Western Harbour Tunnel and Beaches Link project.

The ventilation system analysis for the project has been undertaken with both stages noted as completed. For interim operation, with only the mainline tunnel between M4 East and New M5 in operation, restricting all tunnel sections within the project to a maximum of two traffic lanes would not require any increase in the installed ventilation capacity over and above that required for the completed project.

Expected traffic

The levels of NO_2 and visibility throughout a 24 hour period for the expected traffic scenarios with the project in 2023-DS and 2033-DS are shown in **Figure 9-15** to **Figure 9-21** and the cumulative impacts in 2033-DSC are shown in **Figure 9-22** to **Figure 9-25**. The plots, which show the change in the peak in-tunnel value across 24 hours, throughout the project tunnel and the adjoining WestConnex tunnels, confirm that the tunnel ventilation system would maintain in-tunnel air quality well within operational limits, including the fifteen minute route-averaged NO_2 criterion. Each plot represents multiple journeys through the WestConnex tunnels, including the project, for each hour of the day.

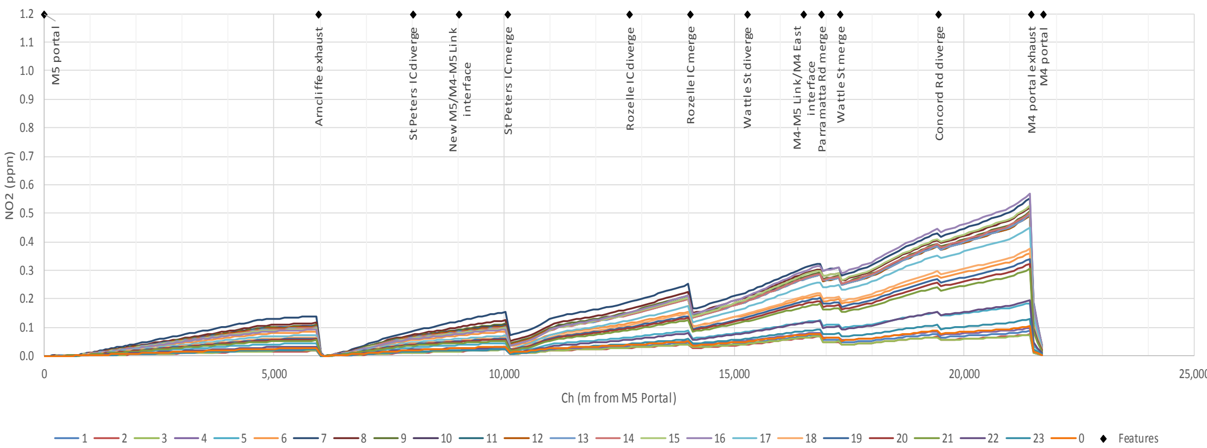


Figure 9-15 In-tunnel hourly NO_2 levels along the route from New M5 portal to M4 East portal through the project 2023-DS

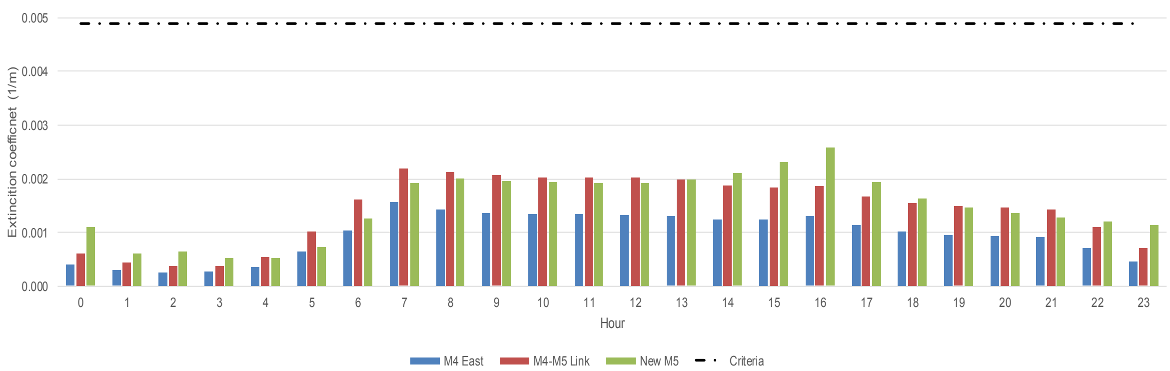


Figure 9-16 Maximum in-tunnel visibility coefficients each hour for each WestConnex tunnel (M4 Motorway to M5 Motorway direction) 2023-DS

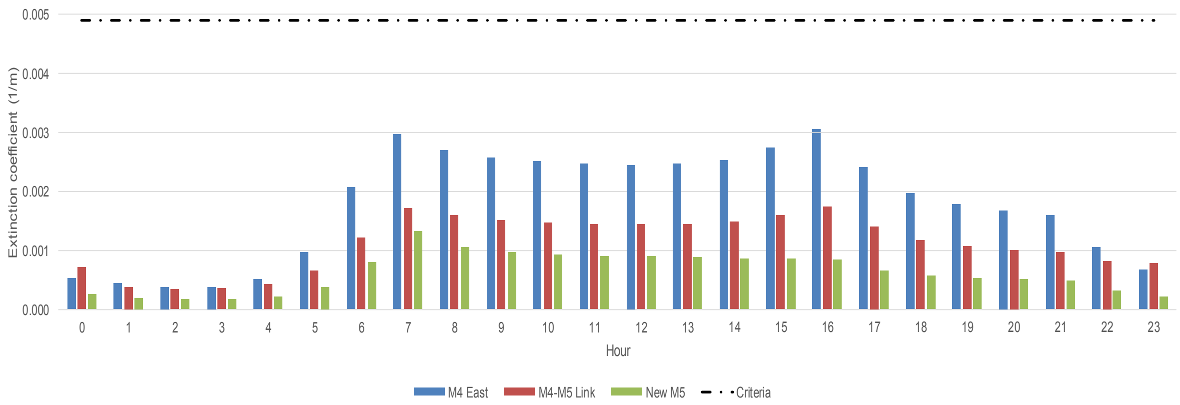


Figure 9-17 Maximum in-tunnel visibility coefficients each hour for each WestConnex tunnel (M5 Motorway to M4 Motorway direction) 2023-DS

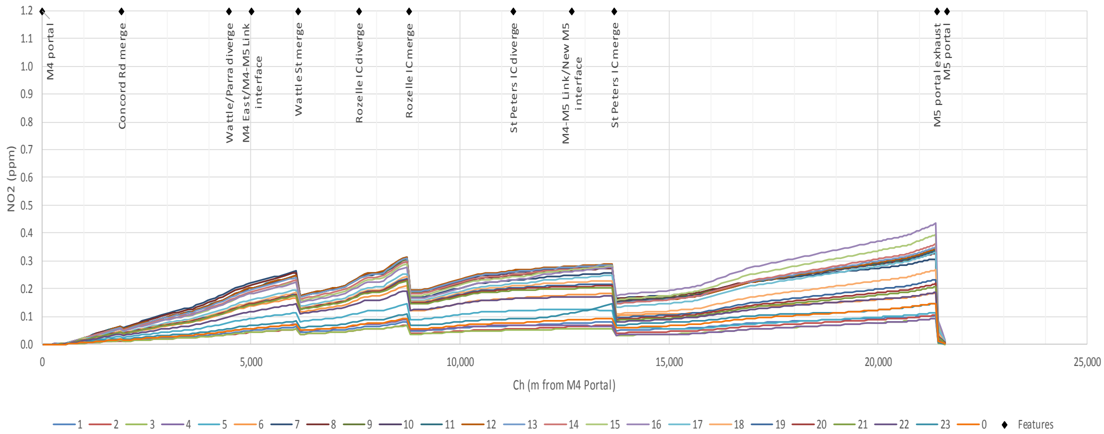


Figure 9-18 In-tunnel NO_2 levels along the route from M4 portal to M5 portal through the project 2033-DS

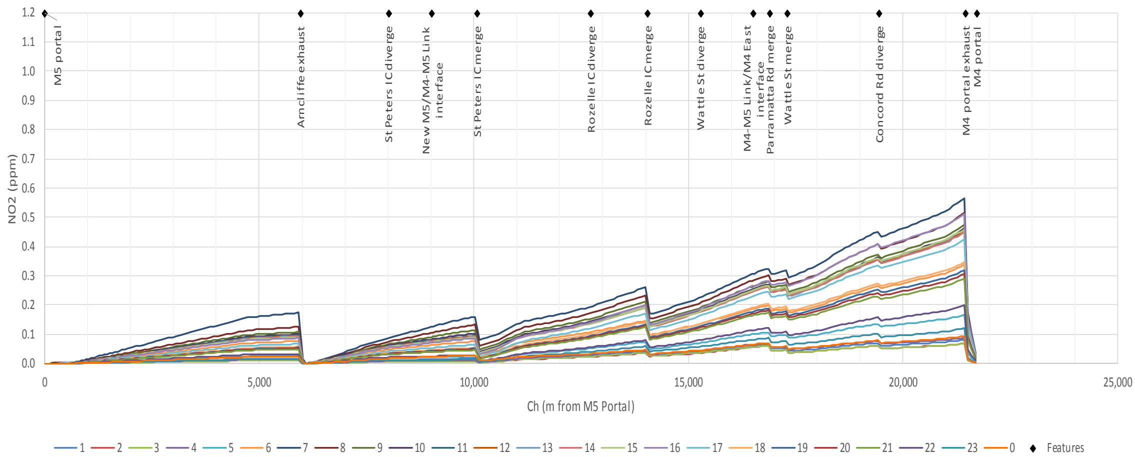


Figure 9-19 In-tunnel NO_2 levels along the route from M5 portal to M4 portal through the project 2033-DS

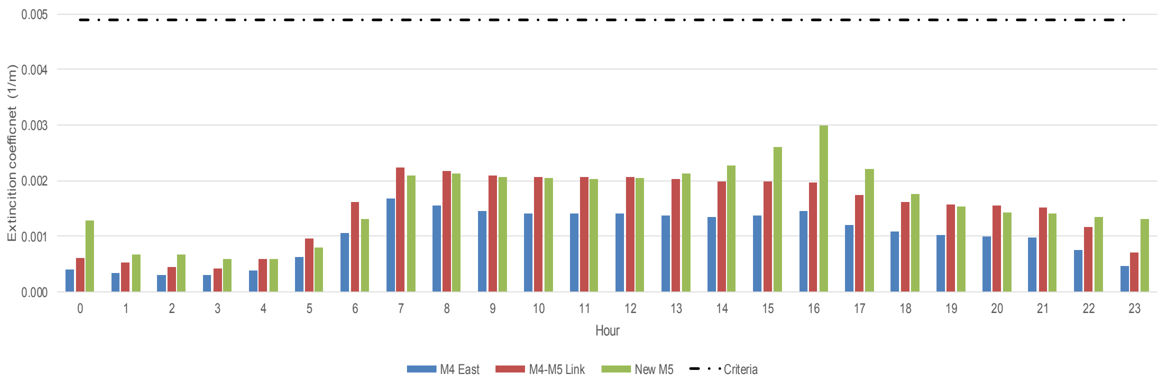


Figure 9-20 Maximum In-tunnel visibility coefficients for each hour for each WestConnex tunnel (M4 Motorway to M5 Motorway direction) 2033-DS

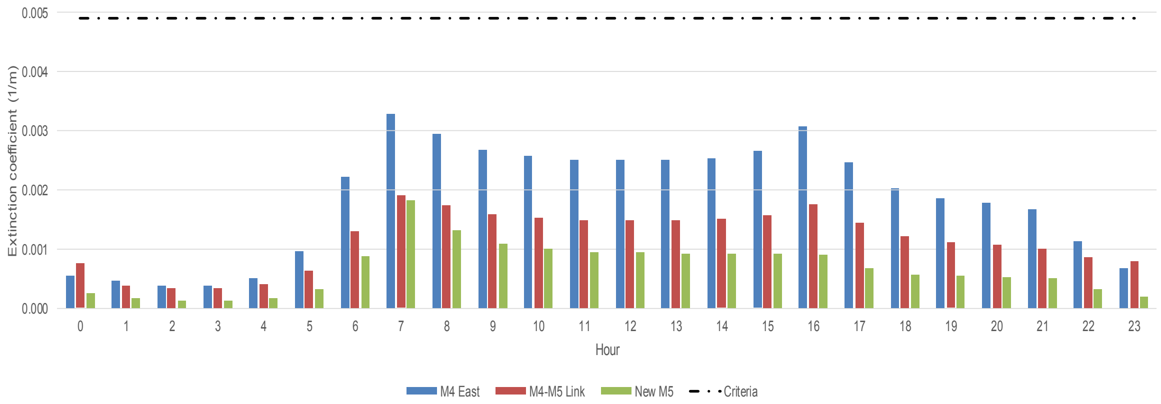


Figure 9-21 Maximum In-tunnel visibility coefficients for M5 Motorway to M4 Motorway direction 2033-DS

2033 cumulative scenarios

These scenarios include traffic coming into the WestConnex tunnels from other proposed projects, ie the proposed future Sydney Gateway, Western Harbour Tunnel and Beaches Link and the F6 Extension projects.

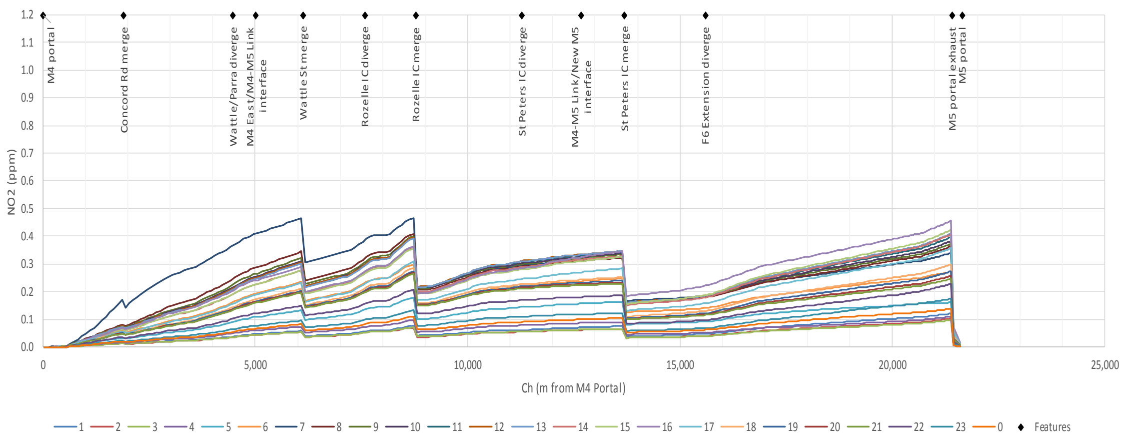


Figure 9-22 In-tunnel NO_2 levels along the route from M4 portal to M5 portal 2033-DSC

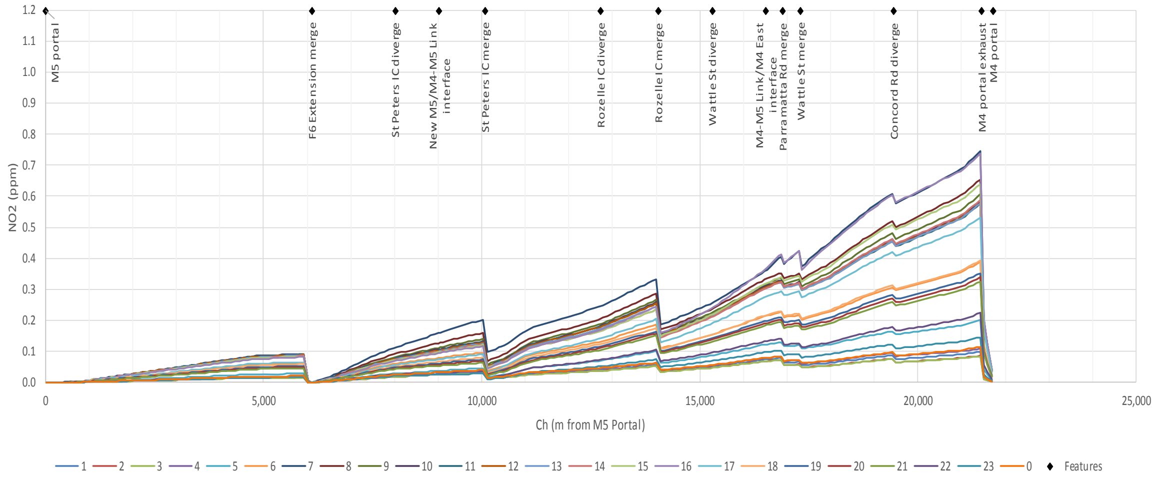


Figure 9-23 In-tunnel NO_2 levels along the route from M5 portal to M4 portal 2033-DSC

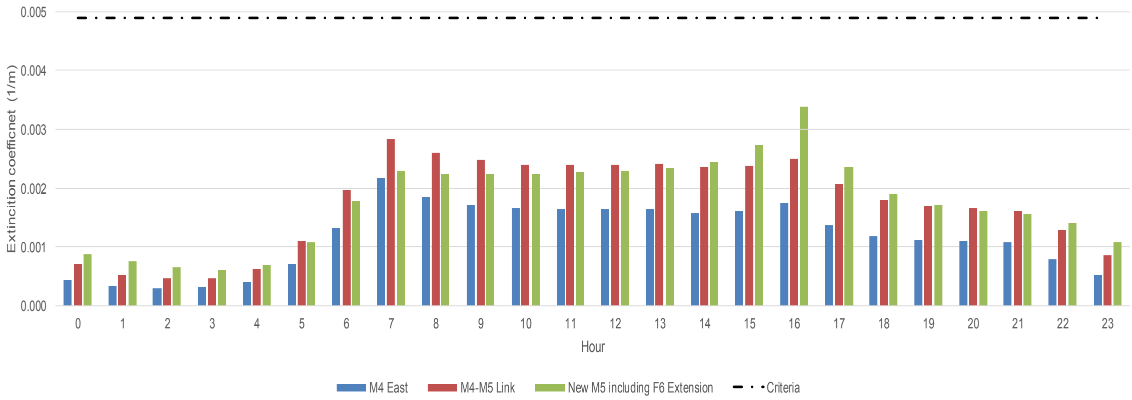


Figure 9-24 Maximum In-tunnel visibility coefficients for M4 Motorway to M5 Motorway direction 2033-DSC

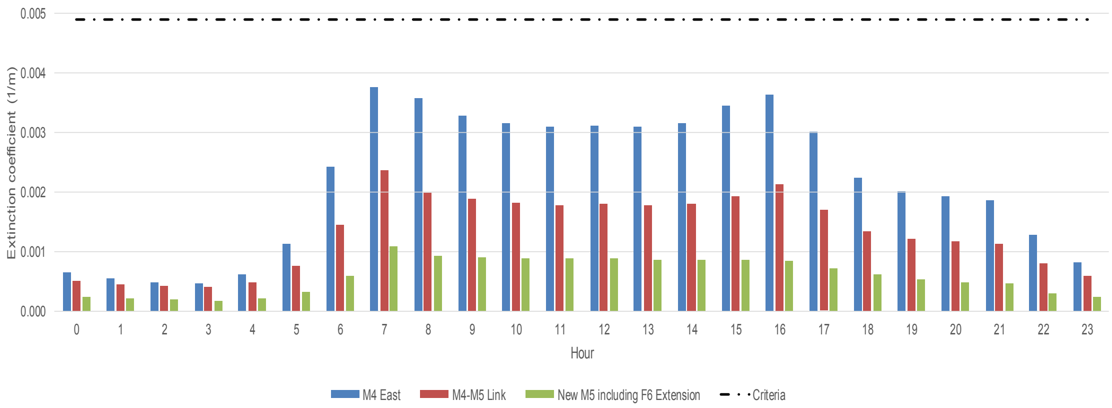


Figure 9-25 Maximum In-tunnel visibility for M5 Motorway to M4 Motorway direction 2033-DSC

Maximum in-tunnel concentrations across all time periods for the expected traffic scenarios, and the regulatory demand traffic, or maximum traffic flow, are presented in **Appendix I** (Technical working paper – Air quality). The maximum concentrations for all traffic scenarios were within the concentrations predicted in the regulatory worst case.

Worst case operations

For the worst case operations, the ventilation system in each simulation was adjusted such that the system met, or was marginally better than, the in-tunnel air quality criteria. Generally speaking, the project ventilation system is expected to be operating in the range of 50 - 75 per cent of its required capacity to meet worst case traffic conditions for expected traffic volumes. The traffic cases assessed are considered to be the theoretical worst case for the purpose of design because in practice, achieving for example, an average speed of 20 kilometres per hour along 22 kilometres of tunnel would be very difficult, if not impossible. Data from the four kilometre long M5 East tunnel in congested conditions, shows that traffic does not travel at or less than 20 kilometres per hour for the length of the tunnel, even though the traffic may be stop/start for short sections near start and end of the tunnel.

Figure 9-25 shows that for almost all cases, 20 kilometres per hour results in the highest pollutant levels in the tunnel. This case determines the number of jet fans required in the tunnel for pollution management because there is less air moving along the tunnel due to the lack of piston with an average traffic speed of 20 kilometres per hour. This compares to 80 kilometres per hour traffic speed where very few (if any) jet fans are needed to generate the required air flows within the tunnels.

For the higher speed cases, the pollutant levels along the tunnel are lower because of greater airflow and fewer vehicles in the tunnel because at higher speeds the vehicles are a greater distance apart compared with lower speeds. It is the high-speed case which determines the volumetric capacity of the ventilation outlets as all air travelling along the tunnel plus air drawn in from the portals must be exhausted at the outlets.

Based on real time travel speed data from the M5 East tunnel, the likelihood of average traffic throughout the tunnel being less than 20 kilometres per hour is of the order of 0.5 per cent of the sampled period from January 2016 to September 2016 (Annexure L of **Appendix I** (Technical working paper: Air quality)). Traffic Management Plans will be developed during the detailed design phase, to provide the capability to further reduce the likelihood of slow moving traffic within the M4-M5 Link. Traffic Management Plans may include active and/or passive control measures to influence driving behaviour to maintain the speed of traffic through the tunnel.

Traffic management measures to prevent average speeds falling below 20 kilometres per hour will include:

- Providing warnings via the tunnel message signs and variable message signs to motorists both inside the tunnel and outside of the tunnel that there is congestion. This would normally result in some motorists in the tunnel exiting via the nearest exit and motorists approaching the tunnel choosing to take an alternative route
- Reducing speed limits on the variable speed limit signs at the tunnel approaches to regulate traffic inflow into the tunnel
- Closing tunnel lanes within ramps and the mainline tunnel to reduce the total volume of traffic within the tunnel to the point where the ventilation system will be able to control air quality to within required limits regardless of average traffic speed. Lane closure is achieved with the use of Lane Use Signals (LUS) located over each lane in the tunnel at 120 metre intervals and tunnel message signs (variable signs) also at 120 metre intervals throughout the tunnels
- Closing ramps and/or the mainline tunnel, generally in response to an incident within the tunnels or downstream of the motorway.

Managing traffic speed above 20 kilometres per hour in any section of the tunnel is also required for safety to minimise the chance of a fire at the rear of a queue of stopped traffic allowing vehicles in front of any fire to drive out of the tunnel without being overrun by smoke. Therefore, it is appropriate to adopt 20 kilometres per hour as the appropriate minimum average traffic speed when designing the ventilation system and assessing pollution.

Further detailed results from the analysis of the worst case operations scenarios are given in Annexure L of **Appendix I** (Technical working paper: Air quality).

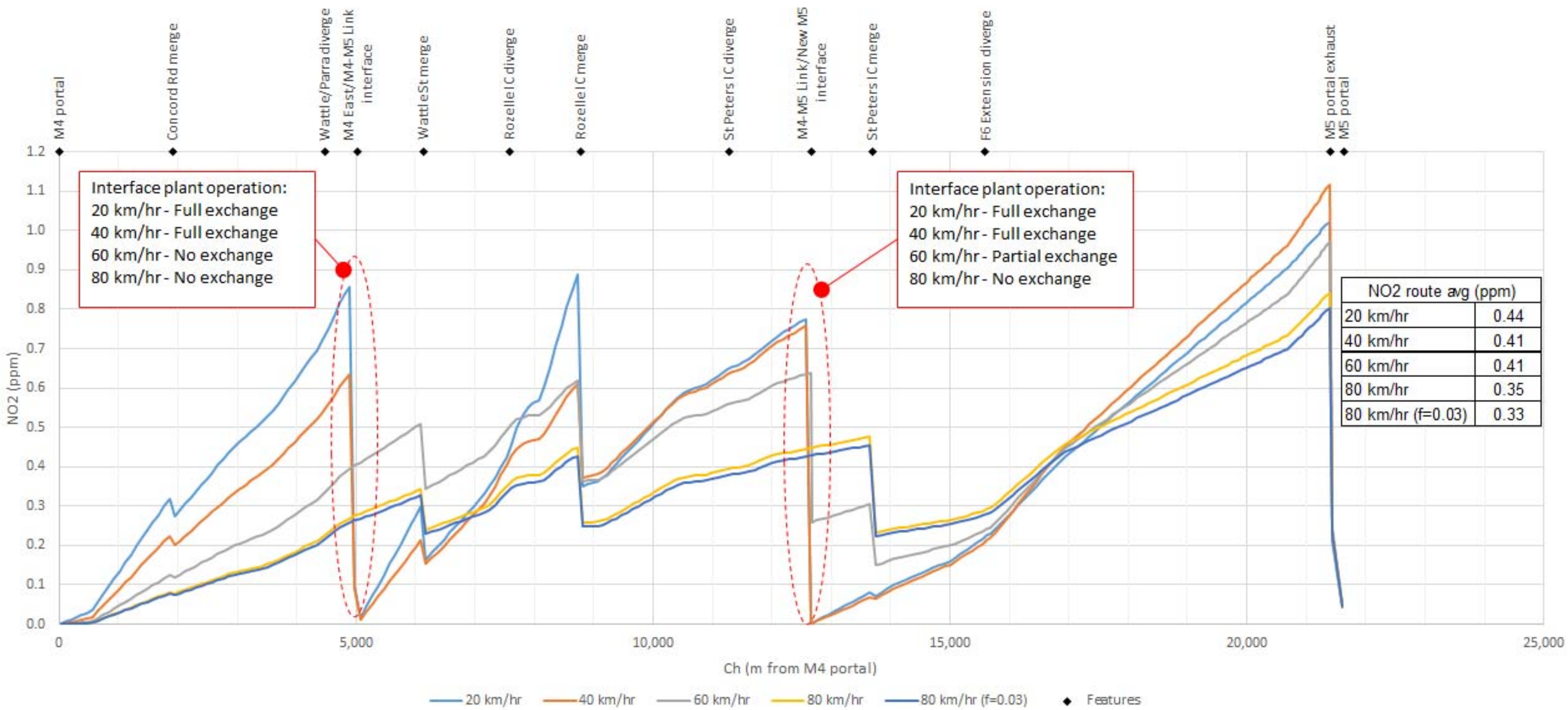


Figure 9-26 In-tunnel NO_2 levels along the route from M4 portal to M5 portal (cumulative, worst case operations)

9.7.2 Ambient air quality

Surface roads

For surface roads the emission and dispersion modelling was undertaken for the main roads in the study area, as defined in the WRTM (v2.3). The WRTM output included surface roads, tunnels, and tunnel access ramps. The road links in the study area are shown for each scenario in **Appendix I** (Technical working paper: Air quality).

It should be noted that some minor changes to the project design were made after the air quality assessment had been completed. These changes were as follows:

- Construction and operation of an additional right-hand turn lane on The Crescent at the intersection with Johnston Street. This would require widening of The Crescent to the north east by around three metres
- The enabling a triple right turn to occur from Wattle Street into Parramatta Road
- Changes to the lane configuration to and from the M4-M5 Link mainline tunnels at St Peters interchange, with a small portion of the ramps being increased by one additional lane.

None of these changes would affect the traffic data from WRTM, and the small changes in road width would have negligible effect on the predictions from the dispersion model.

Percentage changes in emissions between scenarios are shown in **Table 9-24**. Comparing the Do something scenarios with the Do Minimum scenarios, emissions of CO, NO_X, PM_{10} and $PM_{2.5}$ increased by 1.6–2.9 per cent in 2023, and by 2.9–3.2-5 per cent in 2033, depending on the pollutant. For the Do Something Cumulative scenarios, emissions of these pollutants increased by 3.2–5.1 per cent in 2023 and by 7.2–8.2 per cent in 2033, depending on the pollutant. The changes in total hydrocarbons (THC) emissions were relatively small (less than or equal to 1.6 per cent).

The overall changes in emissions associated with the project in a given future scenario year (2023 or 2033) would be smaller than the underlying reductions in emissions from the traffic on the network between 2015 and the scenario year as a result of improvements in emission-control technology. Although there are some differences between the definitions of the Base Year and Do Minimum scenarios, it can be seen from **Table 9-24** that between 2015 and 2023 the total emissions of CO, NO_X and THC from the traffic on the road network are predicted to decrease by about 40 per cent. Between 2015 and 2033 the reductions are between around 50 per cent and 60 per cent. For PM_{10} and $PM_{2.5}$, the underlying reductions are smaller: around six to nine per cent for PM_{10} and 17 to 19 per cent for $PM_{2.5}$. This is because there is currently no anticipated regulation of non-exhaust particles, which form a substantial fraction of the total. In the case of PM_{10}, the underlying reductions in emissions are similar to the increases associated with the project, whereas for $PM_{2.5}$ the underlying reductions are larger than the increases due to the project.

The changes in the total emissions resulting from the project can be viewed as a proxy for its regional air quality impacts. These are discussed further in **section 9.10**.

Table 9-24 Percentage changes in total traffic emissions in the GRAL domain

Scenario comparison	Change in total emissions (%)				
	CO	NOx	PM_{10}	$PM_{2.5}$	THC
Underlying changes in emissions with time[(a)]					
2023-DM vs 2015-BY	-42.3%	-36.4%	-8.7%	-17.1%	-43.1%
2033-DM vs 2015-BY	-61.4%	-49.0%	-6.3%	-18.7%	-63.9%
Changes due to the project in a given year					
2023-DS vs 2023-DM	+1.6%	+2.3%	+2.7%	+2.9%	-1.6%
2023-DSC vs 2023-DM	+3.2%	+4.2%	+4.9%	+5.1%	-1.6%
2033-DS vs 2033-DM	+3.2%	+2.9%	+3.0%	+3.2%	+1.1%

Scenario comparison	Change in total emissions (%)				
	CO	NOx	PM_{10}	$PM_{2.5}$	THC
2033-DSC vs 2033-DM	+7.7%	+7.2%	+8.0%	+8.2%	-0.2%

Note:

(a) The 2023-DM and 2033-DM scenarios include the M4-East and New M5 projects. The 2015-BY scenario does not.

9.7.3 Results for expected traffic scenarios (ground-level concentrations)

Overview

The predicted ground-level concentrations for the expected traffic scenarios are presented, by pollutant, in the following sections of the report. All results, including tabulated concentrations and contour plots, are provided in Annexure K of **Appendix I** (Technical working paper: Air quality).

The pollutants and metrics are treated in turn, and in each case the following have been determined for the 40 community and 86,375 RWR receptors:

- The total ground-level concentration for comparison against the NSW impact assessment criteria and international air quality standards
- The change in the total ground-level concentration. This was calculated as the difference in concentration between the 'Do Something' and 'Do Minimum' scenarios, ie the difference in ground-level concentrations as a result of the project
- The contributions of the background, surface road and ventilation outlet sources to the total ground-level concentration.

The results are presented in the following ways:

- As pollutant concentrations at discrete receptors, using:
  - Bar charts for absolute concentration, and changes in concentration, at the community receptors
  - Ranked bar charts for absolute concentration, and changes in concentration, at the RWR receptors
- As spatially mapped pollutant concentrations (ie contour plots) across the GRAL modelling domain, and also changes in concentration across the domain. These have only been provided for the most important pollutants: NO_2, PM_{10} and $PM_{2.5}$
- As spatially-mapped pollutant concentrations, and changes in concentration, for the areas around project tunnel ventilation facilities. Again, these are only provided for NO_X, PM_{10} and $PM_{2.5}$.

Carbon monoxide (maximum rolling eight hour mean)

Results for community receptors

No model predictions were available for the period with the highest background concentration, so the maximum background value was combined with the maximum model prediction at each receptor. The background was therefore taken to be the same at all locations. As with the one-hour mean, at all the receptors the concentration was well below the NSW impact assessment criterion, which in this case is 10 mg/m^3. No lower criteria appear to be in force internationally.

The changes in the maximum rolling eight hour CO concentration at all the community receptors were mostly less than 0.4 mg/m^3. The largest increase with the project was around 0.6 mg/m^3 (equating to six per cent of the criterion).

The maximum surface road contribution in any with-project scenario was 28 per cent, whereas the tunnel ventilation outlet contribution was zero in all cases. **Appendix I** (Technical working paper-air quality) shows the detailed results for the carbon monoxide predictions.

Nitrogen dioxide (annual mean)

Results for community receptors

Figure 9-27 shows the annual mean NO_2 concentrations for the with-project scenarios at the community receptors. At all these locations, the concentration was below 32 µg/m^3, and therefore well below the NSW impact assessment criterion of 62 µg/m^3. The concentrations at receptors were also below the lower air quality standards that have been adopted elsewhere (eg 40 µg/m^3 in the EU).

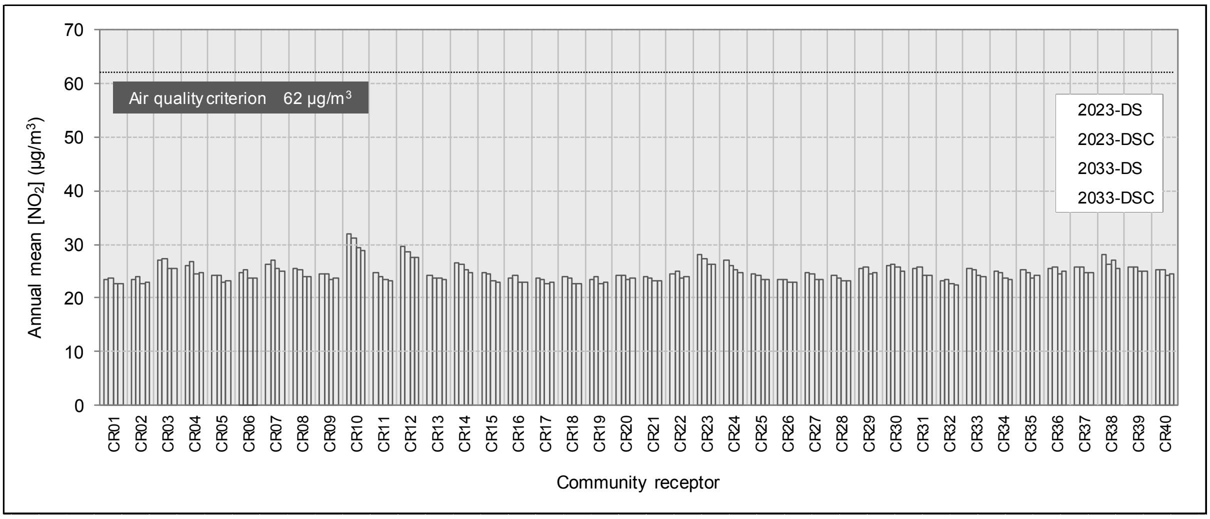


Figure 9-27 Annual mean NO_2 concentration at community receptors (with 2023 and 2033 project (DS) and cumulative (DSC) scenarios)

Figure 9-28 shows the changes in concentration with the project. There was a small increase (<1 µg/m^3) in the NO_2 concentration at some receptors. The largest increase with the project was around 1.6 µg/m^3 at receptor CR38 (Active Kids Mascot), equating to around three per cent of the criterion. At most receptors, there were reductions in NO_2, the largest of which – between around two and four µg/m^3 – were predicted to occur at receptors CR03 (Rosebud Cottage Child Care Centre, Rozelle), CR22 (St Thomas Child Care Centre, Rozelle), CR23 (Billy Kids Early Learning Centre, Lilyfield) and CR31 (Rozelle Public School).

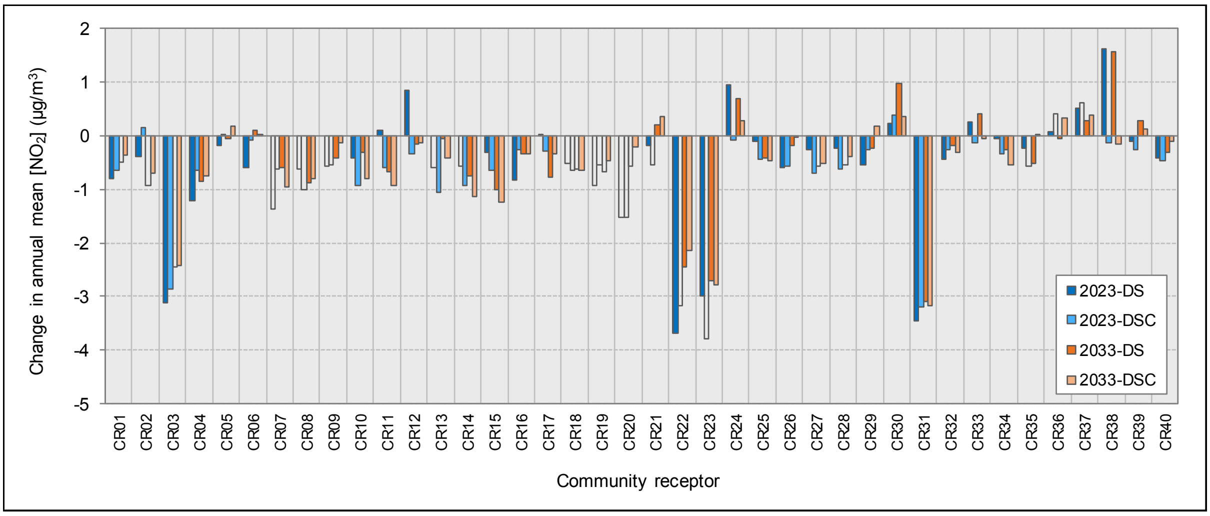


Figure 9-28 Change in annual mean NO_2 concentration at community receptors (with 2023 and 2033 project (DS) and cumulative (DSC) scenarios, relative to Do Minimum scenarios)

Figure 9-29 gives the source contributions to total annual mean NO_2 concentrations in the with-project scenarios. The results indicate that the background component at these receptors is likely to be responsible for, on average, around 80 per cent of the predicted annual mean NO_2, with most of the remainder being due to surface roads. For the with-project scenarios, surface roads were responsible for between 10 per cent and 40 per cent of the total, depending on the scenario and receptor. The contribution of tunnel ventilation outlets was less than 1.4 per cent in all scenarios.

Figure 9-29 Source contributions to annual mean NO2 concentration at community receptors (with 2023 and 2033 project and cumulative scenarios)

Results for RWR receptors

The annual mean NO_2 concentrations at the RWR receptors in the with-project scenarios are shown, with a ranking by total concentration, in **Figure 9-30**.

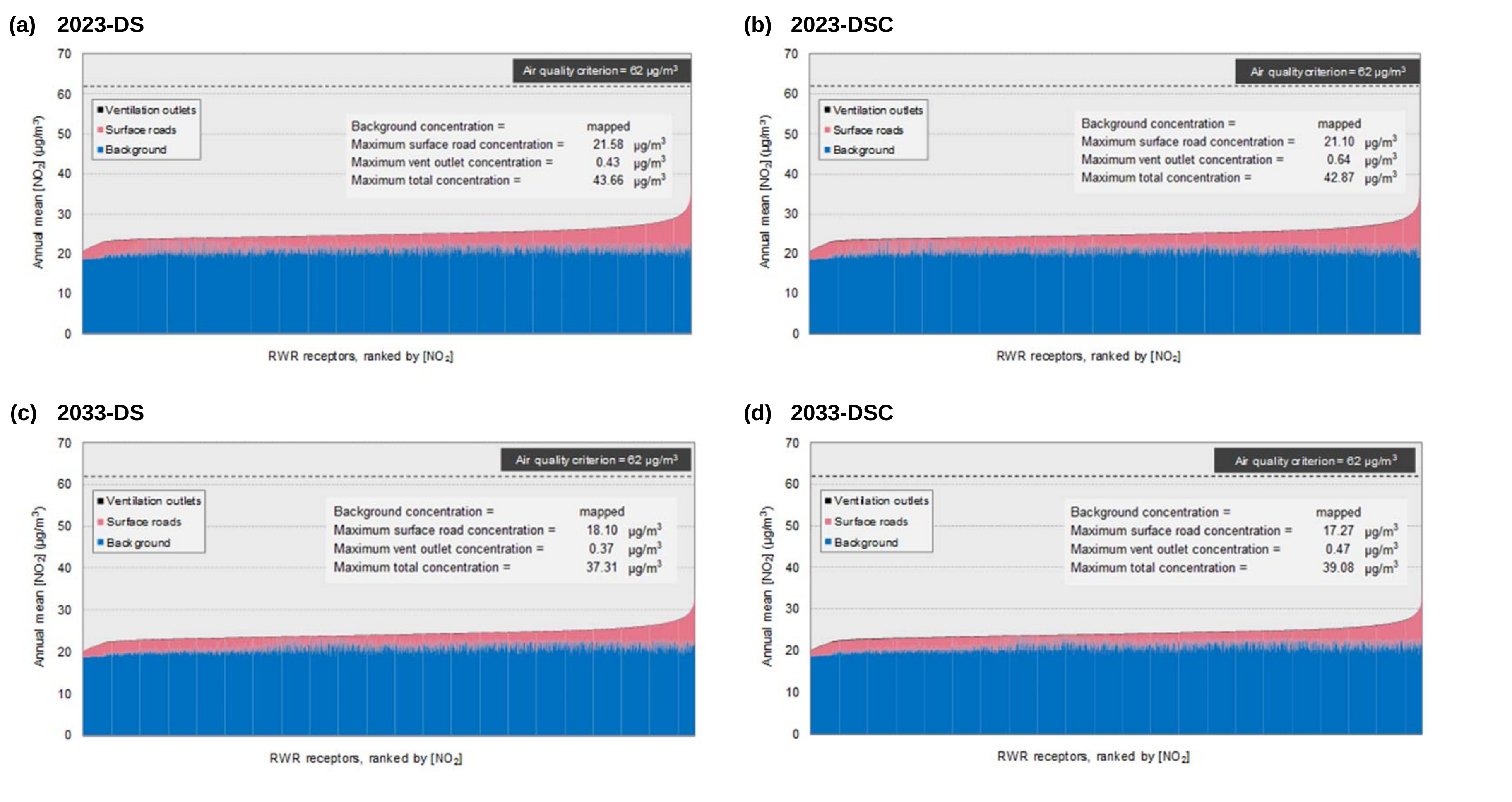


Figure 9-30 Source contributions to annual mean NO_2 concentration at RWR receptors (with-project and cumulative scenarios)

Concentrations at the vast majority (more than 98 per cent) of receptors were between around 20 µg/m^3 and 30 µg/m^3. The annual mean NO_2 criterion for NSW of 62 µg/m^3 was not exceeded at any of the receptors in any scenario.

At all but 11 receptors in the 2023-DS scenario, NO_2 concentrations were also below the EU limit value of 40 µg/m^3. However, the 11 receptors with an exceedance in the 2023DS scenario (with the project) was lower than the 17 receptors with an exceedance in the 2023-DM scenario (without the project), so that the project provides a benefit in these locations. The highest concentrations with the project in 2023 D-S scenarios were predicted to be around 43 µg/m^3. The highest concentrations with the project in 2033 DS were predicted to be around 39 µg/m^3.

The maximum contribution of tunnel ventilation outlets for any scenario and receptor was 0.6 µg/m^3, whereas the maximum surface road contribution was 21.6 µg/m^3. Given that NO_2 concentrations at the majority of receptors were well below the NSW criterion, the contribution of the ventilation outlets was not a material concern.

There was predicted to be an increase in the annual mean NO_2 concentration at between 15 per cent and 20 per cent of receptors, depending on the scenario. Only around 0.1 per cent of receptors were predicted to have an increase of greater than two µg/m^3. Conversely, there was a reduction in annual mean NO_2 at between around 80 per cent and 85 per cent of receptors.

Contour plots – all sources

Contour plots were developed to illustrate the spatial distribution of pollutant concentrations (from all sources) across the GRAL domain. Only the contour plots showing the change in pollutants as a result of the project in 2023 and 2033 are shown in this chapter (see **Figure 9-31** and **Figure 9-32**). The contour plots for all other scenarios are given in Annexure K of **Appendix I** (Technical working paper: Air quality). The green shading show decreases in concentration and the purple shading shows an increase in concentration. The scale on the plots indicates the concentrations represented by the depth of the colour.

The plots are based on 1.8 million grid points, spaced at 10-metre intervals across the domain. Many of the points fall along the axes of roads, and are therefore not necessarily representative of population exposure. The plots illustrate the strong links between the spatial distribution of air pollution and the traffic on the road network. The figures also show main surface roads and the locations of tunnel ventilation outlets.

It should be noted that some of the roads in the model are presented as being on the surface, whereas in reality, they are (minor) tunnels. The main examples of this are the relatively short tunnel on General Holmes Drive that passes under the airport runway, and the Cooks River Tunnel. It was not considered necessary to represent these roads as tunnels given that they were some distance from sensitive receptor locations (moreover, decreases in concentration were predicted along these roads).

The highest absolute concentrations are found along the most heavily trafficked roads in the GRAL domain, such as the Western Distributor, Anzac Bridge and General Holmes Drive to the south of the airport. It should be noted that the Do Minimum scenarios also include the M4 East and New M5 projects, and therefore some roads which are currently heavily trafficked are not as prominent as might be expected. A good example of this is Parramatta Road, which would have reduced traffic as a result of the M4 East project. It is noticeable that the tunnel ventilation outlets have little impact on total annual mean NO_2 concentrations.

The purple shading to the north of Sydney Airport is the estimated change from the proposed future Sydney Gateway which would be a new surface road, hence there would be a re-distribution of traffic and therefore emissions from other parts of the road network to this new road.

There are predicted to be marked reductions in concentration along some major roads, and increases on others, in proportion to the changes in traffic in WRTM. **Table 9-25** summarises the average weekday two-way traffic on some affected roads in all scenarios from WRTM, and **Table 9-26** gives the changes between scenarios.

In **Figure 9-31** there are noticeable decreases in NO_2 along Dobroyd Parade/City West Link and Parramatta Road to the southeast of the Parramatta Road ventilation station. In the 2023-DM scenario, the traffic to and from the M4 East tunnel would access the tunnel using these roads. In the with-project scenarios, the M4-M5 Link tunnel connects to the M4 East tunnel, thus relieving these roads. There are reductions in traffic on City West Link and Parramatta Road of between 19 and 27 per cent.

A substantial reduction in surface traffic and consequent reduction in NO_2 concentration is predicted along the Victoria Road corridor south of Iron Cove at Rozelle. This is due to traffic being diverted through the Iron Cove Link tunnels. For example, the average traffic volume on Victoria Road would decrease from around 76,000 vehicles per day without the project in 2033 to around 29,000 vehicles per day with the project in 2033 which is a reduction of around 60 per cent. On the other hand, there would be around a six percent increase in traffic to the north of the Iron Cove Link in 2023 with the project and seven per cent in 2033 with the project. An increase of around 13 per cent is expected in both the 2023 and 2033 cumulative scenarios.

There would also be reductions in concentrations along General Holmes Drive, the Princes Highway and the M5 East Motorway. NO_2 concentrations are predicted to increase along Canal Road, which would be used to access St Peters interchange, and other roads associated with the proposed future Sydney Gateway project.

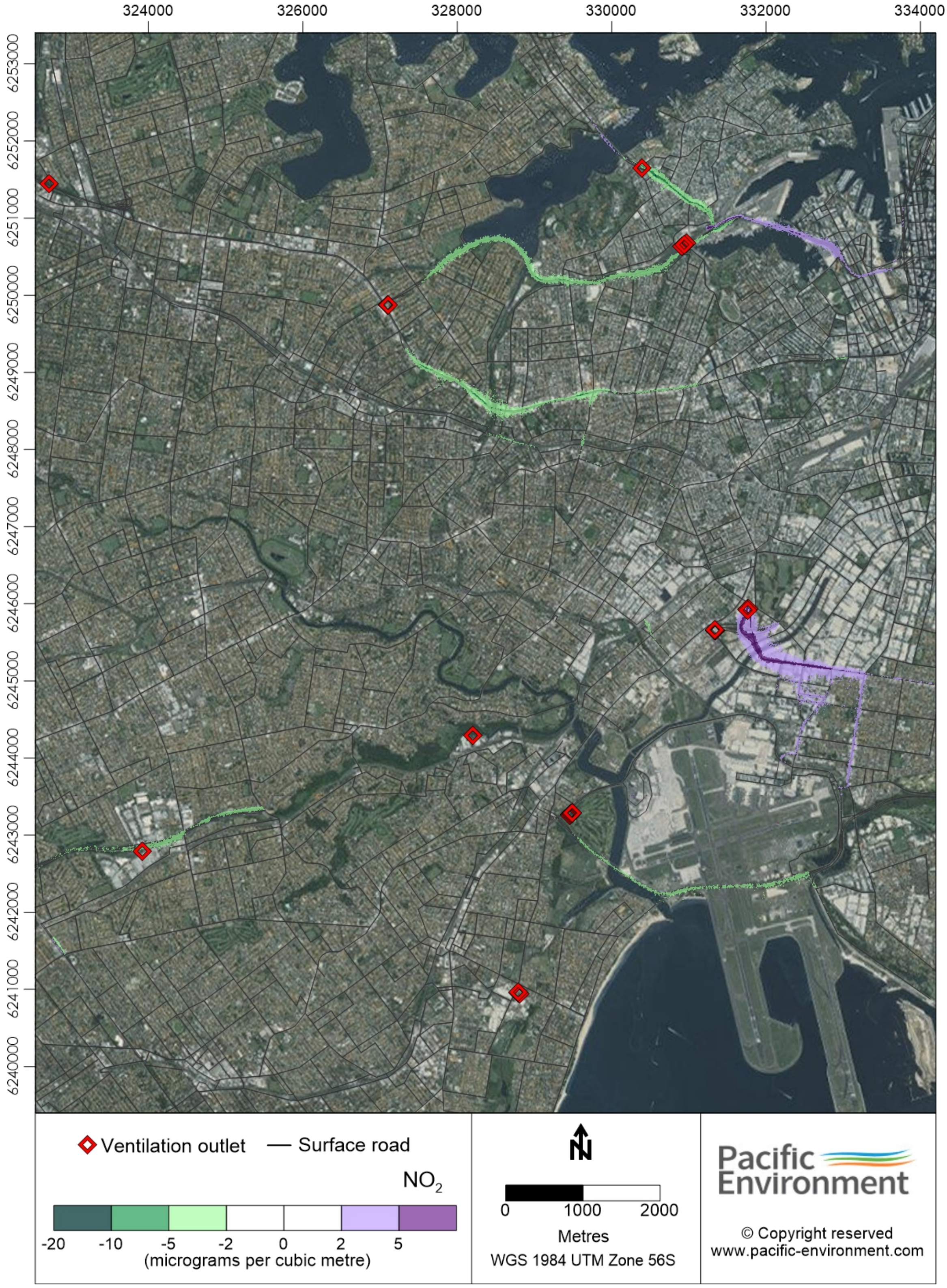


Figure 9-31 Contour plot of change in annual mean NO_2 concentration with the project (2023-DS)

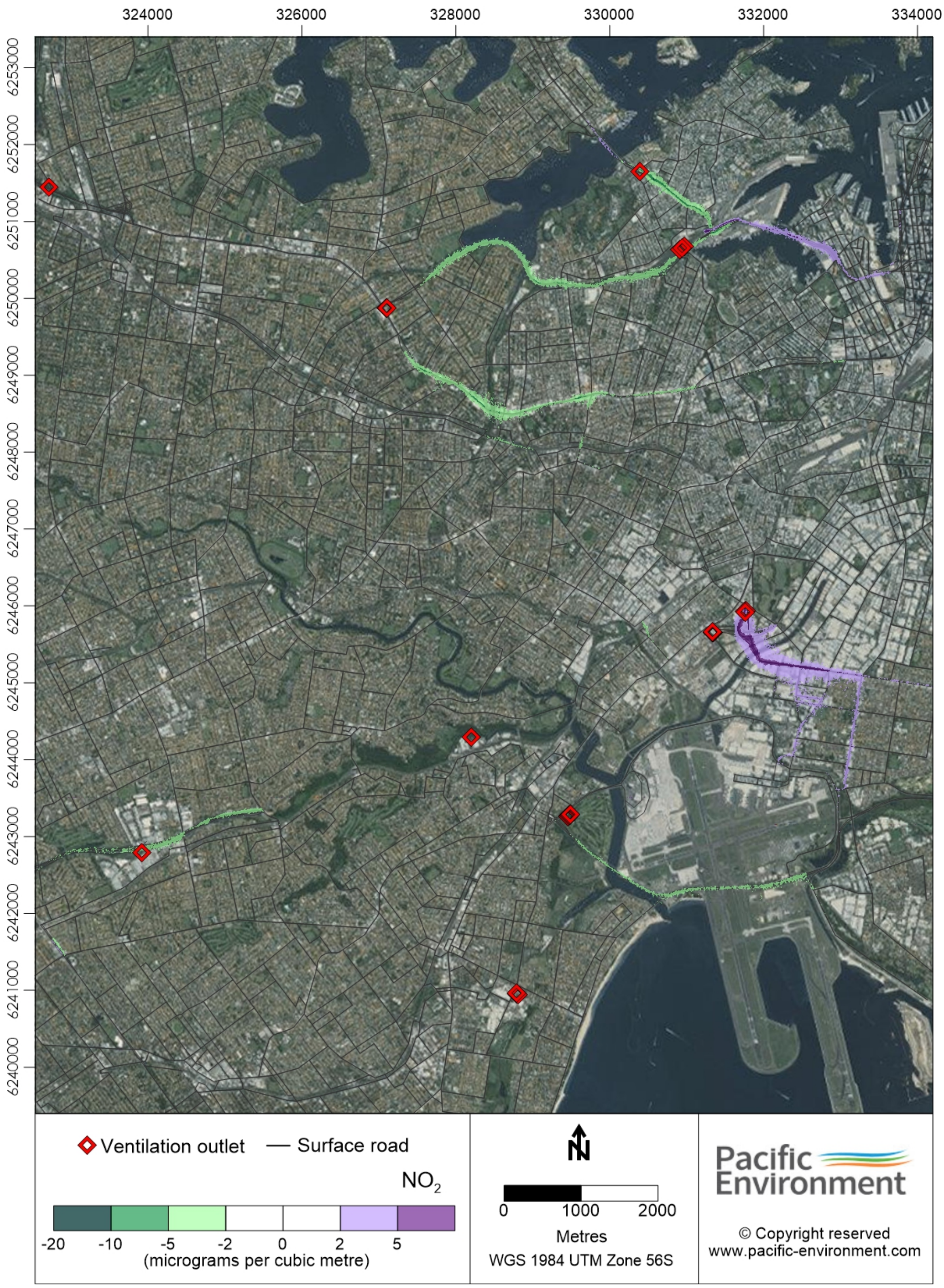


Figure 9-32 Contour plot of change in annual mean NO_2 concentration with the project (2033-DS)

Table 9-25 Average weekday two-way traffic volume on selected roads

Road	Average weekday two way traffic volume by scenario (vehicles per day)					
	2023-DM	2023-DS	2023-DSC	2033-DM	2033-DS	2033-DSC
City West Link	63,071	48,498	46,603	65,242	52,876	50,319
Parramatta Road, southeast of ventilation facility	76,192	56,553	57,195	82,179	60,375	60,659
Victoria Road, south of Iron Cove	72,930	25,457	25,226	75,852	29,215	29,110
Victoria Road, north of Iron Cove	78,171	83,217	89,211	81,866	84,932	89,742
Anzac Bridge	154,362	190,953	183,862	162,184	202,886	196,139
General Holmes Drive	166,127	156,468	155,124	182,487	171,804	159,155
Princes Highway	74,370	68,283	55,157	79,208	71,642	53,135

Table 9-26 Changes in average weekday two-way traffic volume on selected roads

Road	Change in average weekday two-way traffic volume by scenario (vehicles per day/%)							
	2023-DS minus 2023-DM		2023-DSC minus 2023-DM		2033-DS minus 2033-DM		2033-DSC minus 2033-DM	
City West Link	-14,573	(-23%)	-16,468	(-26%)	-12,366	(-19%)	-14,923	(19%)
Parramatta Road, southeast of ventilation facility	-19,639	(-26%)	-18,997	(-25%)	-21,804	(-27%)	-21,520	(-27%)
Victoria Road, south of Iron Cove	-47,473	(-65%)	-47,704	(-65%)	-46,637	(-61%)	-46,742	(-61%)
Victoria Road, north of Iron Cove	+5,046	(+6%)	+11,040	(+14%)	+3,066	(+4%)	+7,876	(+4%)
Anzac Bridge	+36,591	(+24%)	+29,500	(+19%)	+40,702	(+25%)	+33,955	(+25%)
General Holmes Drive	-9,659	(-6%)	-11,003	(-7%)	-10,683	(-6%)	-23,332	(-6%)
Princes Highway	-6,087	(-8%)	-19,213	(-26%)	-7,566	(-10%)	-26,073	(-10%)

Contour plots – ventilation outlets only (full GRAL domain)

Contour plots for annual mean NO_X (not NO_2) in the GRAL domain were also produced for the tunnel ventilation outlets only. NO_x rather than NO_2 is calculated for the ventilation outlet contributions for both annual mean and maximum and one hour concentrations because there is no practical way to calculate the outlet contribution to one hour maxima for NO_2 across the domain. The NO_2 concentrations from the outlets would, in any case, be very small given that the NOx concentration is already small, and therefore NO_x is a conservative indicator for NO_2. The contour plots for all scenarios are shown in Annexure K of **Appendix I** (Technical working paper: Air quality). The methodology for calculation of NO_2 from NO_x is discussed in Annexure G of **Appendix I** (Technical working paper: Air quality).

Nitrogen dioxide (maximum one hour mean)

Results for community receptors

The maximum one hour NO_2 concentrations at the 40 community receptors in the with-project scenarios are **Figure 9-33**. At all receptor locations the maximum concentration was below the NSW impact assessment criterion of 246 µg/m^3, and in most cases around 200 µg/m^3.

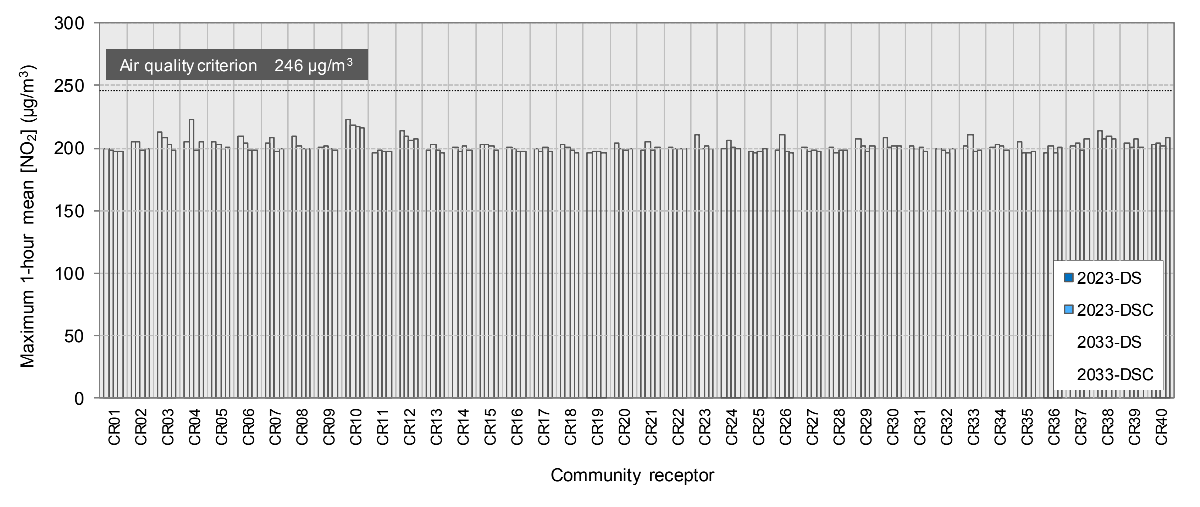


Figure 9-33 Maximum one hour mean NO_2 concentration at community receptors (with-project and cumulative scenarios)

The changes in the maximum one hour NO_2 concentration relative to the Do Minimum scenarios are shown in **Figure 9-34.** Again, there was a mixture of small (relative to the NSW criterion) increases and decreases. There were some notable increases in the maximum concentration at a small number of receptors, but as observed above these did not result in any exceedances of the NSW criterion.

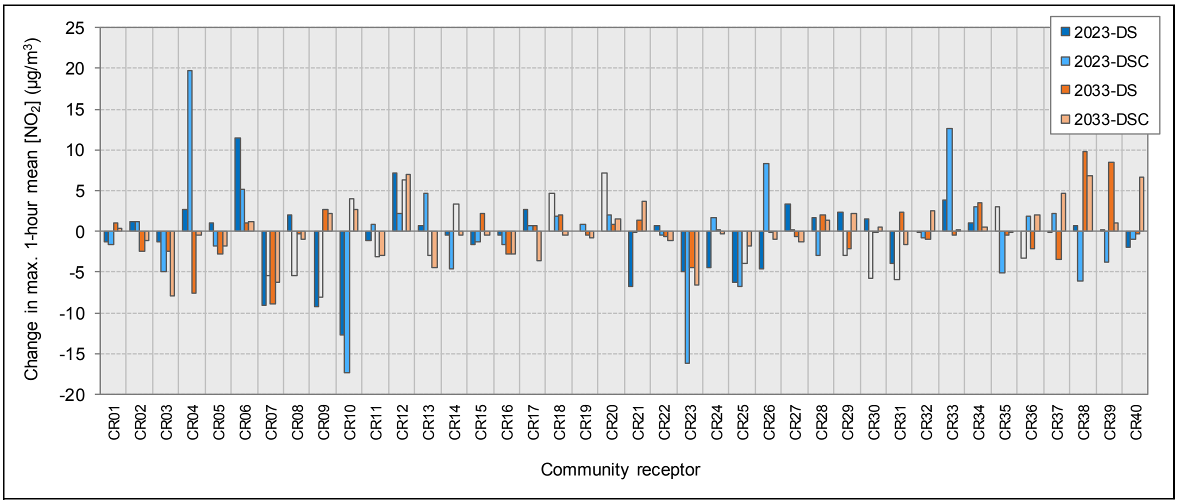


Figure 9-34 Change in maximum one hour mean NO_2 concentration at community receptors (with-project and cumulative scenarios, relative to corresponding Do Minimum scenarios)

The source contributions for the community receptors are shown in **Figure 9-35**. As with the annual mean, the background was the most important source, with generally a small contribution from surface roads. The tunnel ventilation outlet contribution to the maximum NO_2 concentration was either zero or, at one receptor alone, negligible (0.2 per cent).

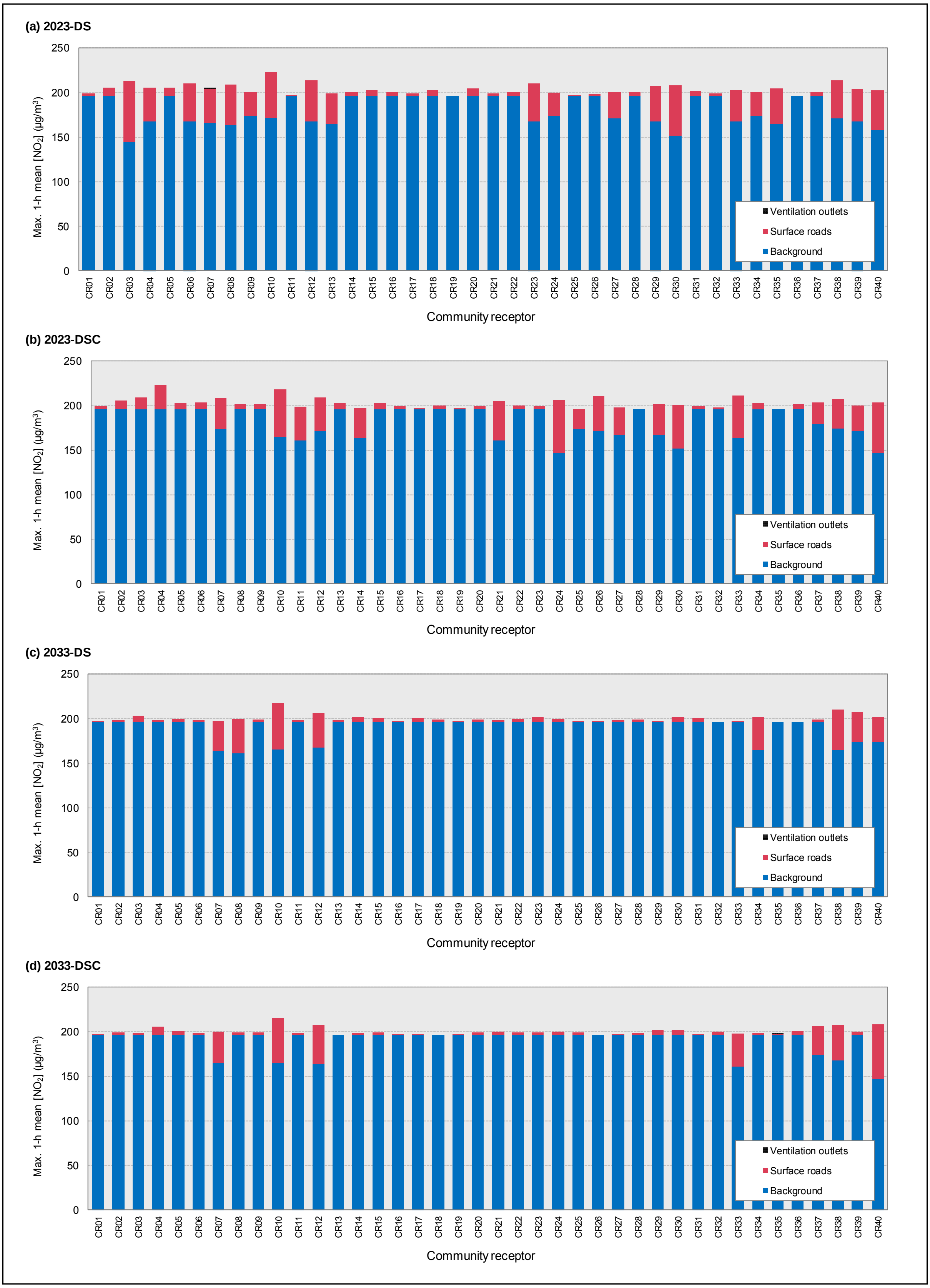


Figure 9-35 Source contributions to maximum one hour mean NO_2 concentration at community receptors (2023 and 2033 with-project (DS) and cumulative (DSC) scenarios)

Results for RWR receptors

The maximum one hour mean NO_2 concentrations at the RWR receptors in the with-project contributions and cumulative scenarios are shown, with a ranking by total concentration, in **Figure 9-36**. There were some predicted exceedances of the NSW one hour NO_2 criterion (246 μg/m^3), both with and without the project.

In the 2023-DM (without the project) scenario the maximum concentration exceeded the NSW criterion at around 5,700 receptors (6.6 per cent of all receptors), but with the introduction of the project in the 2023-DS scenario, this decreased to around 3,700 receptors (4.4 per cent). In the 2023-DSC scenario, the number decreased further (3,200 receptors, 3.8 per cent). In the 2033-DM scenario, there were exceedances at around 1,100 receptors (1.3 per cent), decreasing to 880 receptors (one per cent) in the 2033-DS scenario. In the 2033-DSC scenario, the number decreased to around 660 receptors (less than one per cent).

Although the ventilation outlet contributions to NO_2 could not be separated from surface contributions, the maximum contribution of tunnel outlets to NO_X at any receptor in the with-project scenarios was 57 μg/m^3 in 2023-DSC. This would equate to a very small NO_2 contribution relative to the air quality assessment criterion.

No exceedances of the NSW NO_2 criterion have been measured at ambient air quality monitoring stations in Sydney in recent years, and to some extent the predicted exceedances may be a result of the conservatism in some of the modelling assumptions, and the tendency of the modelling process to overestimate maximum NO_2 concentrations (see Figure J-6 in Annexure J of **Appendix I** (Technical working paper: Air quality)). The extent of the overestimation may also be high in 2023 and 2033 given the assumption of a higher NO_2/NO_X ratio in future years.

The changes in the maximum one hour mean NO_2 concentration at the RWR receptors in the with-project scenarios are shown and ranked by change in concentration as a result of the project, in **Figure 9-36**. Increases in the maximum one hour NO_2 concentration of between 26 per cent and 33 per cent of receptors were predicted, depending on the scenario. Conversely, there was a reduction in the maximum concentration between around 67 per cent and 74 per cent of receptors.

At the majority of receptors the change was relatively small. At around 93 per cent of receptors in 2023, the change in concentration (either an increase or a decrease) was less than 20 μg/m^3. Some of the changes at receptors were much larger and unrealistically high (up to 234 μg/m^3). An explanation of these high concentrations is provided in **section 9.7.4**.

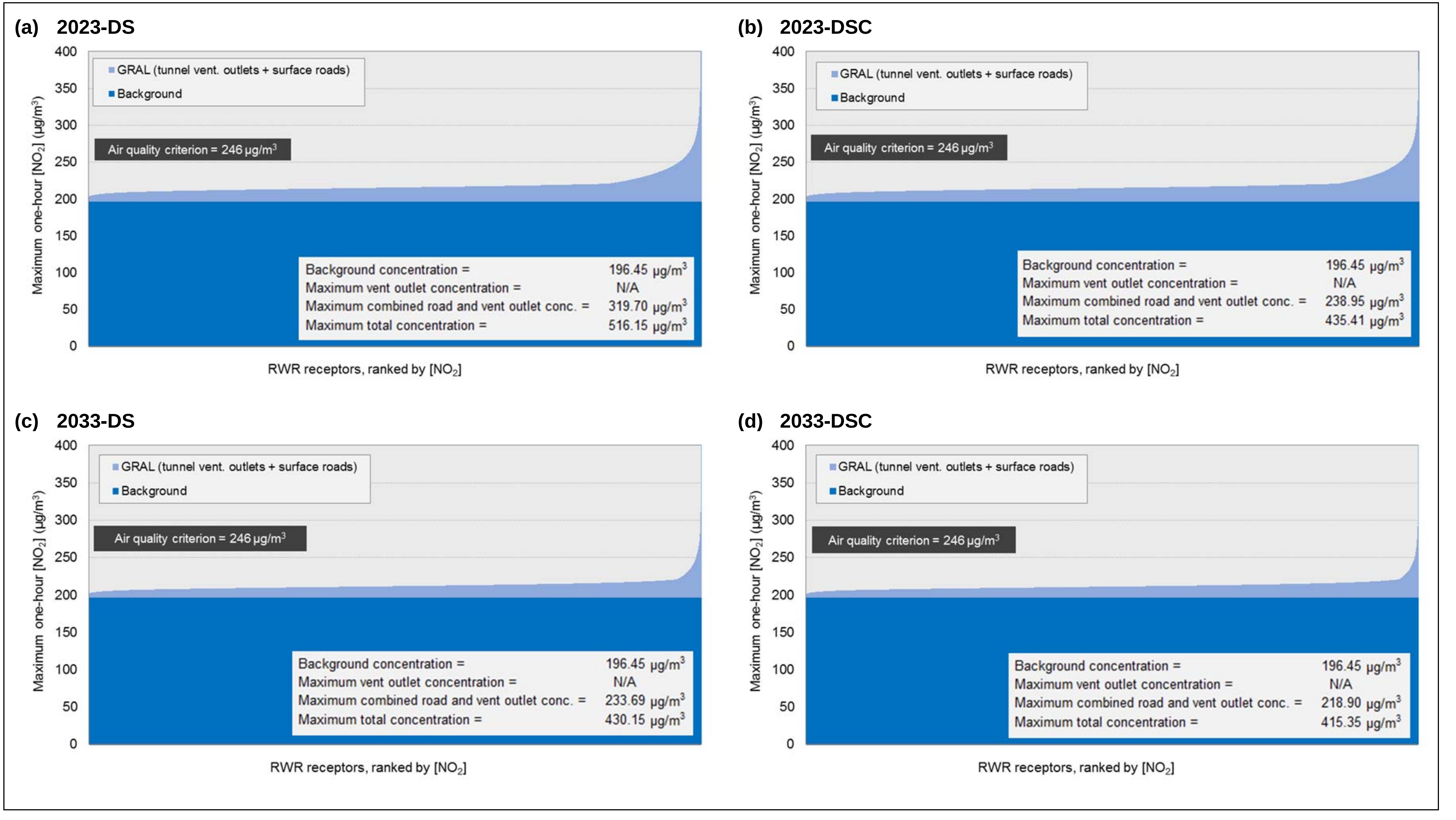


Figure 9-36 Source contributions to maximum one-hour mean NO_2 concentration at RWR receptors (with-project and cumulative scenarios)

Contour plots – all sources (background, surface roads and ventilation outlets)

Contour plots of change in maximum one hour NO_2 concentrations in the 2023-DS and 2033-DS scenarios are provided in **Figure 9-37** and **Figure 9-38.**

It is important to note that these plots do not represent a particular time period; each point in the plot is a maximum value for any hour of the year. The locations with the highest concentrations and largest changes in concentration are similar to this for annual mean NO_2 (refer to **Appendix I** Technical working – Air Quality).

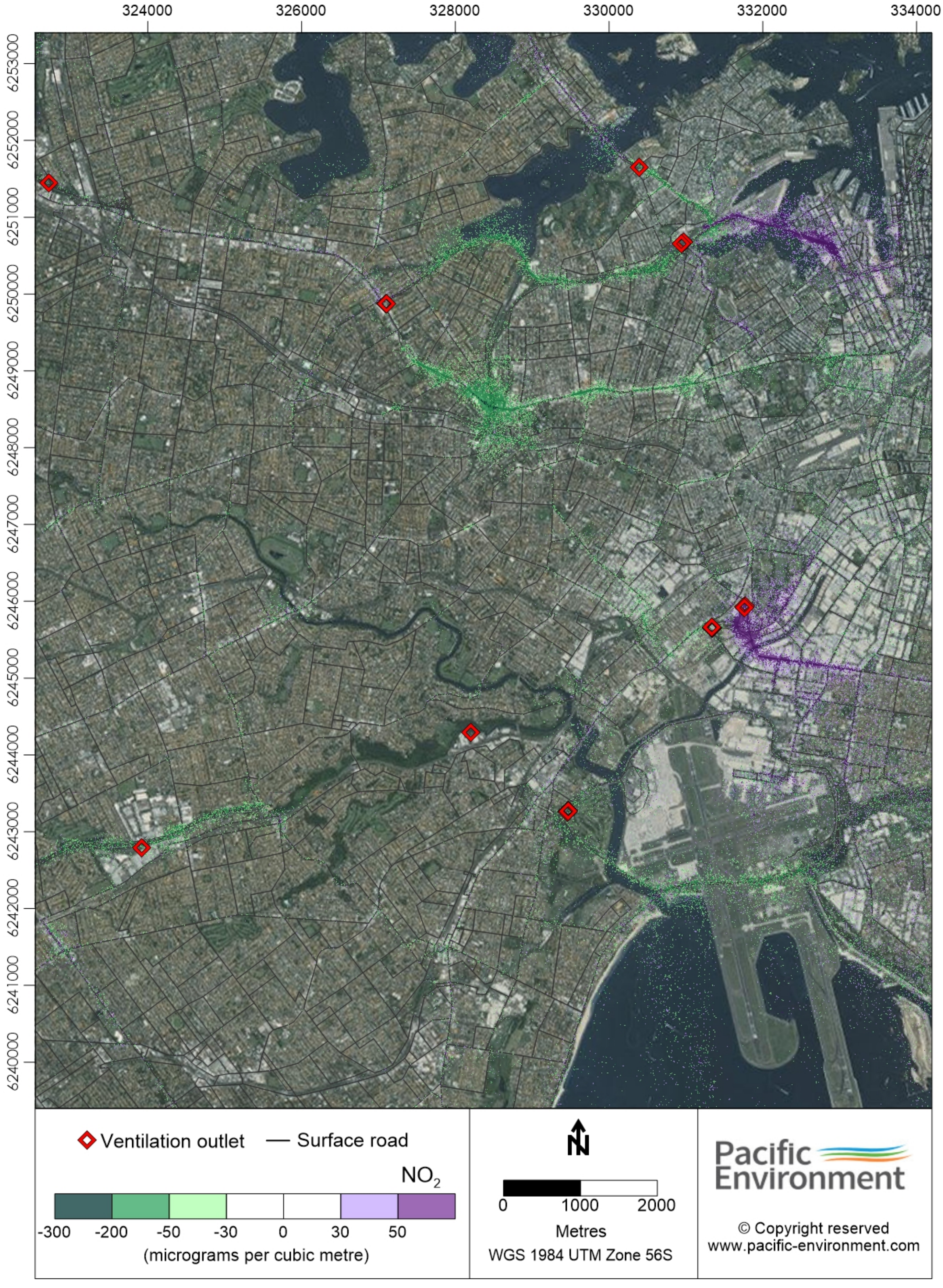


Figure 9-37 Contour plot of change in maximum one hour NO_2 concentration with the project (2023-DS)

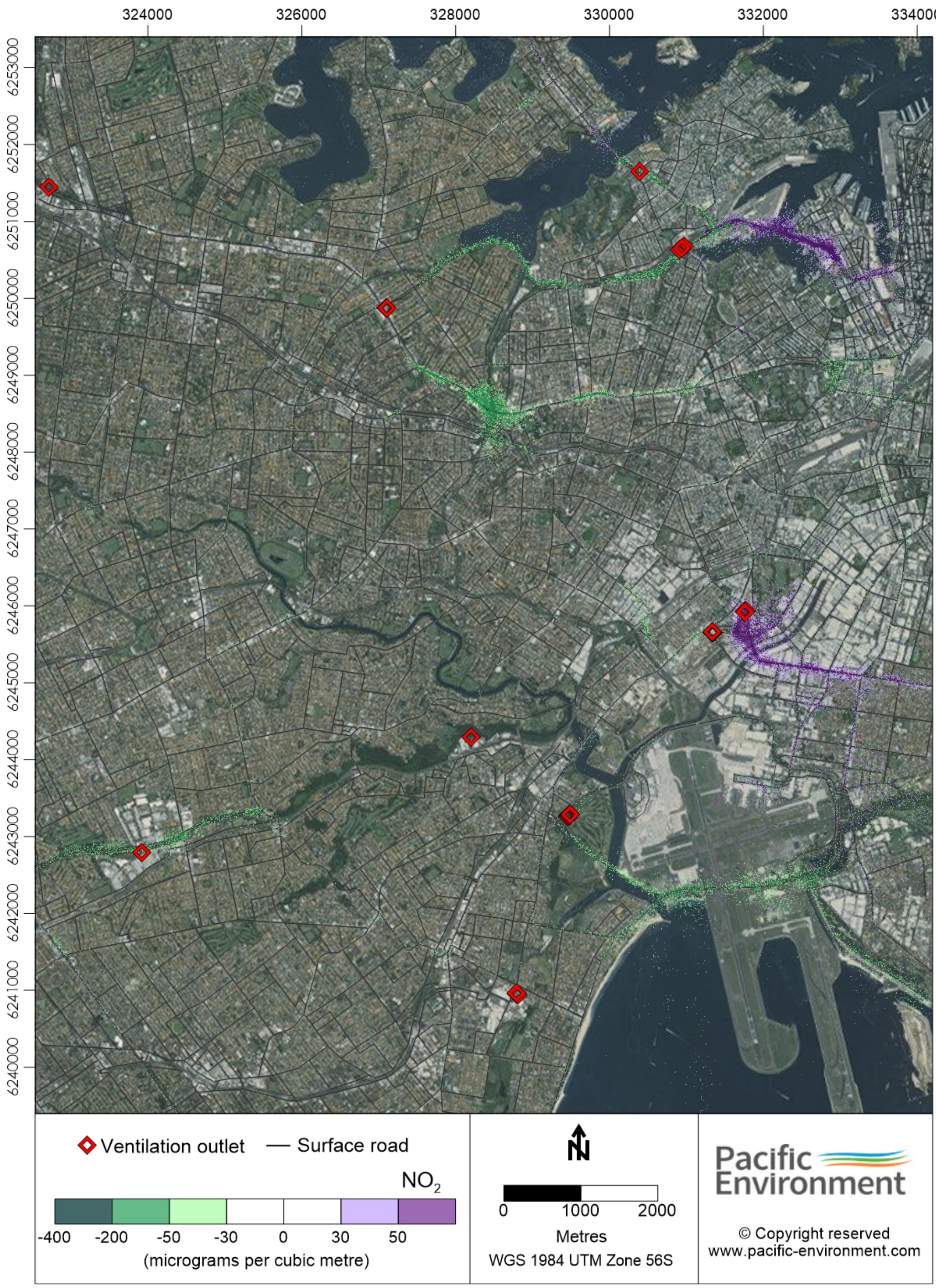


Figure 9-38 Contour plot of change in maximum one hour NO_2 concentration with the project in (2033-DS)

PM_{10} (annual mean)

Results for community receptors

The annual mean PM_{10} concentrations community receptors are shown in **Figure 9-39**. These were all below the NSW impact assessment criterion of 25 µg/m^3. At all but one of the receptors the concentration was below 20 µg/m^3; receptor CR10 (University of Notre Dame, Broadway) had concentrations that were slightly above 20 µg/m^3. PM_{10} concentrations at these receptors – several of which are near busy roads in Sydney – were only slightly above the lowest PM_{10} standards in force in other countries (18 µg/m^3 in Scotland).

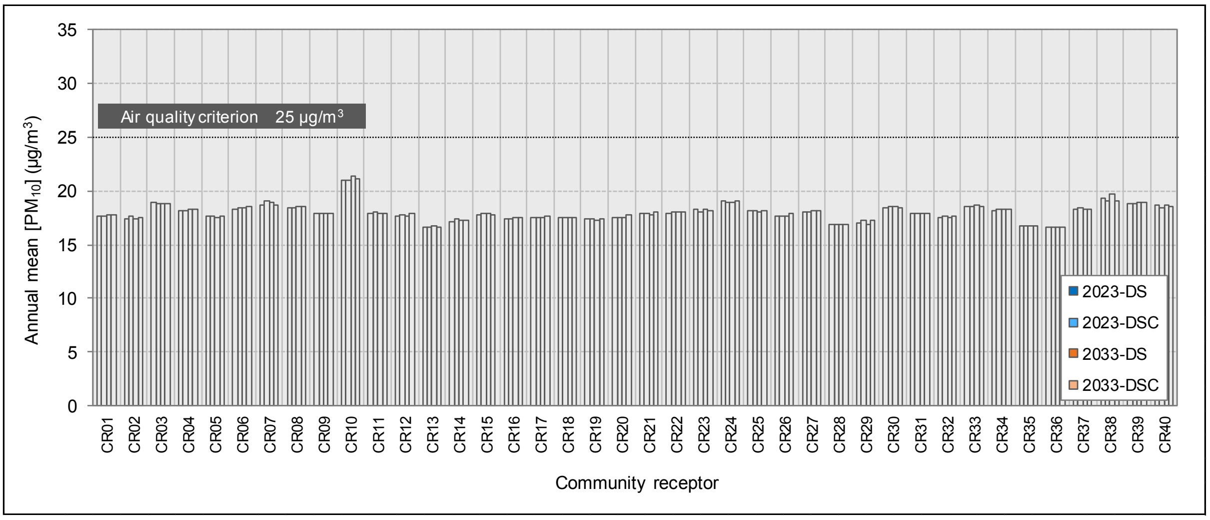


Figure 9-39 Annual mean PM_{10} concentration at community receptors (with-project (DS) and cumulative (DSC) scenarios)

Figure 9-40 shows the changes in PM_{10} concentration. The largest increase was around 0.8 µg/m^3 (three per cent of the criterion) at receptor CR38 (Active Kids, Mascot), and the largest decrease slightly more than 1.0 µg/m^3. Concentrations decreased at most of the receptors. There is a high background and surface road contribution at receptor CR38.

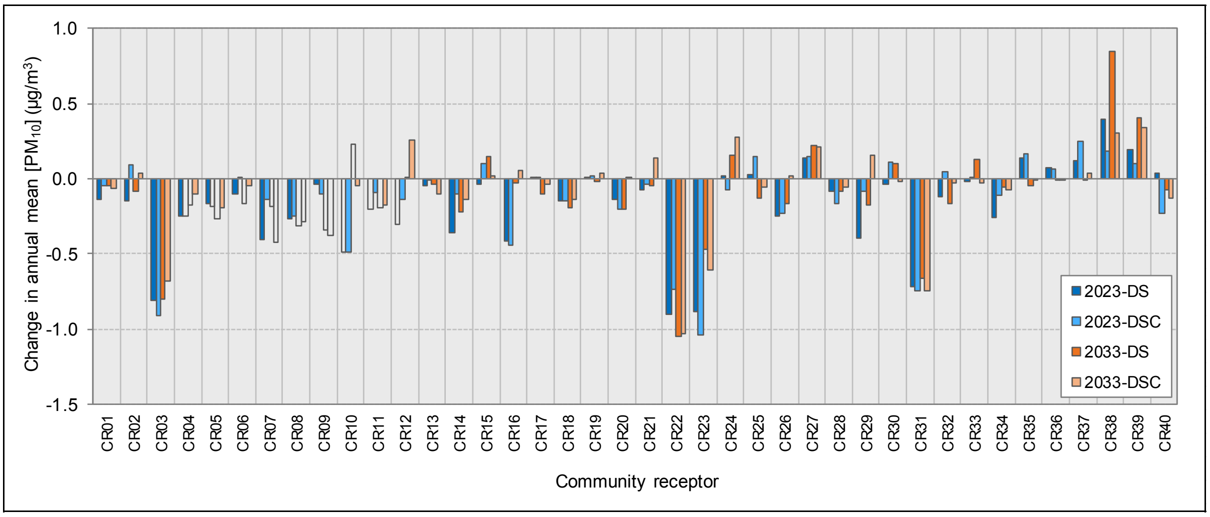


Figure 9-40 Change in annual-mean PM_{10}-concentration at community receptors DS and DSC scenarios, relative to corresponding DM scenarios)

Concentrations in the with-project scenarios were again dominated by the background in **Figure 9-41**, with a small contribution from roads (0.8–4.4 µg/m^3) and a negligible contribution from tunnel ventilation outlets (less than around 0.2 µg/m^3).

Figure 9-41 Source contributions to annual mean PM_{10} concentration at community receptors DS and DSC

Results for RWR receptors

The ranked annual mean PM_{10} concentrations at the RWR receptors are shown in **Figure 9-42.** The concentration at the majority of receptors was below 20 μg/m^3, with only a very small proportion of receptors having a concentration just above the NSW assessment criterion of 25 μg/m^3. The highest predicted concentration at any receptor in a with-project scenario was 26.5 μg/m^3. The surface road contribution was between 0.05 μg/m^3 and 9.8 μg/m^3, with an average of 1.1–1.2 μg/m^3. The largest contribution from tunnel ventilation outlets was 0.37 μg/m^3 in the 2023-DSC scenario.

The changes in the annual mean PM_{10} concentration at the RWR receptors are shown, ranked by change in concentration, in **Figure 9-42**. There was an increase in concentration at 32 to 36 per cent of the receptors, depending on the scenario. At the majority of receptors the change was relatively small, and where there was an increase, this was greater than 2.5 μg/m^3 at only a single receptor in the 2023-DSC and 2033-DSC scenarios.

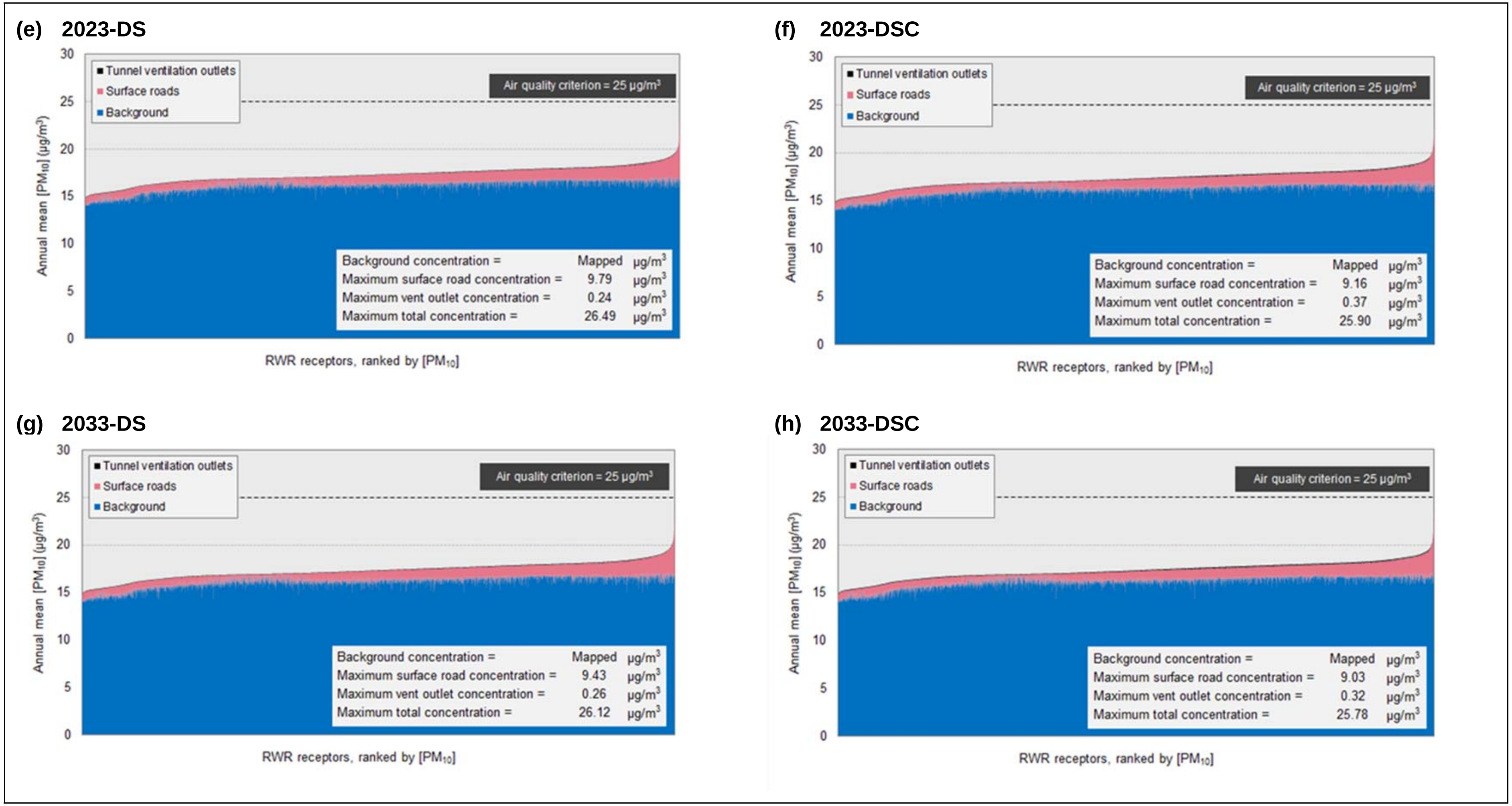


Figure 9-42 Source contributions to annual mean PM_{10} concentration at RWR receptors (with-project and cumulative scenarios)

Contour plots – all sources

The contour plots for the changes in annual mean PM_{10} in the 2023 and 2033-DS scenarios are presented in **Figure 9-43** and **Figure 9-44.** The plots show variable changes reflective of the changes in traffic on the surface road network similar to those for NO_2.

Figure 9-43 Contour plot of change in annual mean PM_{10} concentration with the project (2023-DS)

Figure 9-44 Contour plot of change in annual mean PM_{10} concentration with the project (2033-DS)

PM_{10} (maximum 24 hour mean)

Results for community receptors

Figure 9-45 presents the maximum 24 hour mean PM_{10} concentrations at the community receptors. At all locations, and in all scenarios, the concentration was close to the NSW impact assessment criterion of 50 µg/m^3, which is also the most stringent standard internationally. The number of community receptors with an exceedance of the criterion decreased from 16 in the 2023-DM scenario to 11 in the 2023-DS scenario and 12 in the 2023-DSC scenario. In 2033, the number of receptors exceeding the criterion decreased from 14 in the 2033-DM scenario to 12 in the 2033-DS scenario, but increased to 17 in the 2033-DSC scenario. However, it should be noted that the community receptors only formed a very small subset of all the receptors, in the GRAL domain.

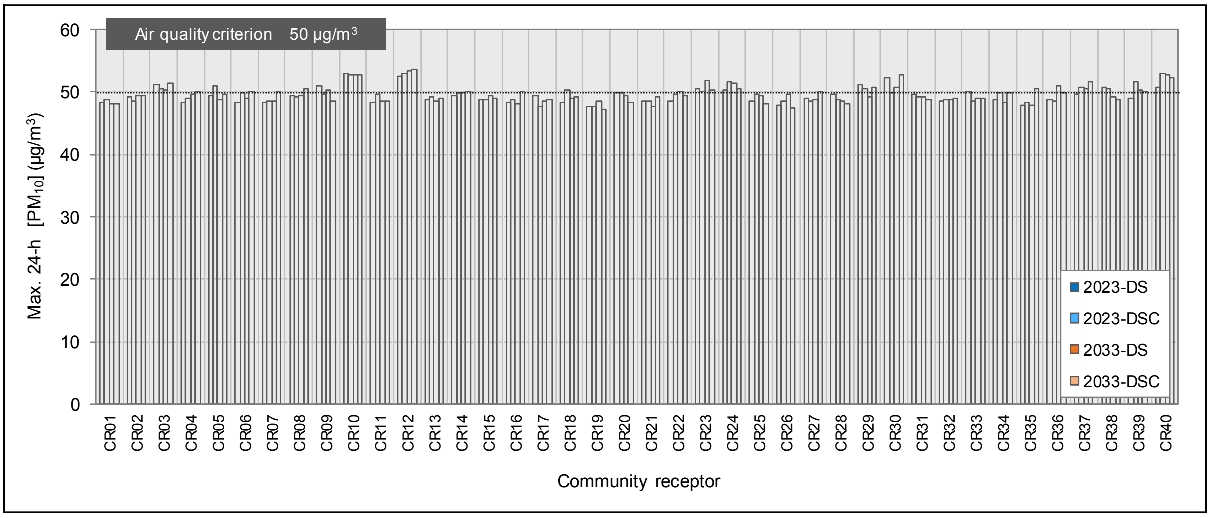


Figure 9-45 Maximum 24 hour mean PM_{10} concentration at community receptors (with-project (DS) and cumulative (DSC) scenarios)

Figure 9-46 shows the changes in concentration in the Do Something and Cumulative scenarios relative to the Do Minimum scenarios for the community receptors. At most receptors, the change was less than two µg/m^3, and at all receptors it was less than four µg/m^3. There was no pattern in the changes by year or by scenario.

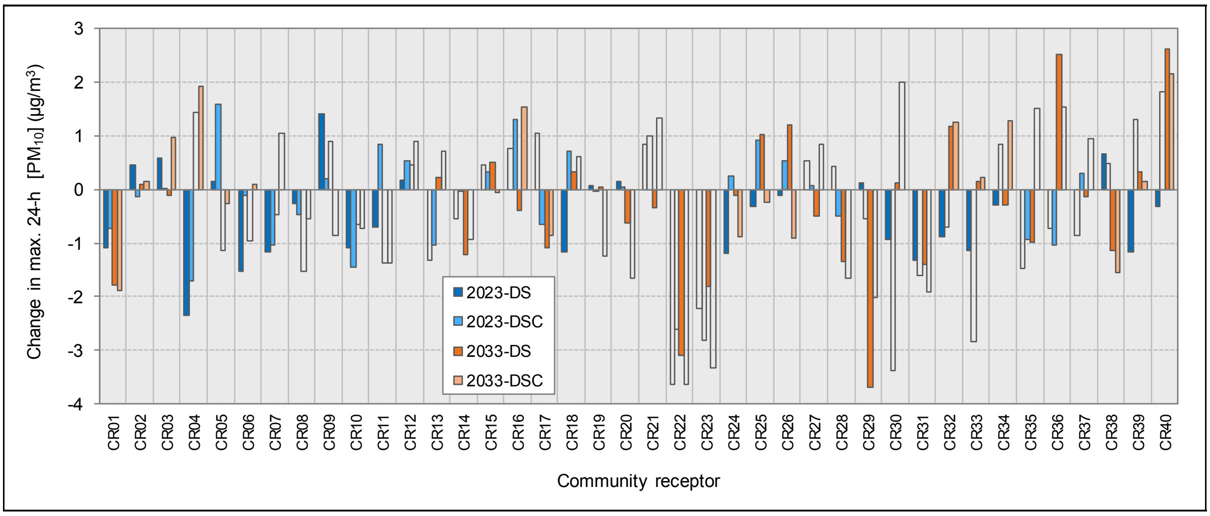


Figure 9-46 Change in maximum 24 hour mean PM_{10} concentration at community receptors (with-project (DS) and cumulative (DSC) scenarios, relative to corresponding Do Minimum scenarios)

Figure 9-47 demonstrates that the surface road contribution to the maximum 24 hour PM_{10} concentration at each receptor was small (generally less than around five µg/m^3). The exception to this was receptor CR10, which had a road contribution of 15.1 to 21 µg/m^3. This receptor (University of Notre Dame at Broadway) is a unique case as a result of a particularly low background combined with a large traffic contribution on the date that the synthetic background profiles were developed as discussed in **Appendix I** (Technical working paper: Air quality). At all community receptors except CR10, the maximum total 24 hour concentration occurred on one day of the year (1 July), and coincided with the highest 24 hour background concentration in the synthetic PM_{10} profile (46.2 µg/m^3).

The tunnel ventilation outlet contribution at the community receptors was negligible, being less than 0.4 µg/m^3 in all cases.

Results for RWR receptors

The results for the RWR receptors were highly dependent on the assumption for the background concentration. Because this was assumed to be the maximum concentration in the synthetic background profile (ie 46.2 µg/m^3), the total concentration at the majority of receptors in the with-project scenarios (77 to 80 per cent) was above the NSW impact assessment criterion of 50 µg/m^3.

The proportion of receptors with a concentration above the criterion decreased slightly as a result of the project, such as from 82 per cent in the 2023-DM scenario to 78 per cent in the 2023-DS scenario. The contributions of surface roads and ventilation outlets were not additive. The maximum contribution of tunnel ventilation outlets at any receptor in a scenario was between 1.2 µg/m^3 to 1.9 µg/m^3, depending on the scenario.

The changes in the maximum 24 hour mean PM_{10} concentration with the project are ranked by change in concentration in **Figure 9-48**. There was an increase in concentration at between 37 and 39 per cent of the receptors, depending on the scenario. The largest predicted increase in concentration at any receptor as a result of the project was 13.3 µg/m^3, and the largest predicted decrease was 11.8 µg/m^3. Where there was an increase, this was greater than five µg/m^3 (10 per cent of the criterion) at just 0.1 per cent of receptors.

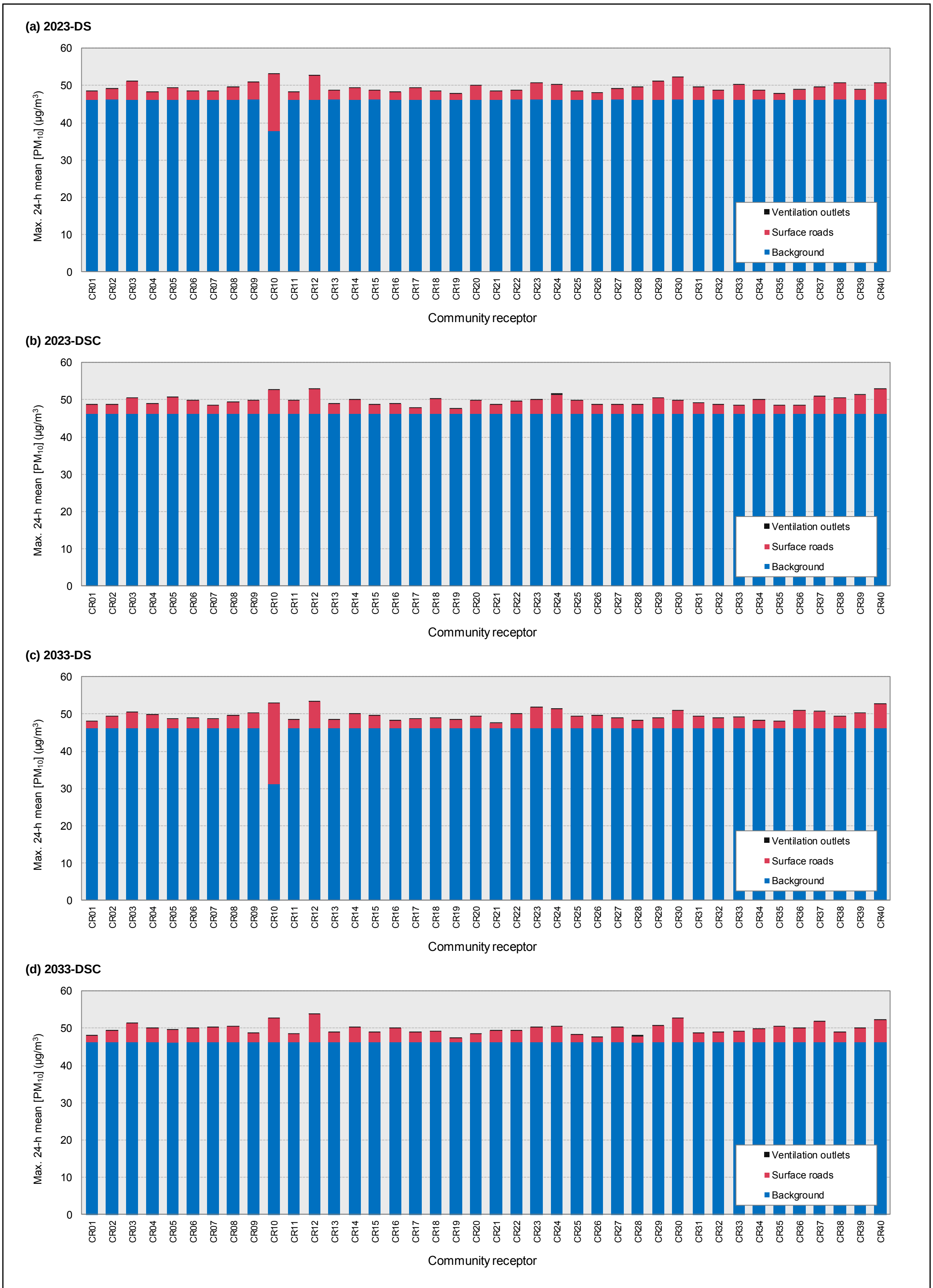


Figure 9-47 Source contributions to maximum 24 hour mean PM_{10} concentration at community receptors in the DS and DSC scenarios

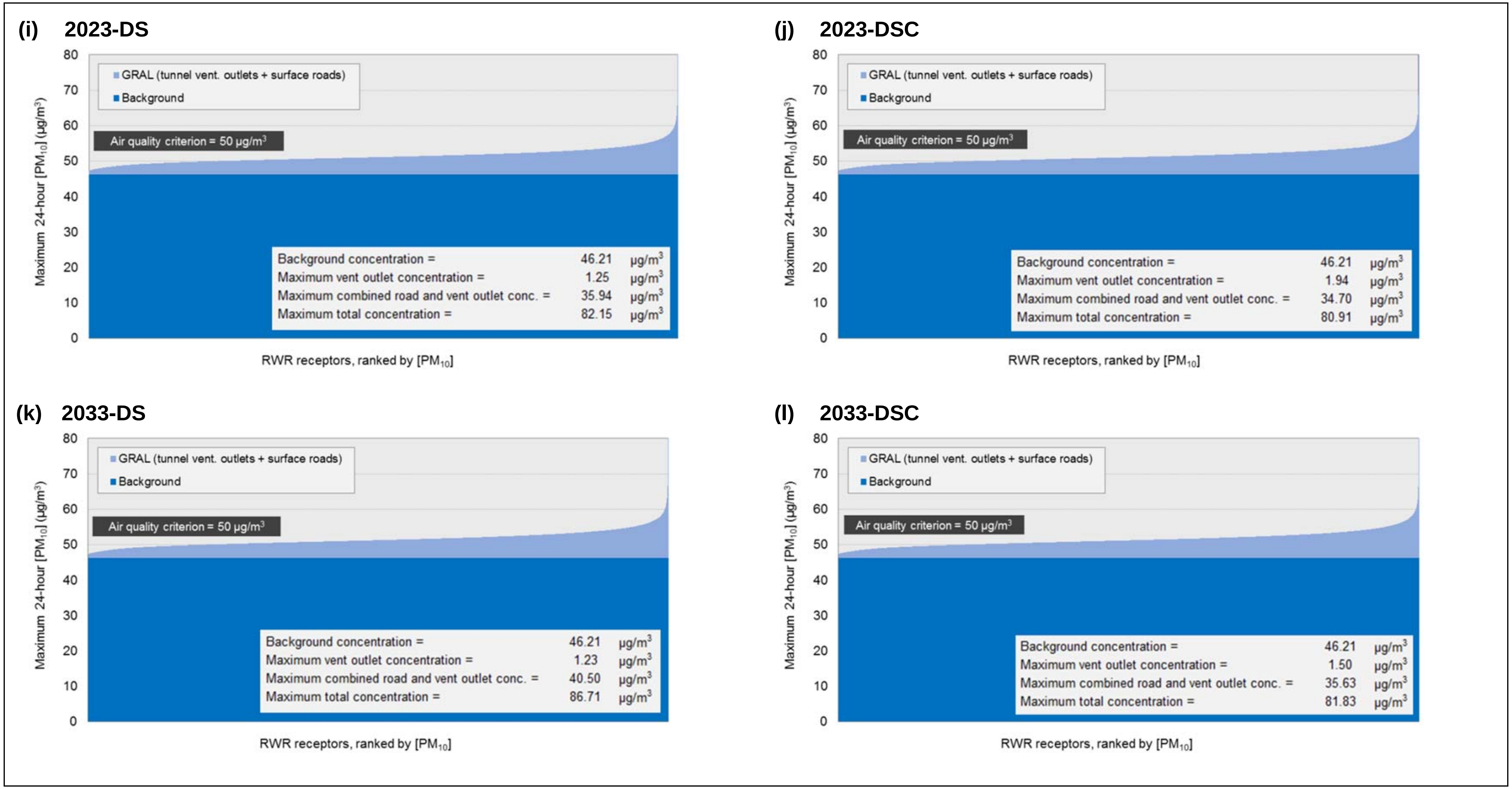


Figure 9-48 Source contributions to maximum 24-hour mean PM_{10} concentration at RWR receptors (with-project and cumulative scenarios)

Contour plots – all sources

The contour plots for maximum 24 hour average PM_{10} in the 2033-DM and 2033-DSC scenarios are given in **Figure 9-49** and **Figure 9-50**. The changes in maximum 24 hour PM_{10} are shown in **Figure 9-51**.

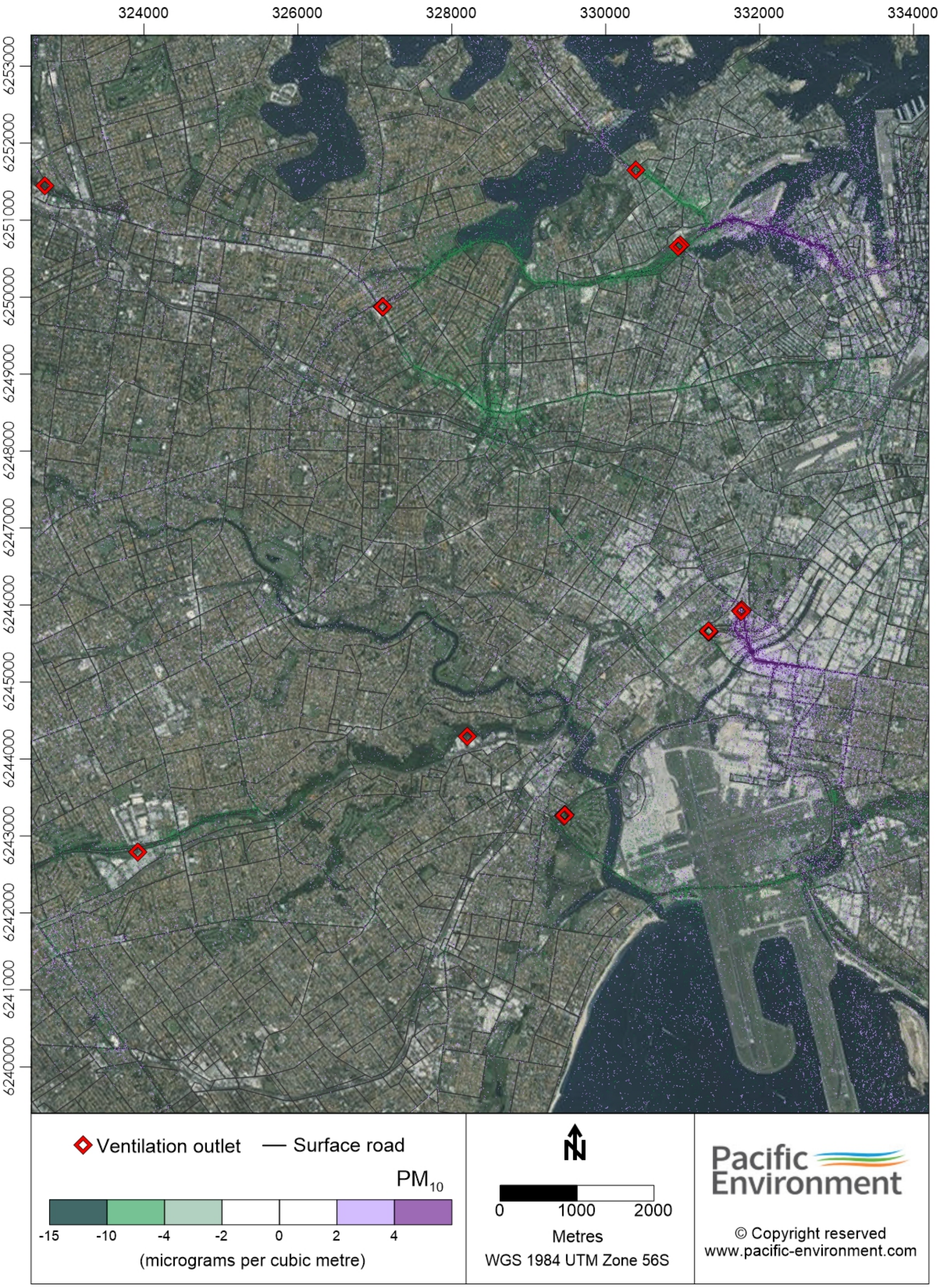


Figure 9-49 Contour plot of change in maximum 24 hour average PM_{10} concentration with the project (2023-DS)

Figure 9-50 Contour plot of change in maximum 24 hour average PM_{10} concentration with the project (2033-DS)

$PM_{2.5}$ (annual mean)

Results for community receptors

Figure 9-51 presents the annual mean $PM_{2.5}$ concentrations at the community receptors. The results are based on an assumed background concentration of eight µg/m^3 (the AAQNEPM standard), and therefore the Figure shows exceedances at all receptors. Clearly, there would also be exceedances of the NSW target of seven µg/m^3. Internationally, there are no standards lower than eight µg/m^3 for annual mean $PM_{2.5}$. The next lowest is 12 µg/m^3 (California and Scotland). Any increases with the project were generally less than 0.2 µg/m^3; the largest increase (0.56 µg/m^{3t} receptor CR38, in the 2033-DS scenario) equated to seven per cent of the air quality criterion.

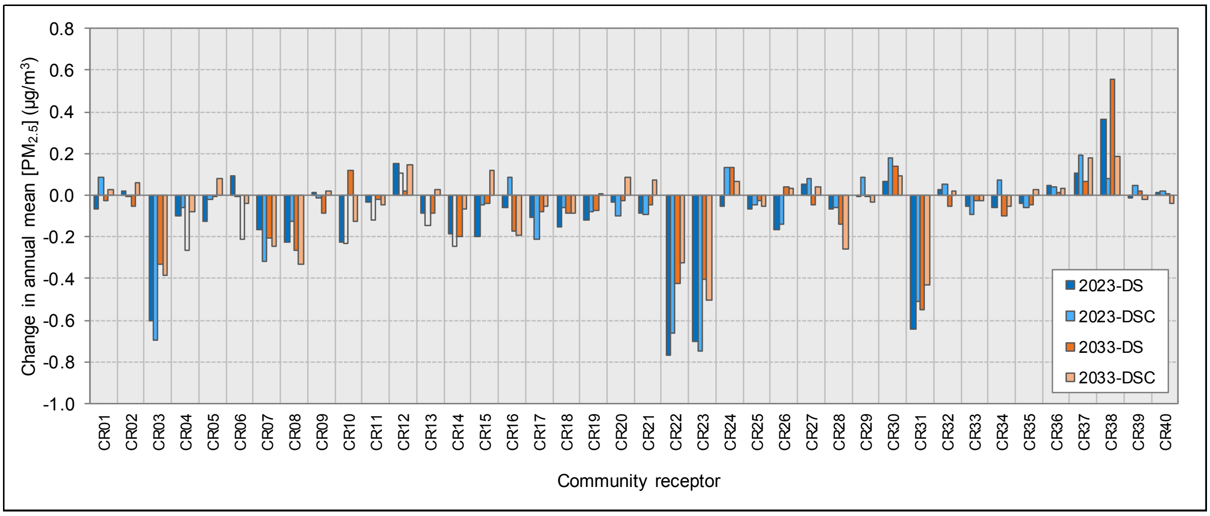


Figure 9-51 Change in annual mean $PM_{2.5}$ concentration at community receptors (with-project (DS) and cumulative (DSC) scenarios, relative to corresponding Do Minimum scenarios)

Figure 9-52 shows that concentrations were again dominated by the background contribution. The surface road contribution was between 0.5 µg/m^3 and 2.7 µg/m^3. The largest contribution from tunnel ventilation outlets at any receptor was just 0.14 µg/m^3.

Figure 9-52 Source contributions to annual mean $PM_{2.5}$ concentration at community receptors (DS and DSC scenarios)

Results for RWR receptors

The ranked annual mean $PM_{2.5}$ concentrations at the RWR receptors in the with-project scenarios, are shown in **Figure 9-52**, including the contributions of surface roads and ventilation outlets. As the background concentration was taken to be the same as the NSW criterion of eight μg/m^3, the total concentration at all receptors was above this value. The highest concentration at any receptor was 14.2 μg/m^3 but, as with other pollutants and metrics, high values were only predicted for a small proportion of receptors and are unlikely to reflect real-world exposure situations. In the with-project scenarios, the largest surface road contribution at any receptor was 5.4 μg/m^3. The largest contribution from tunnel ventilation outlets in these scenarios was 0.17 μg/m^3.

The change in the annual mean $PM_{2.5}$ concentration at the RWR receptors in the with-project scenarios, are ranked in **Figure 9-53**. There was an increase in concentration at between 29 per cent and 37 per cent of the receptors, depending on the scenario. The largest predicted increase in concentration at any receptor as a result of the project was 2.3 μg/m^3, and the largest predicted decrease was also 2.3 μg/m^3. Where there was an increase, this was greater than 0.1 μg/m^3 at around 2–3 per cent of receptors.

The increase in annual mean $PM_{2.5}$ at sensitive receptors with the project ($\Delta PM_{2.5}$) is a key metric for assessing the risk to human health. For the M4-M5 Link project, the acceptable value of $\Delta PM_{2.5}$ was determined to be 1.8μg/m^3. Only one receptor (RWR-46456) had a predicted change in $PM_{2.5}$ above this value. However, this receptor is a commercial/industrial building that is very close to the indicative alignment of the proposed future Sydney Gateway, and would not represent a real-world exposure situation in the future. Given the proximity of these areas to Sydney Airport (runways and flight paths) it is considered unlikely that they would be rezoned for residential use and the increases in $PM_{2.5}$ are principally related to the Sydney Gateway project. Emissions to air related to the Sydney Gateway project have been estimated on the basis of provisional information in relation to roadway layout only. The maximum impacts predicted are on roadways/locations that may be within the future roadway alignments. The Sydney Gateway project would be subject to separate environmental assessment and approval, in which more detailed assessment of impacts in this area would be undertaken.

Contour plots – all sources

The contour plots for absolute annual mean $PM_{2.5}$ are given in **Figure 9-54** (2033-DM) and **Figure 9-55** (2033-DSC). The contour plot for the change in concentration associated with the project is shown in **Figure 9-55**.

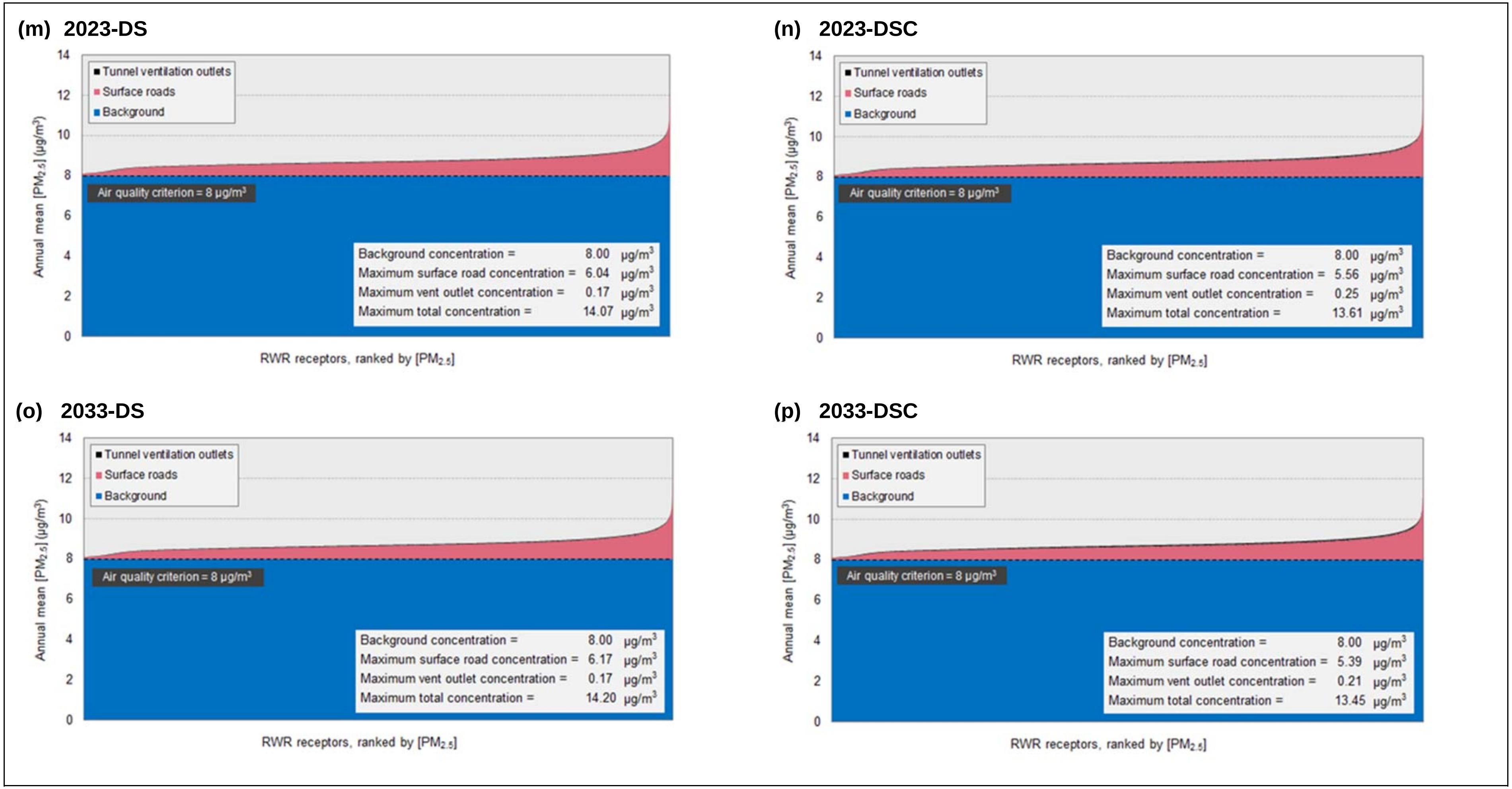


Figure 9-53 Source contributions to annual mean $PM_{2.5}$ concentration at RWR receptors (with-project and cumulative scenarios)

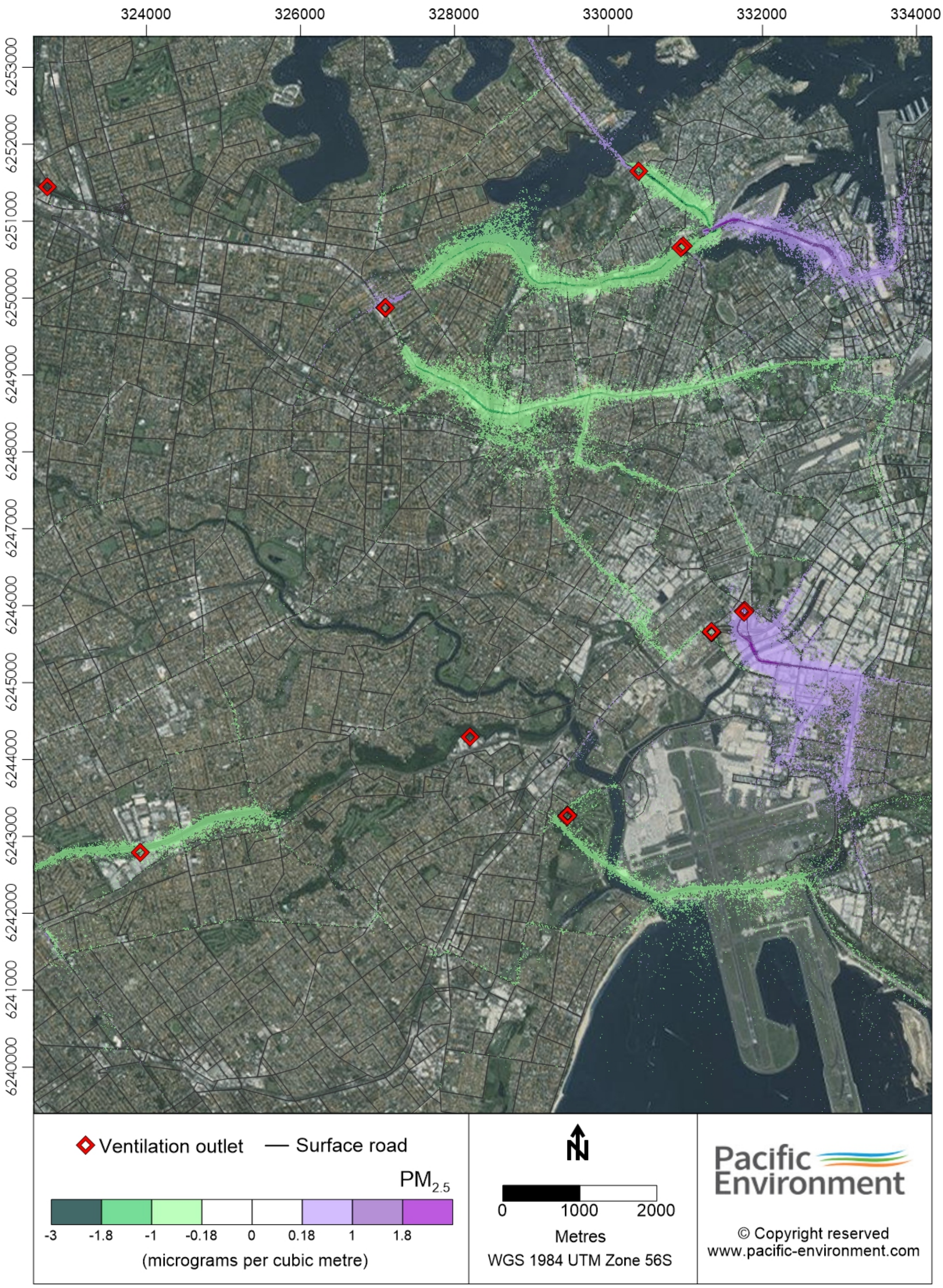


Figure 9-54 Contour plot of change in annual mean $PM_{2.5}$ concentration (2023-DS)

Figure 9-55 Contour plot of change in annual mean $PM_{2.5}$ concentration (2033-DS scenario)

$PM_{2.5}$ (maximum 24 hour mean)

Results for community receptors

The maximum 24 hour mean $PM_{2.5}$ concentrations at the community receptors with the project are presented in **Figure 9-56**. At all receptor locations, the maximum concentration was above the NSW impact assessment criterion of 25 µg/m^3, although exceedances were already predicted without the project. Internationally, there are no standards lower than 25 µg/m^3 for 24 hour $PM_{2.5}$, however, the AAQNEPM includes a long-term goal of 20 µg/m^3.

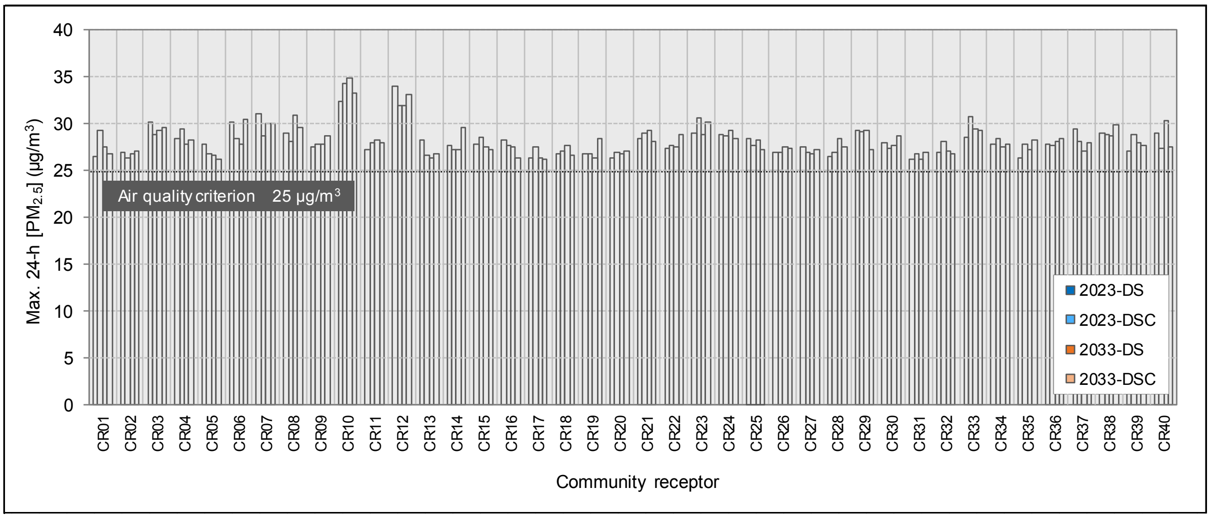


Figure 9-56 Maximum 24 hour $PM_{2.5}$ concentration at community receptors (DS and DSC scenarios)

Figure 9-57 presents the changes in maximum 24 hour $PM_{2.5}$ with the project at the community receptors. At the majority of receptors, there was a decrease in annual mean $PM_{2.5}$. Most of the increases with the project were less than 0.2 µg/m^3. The largest increase (2.9 µg/m^3 at receptor CR40, in the 2033-DSC scenario) equated to 11 per cent of the air quality criterion.

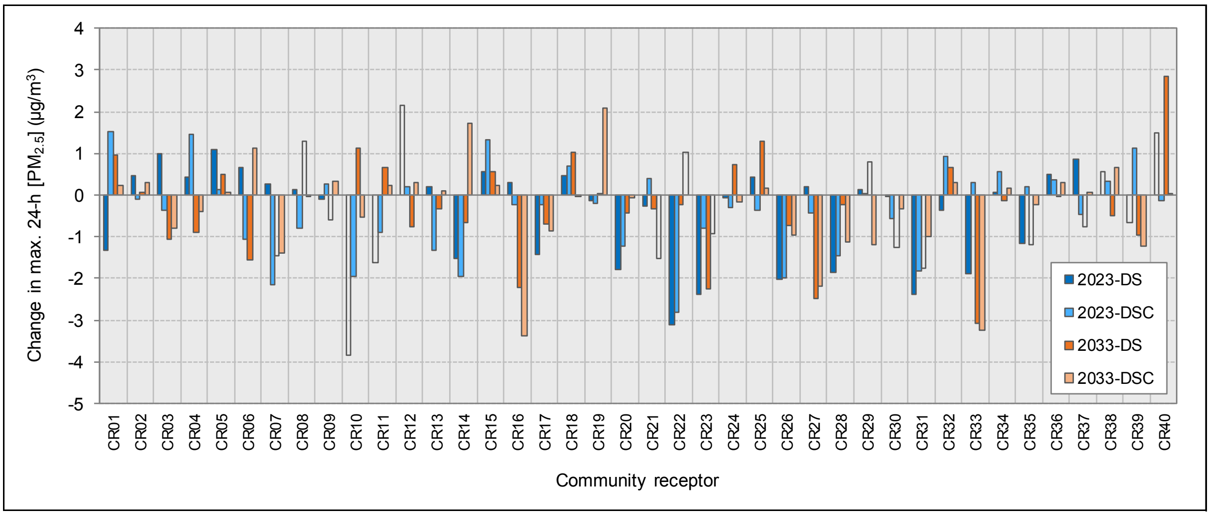


Figure 9-57 Change in maximum 24 hour $PM_{2.5}$ concentration at community receptors (DS and DSC scenarios), relative to corresponding DM scenarios

The combined road and ventilation outlet contributions to the maximum 24 hour $PM_{2.5}$ concentration at the community receptors were relatively small, as shown in The tunnel ventilation outlet contributions alone were negligible in all cases (<0.15 µg/m^3).

Figure 9-58 shows that the concentrations were again dominated by the background contribution. The surface road contribution was between 0.5 µg/m^3 and 2.7 µg/m^3. The largest contribution from tunnel ventilation outlets at any receptor was 0.14 µg/m^3.

Figure 9-58 Source contributions to maximum 24 hour mean $PM_{2.5}$ -concentration at community receptors (with-project (DS) and cumulative (DSC) scenarios)

Results for RWR receptors

The ranked maximum 24 hour mean $PM_{2.5}$ concentrations at the RWR receptors in the with-project scenarios are shown in **Figure 9-59**. The concentration at all receptors was above the NSW impact assessment criterion of 25 μg/m^3. As with PM_{10}, the contributions of surface roads and ventilation outlets are not shown separately as these were not additive. The maximum contribution of tunnel outlets at any receptor with the project was 1.2 μg/m^3.

The changes in the maximum 24 hour mean $PM_{2.5}$ concentration at the RWR receptors in the with-project scenarios are ranked in **Figure 9-59**. There was an increase in concentration at between 36 per cent and 39 per cent of the receptors, depending on the scenario. The largest predicted increase in concentration at any receptor as a result of the project was 8.7 μg/m^3 (2023-DSC scenario), and the largest predicted decrease was 8.2 μg/m^3. For most of the receptors the change in concentration was small; where there was an increase in concentration, this was greater than 2.5 μg/m^3 at only 0.2 to 0.3 per cent of receptors.

Contour plots – all sources

The contour plots for maximum 24 hour $PM_{2.5}$ in the 2023-DS and 2033-DS scenarios are given in **Figure 9-60** and **Figure 9-61** respectively.

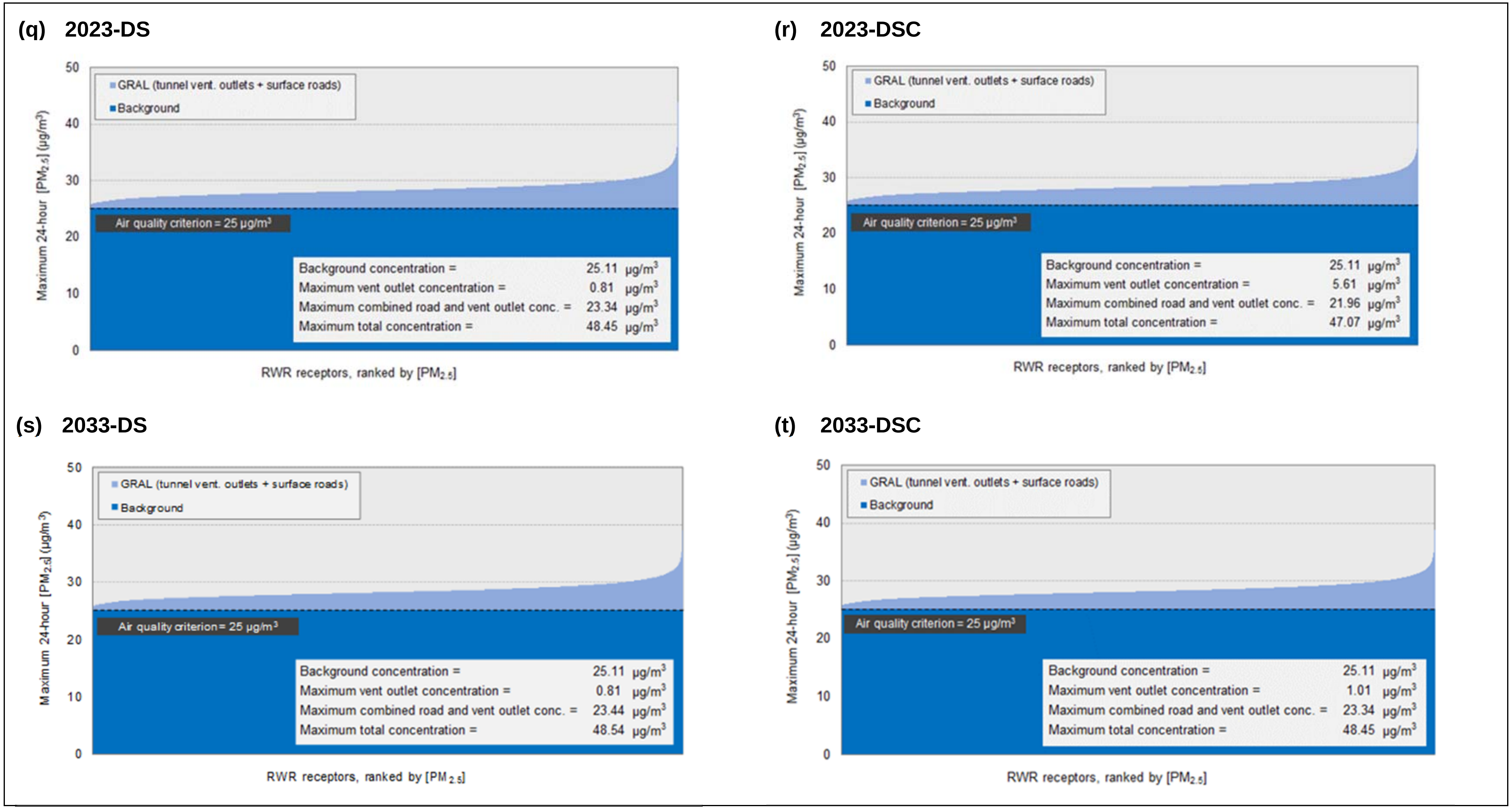


Figure 9-59 Source contributions to maximum 24 hour mean $PM_{2.5}$ concentration at RWR receptors (DS and DSC scenarios)

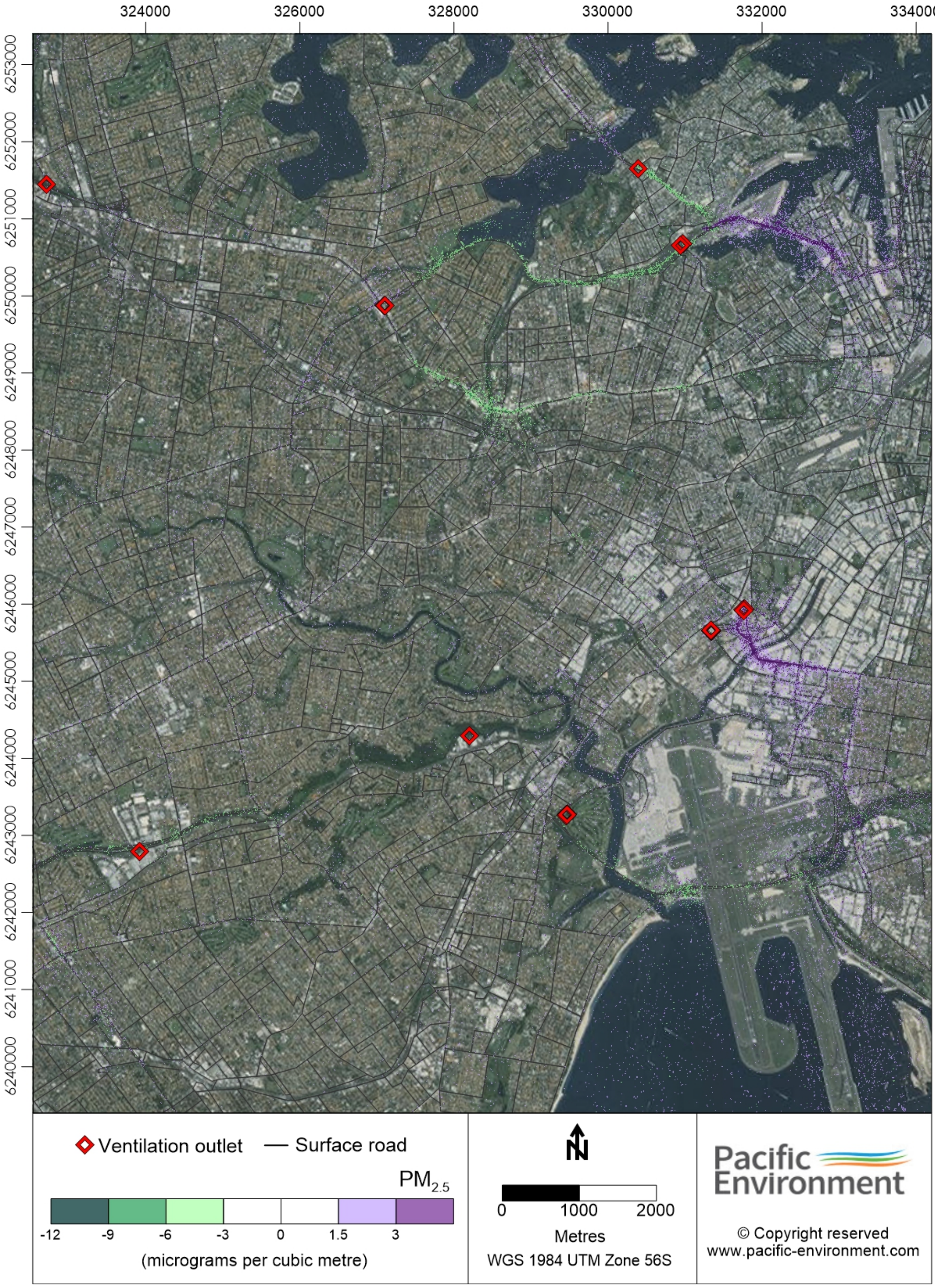


Figure 9-60 Contour plot of change in maximum 24 hour average $PM_{2.5}$ concentration in 2023-DS

Figure 9-61 Contour plot of change in maximum 24 hour average $PM_{2.5}$ concentration in 2033-DS

Air toxics

Four air toxics – benzene, PAHs (as BaP), formaldehyde and 1,3-butadiene – were assessed. These compounds were taken to be representative of the much wider range of air toxics associated with motor vehicles, and they have commonly been used for assessment of road projects.

The changes in the maximum one hour benzene concentration at the community receptors as a result of the project are shown in **Figure 9-62**, where they are compared with the NSW impact assessment criterion from the NSW EPA Approved Methods. These changes took into account emissions from both surface roads and tunnel ventilation outlets. It can be seen from the Figure that there where there was an increase in the concentration, this was well below the assessment criterion. The changes in the maximum one hour BaP, formaldehyde and 1,3-butadiene concentration are presented in **Figure 9-63**, **Figure 9-64** and **Figure 9-65** respectively. For each compound, where there was an increase in the concentration, this was well below the NSW impact assessment criterion. The largest increases for the community receptors were also representative of the largest increases for the RWR receptors.

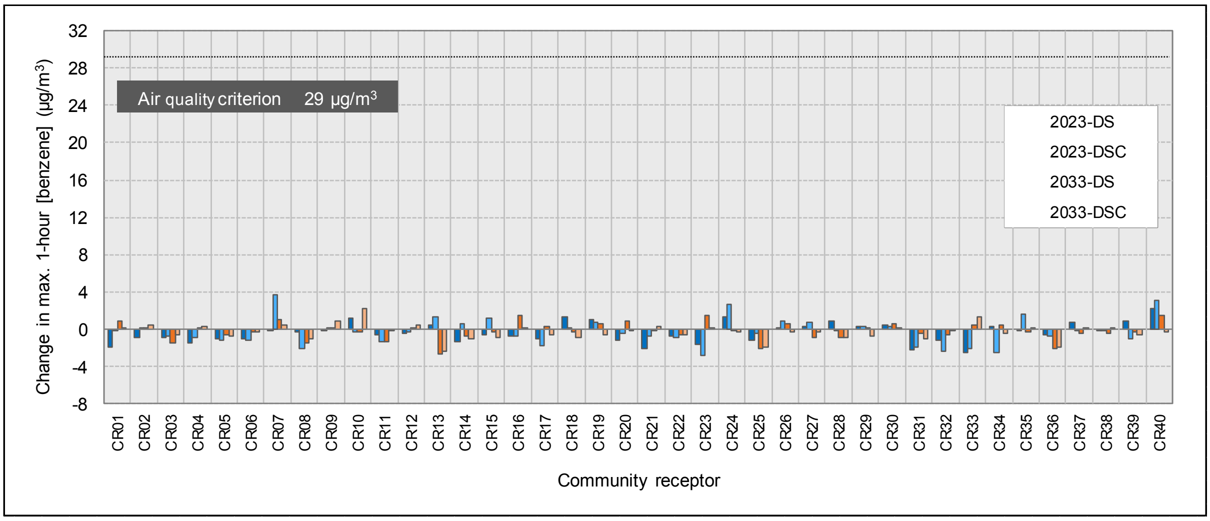


Figure 9-62 Change in maximum one hour mean benzene -concentration at community receptors (DS and DSC scenarios)

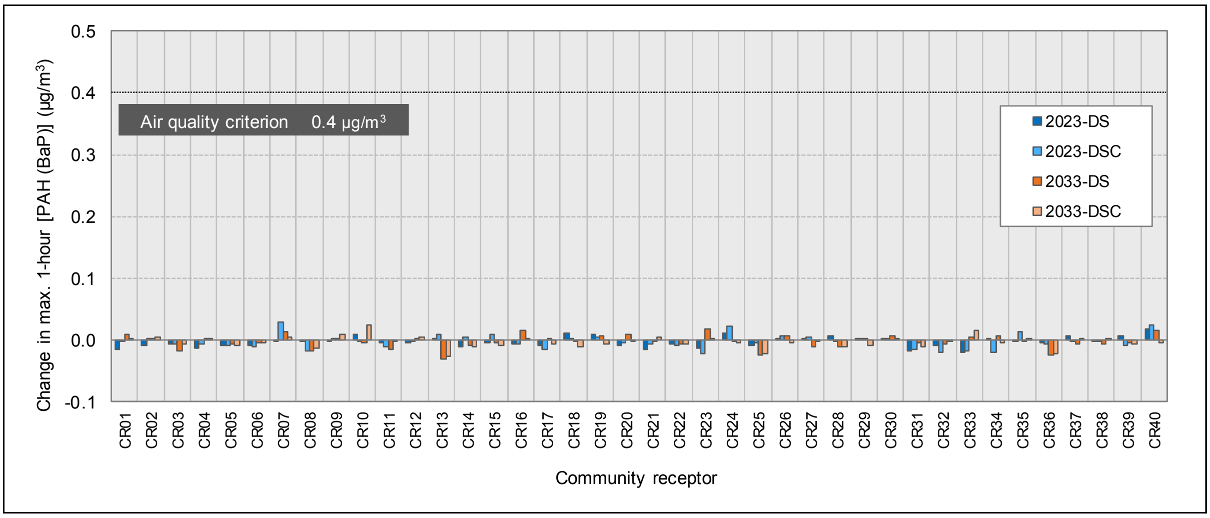


Figure 9-63 Change in maximum one hour mean BaP concentration at community receptors (DS and DSC scenarios)

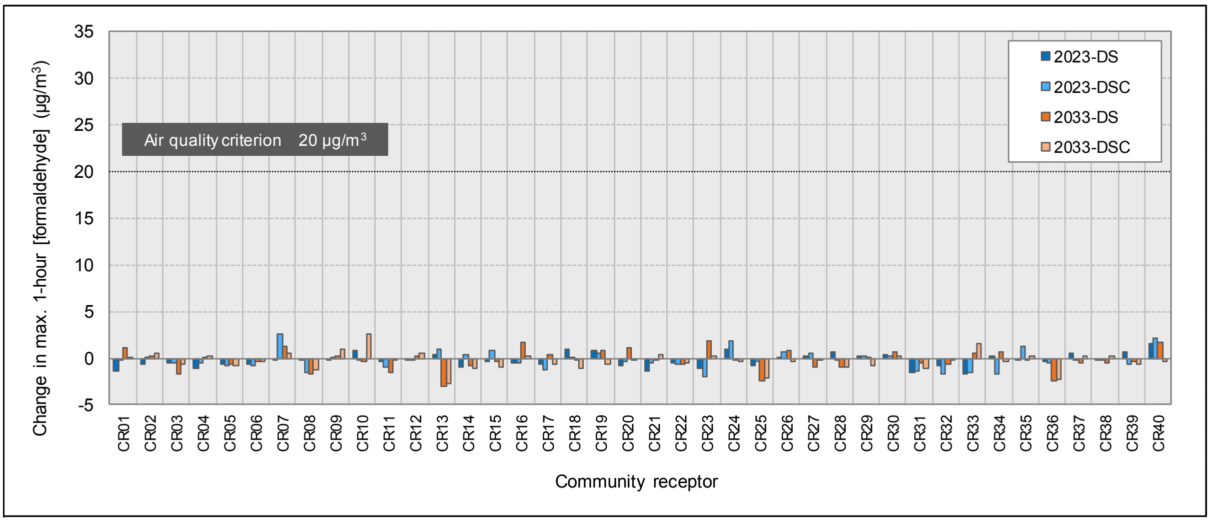


Figure 9-64 Change in maximum one hour mean formaldehyde concentration at community receptors (with-project (DS) and cumulative (DSC) scenarios)

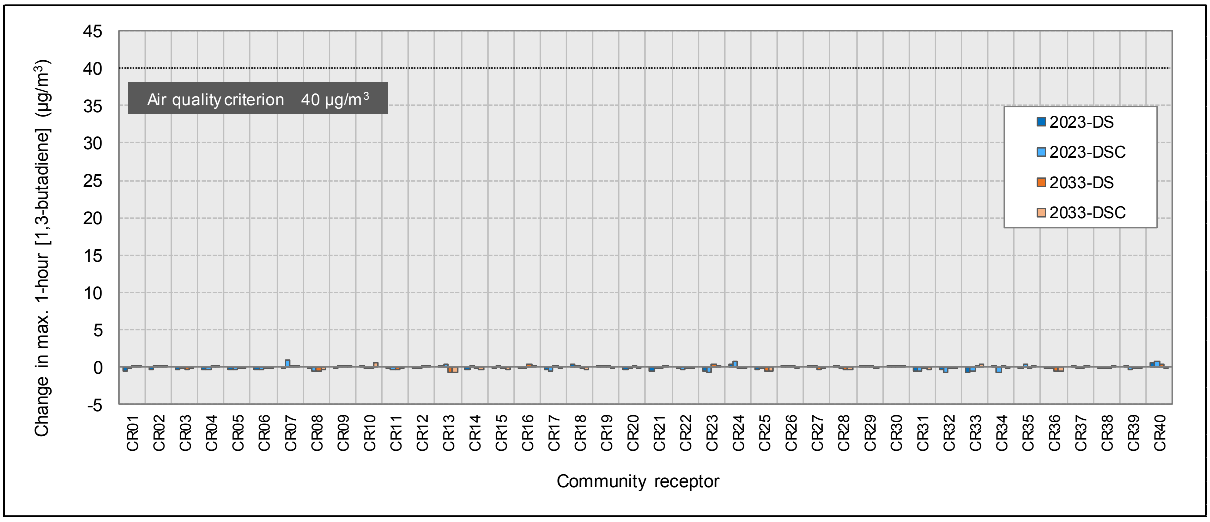


Figure 9-65 Change in maximum one hour mean 1,3-butadiene concentration at community receptors (with-project (DS) and cumulative (DSC) scenarios)

9.7.4 Reasons for unrealistically high ground level concentrations at some RWR receptor locations

The predicted maximum one-hour NO_2 concentrations were very high at a small number of RWR locations. These elevated levels are not considered to be representative of exposure concentrations that would occur within the study area. This is due to the combined effect of the approach adopted for converting NOx to NO_2 (that overestimates short-term one-hour average concentrations), and the use of a contemporaneous assessment of background and project impacts. The contemporaneous approach assumes that the highest background concentrations may occur during the same hour as the maximum incremental change from the project. This results in a very high estimate of total NO_2 concentrations that is not expected to occur (refer to **Appendix I** (Technical working paper: Air quality) for more detailed discussion).

9.7.5 Results for expected traffic scenarios (elevated receptors)

Annual mean $PM_{2.5}$

Figure 9-66 and **Figure 9-67** present contour plots for the changes in annual mean $PM_{2.5}$ concentration in the 2033-DSC scenario, and for receptor heights of 10 metres and 30 metres respectively. These plots can be compared with the changes in ground level annual mean concentration for the same scenario. It should be noted that, for the 10 metre and 30 metre outputs, it was not necessarily the case that there were existing buildings at these heights at the receptor locations.

The reduced influence of surface roads at a receptor height of 10 metres compared with ground level can be seen in **Figure 9-66**. However, because the influence of surface roads in the Do Minimum case at 10 metres was also reduced, the distributions of changes in annual average $PM_{2.5}$ concentration at 10 metres and ground level were quite similar. For example, where there was an increase in annual mean $PM_{2.5}$ at the height of 10 metres, this was greater than 0.1 µg/m^3 for 2.9 per cent of receptors (compared with 3.2 per cent at ground level). However, the largest changes in concentration at 10 metres were smaller than those at ground level. The largest increase at the height of 10 metres for the RWR locations was 0.79 µg/m^3, which can be compared with the maximum increase for any ground level receptor in the 2033-DSC scenario of 2.3 µg/m^3.

Figure 9-67 show that the situation was quite different at a height of 30 metres. At this height the changes in annual mean $PM_{2.5}$ associated with surface roads are negligible at all locations, with the small increases closer to the ventilation outlets. The increase in $PM_{2.5}$ was greater than 1.8 µg/m^3 at a height of 30 metres at just one industrial location. However, the height of the existing building is 8.3 metres. The largest increases for residential locations at a height of 30 metres is between 1.41 and 1.43 µg/m^3 for a small group of locations close to the location of the M4-M5 Link ventilation facility at Campbell Road, St Peters. However, the height of the existing buildings at these locations is less than five metres. The results show that there would not be any significant impact on existing buildings however consideration would need to be given to detailed assessment of any future high rise buildings planned for these locations.

Maximum 24 hour $PM_{2.5}$

Figure 9-68 and **Figure 9-69** present the contour plots showing the changes in maximum 24 hour $PM_{2.5}$ concentration in the 2033-DSC scenario at receptor heights of 10 metres and 30 metres respectively. There are no existing buildings greater than 10 metres in height at the RWR receptor locations.

At a height of 10 metres, the maximum changes in concentration were slightly lower than at ground level but, as with the annual mean, the distributions of changes were quite similar. The largest increase in 24 hour $PM_{2.5}$ at the height of 10 metres for the RWR receptors was 6 µg/m^3, which can be compared with the maximum increase for any ground-level RWR receptor in the 2033-DSC scenario of 7.7 µg/m^3. Where there was an increase in $PM_{2.5}$ at the height of 10 metres, this was greater than 2.5 µg/m^3 (10 per cent of the assessment criterion) for 0.1 per cent of receptors locations (compared with 0.2 per cent at ground level).

At the height of 30 metres the largest increases in the maximum 24 hour $PM_{2.5}$ concentrations were again in the vicinity of the ventilation outlets, and these largest increases were greater than those at 10 metres and ground level. Again, there was a large increase of 36.6 µg/m^3 at one industrial location. There was predicted to be an increase in maximum 24 hour $PM_{2.5}$ of more than 2.5 µg/m^3 (10 per cent of the assessment criterion) at 86 (0.1 per cent) receptors. Of these, 67 were at residential locations, and of these 67, the ones with the largest increases were close to the location of the M4-M5 Link ventilation facility at St Peters. Again, the actual height of buildings at these locations was less than 10 metres so no actual exposures would occur at a height of 30 metres.

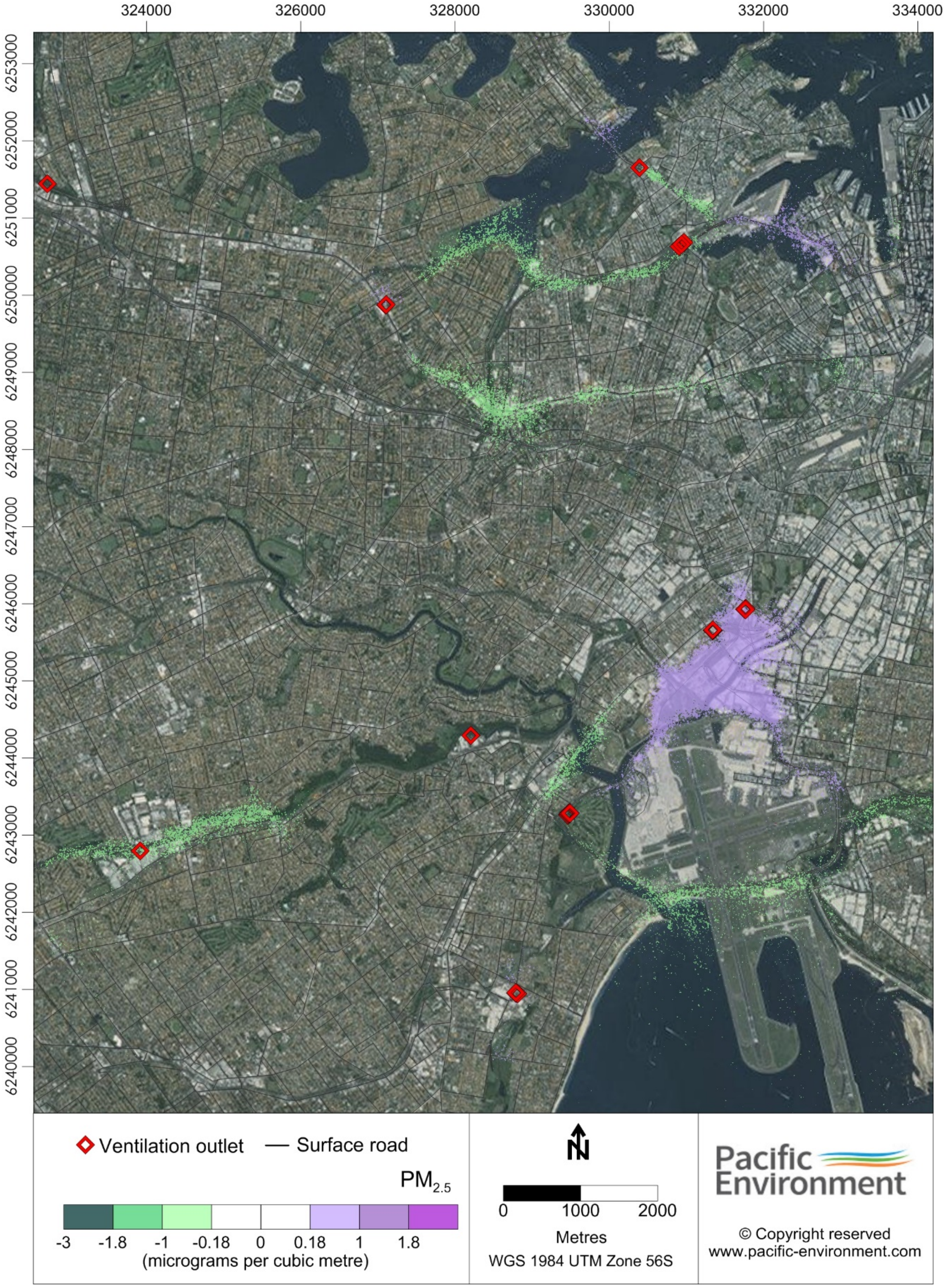


Figure 9-66 Contour plot of change in annual mean $PM_{2.5}$ concentration in 2033-DSC minus 2033-DM, 10 metre receptor height

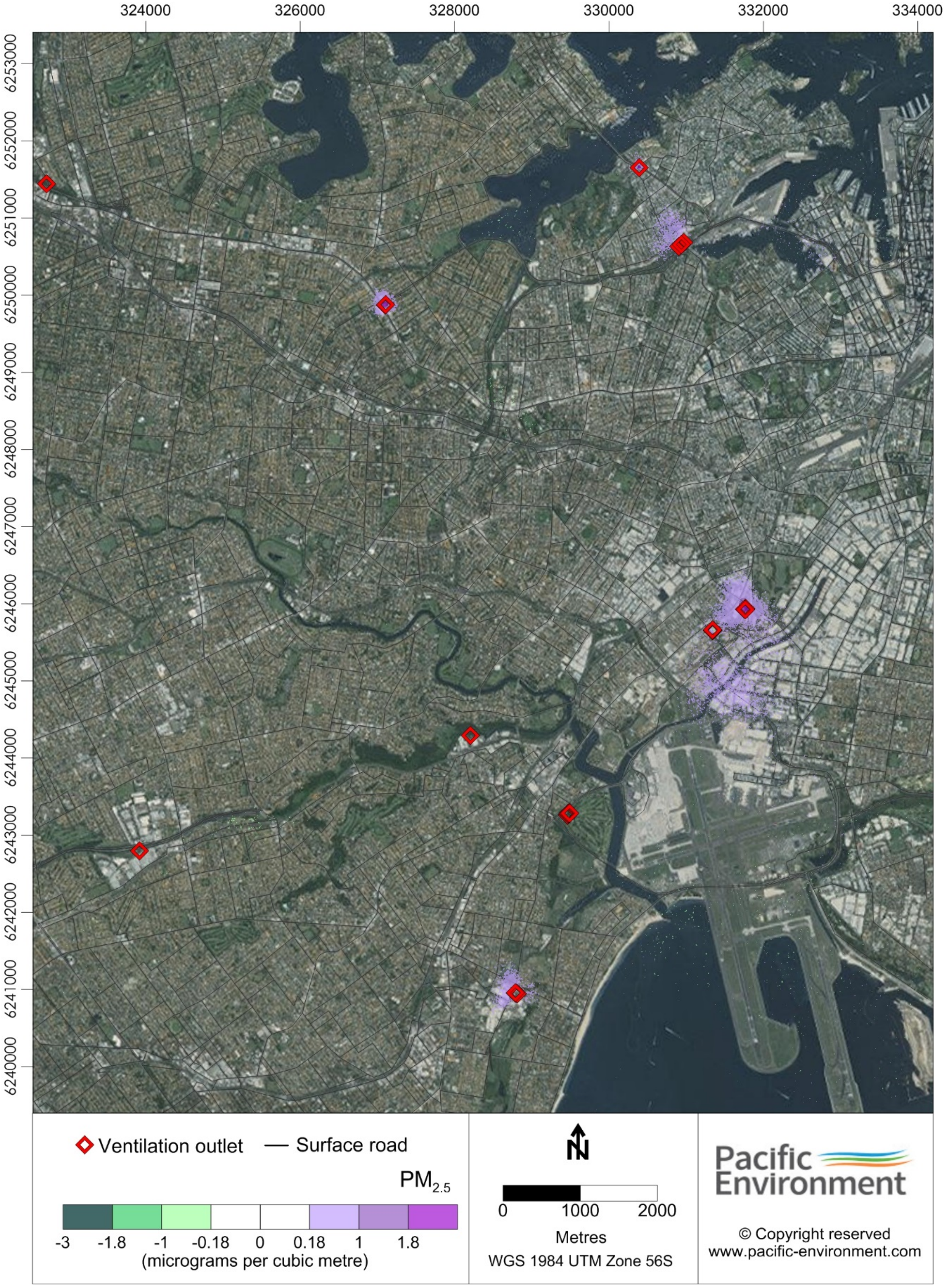


Figure 9-67 Contour plot of change in annual mean $PM_{2.5}$ concentration in the 2033-DSC minus 2033-DM, 30 metre receptor height

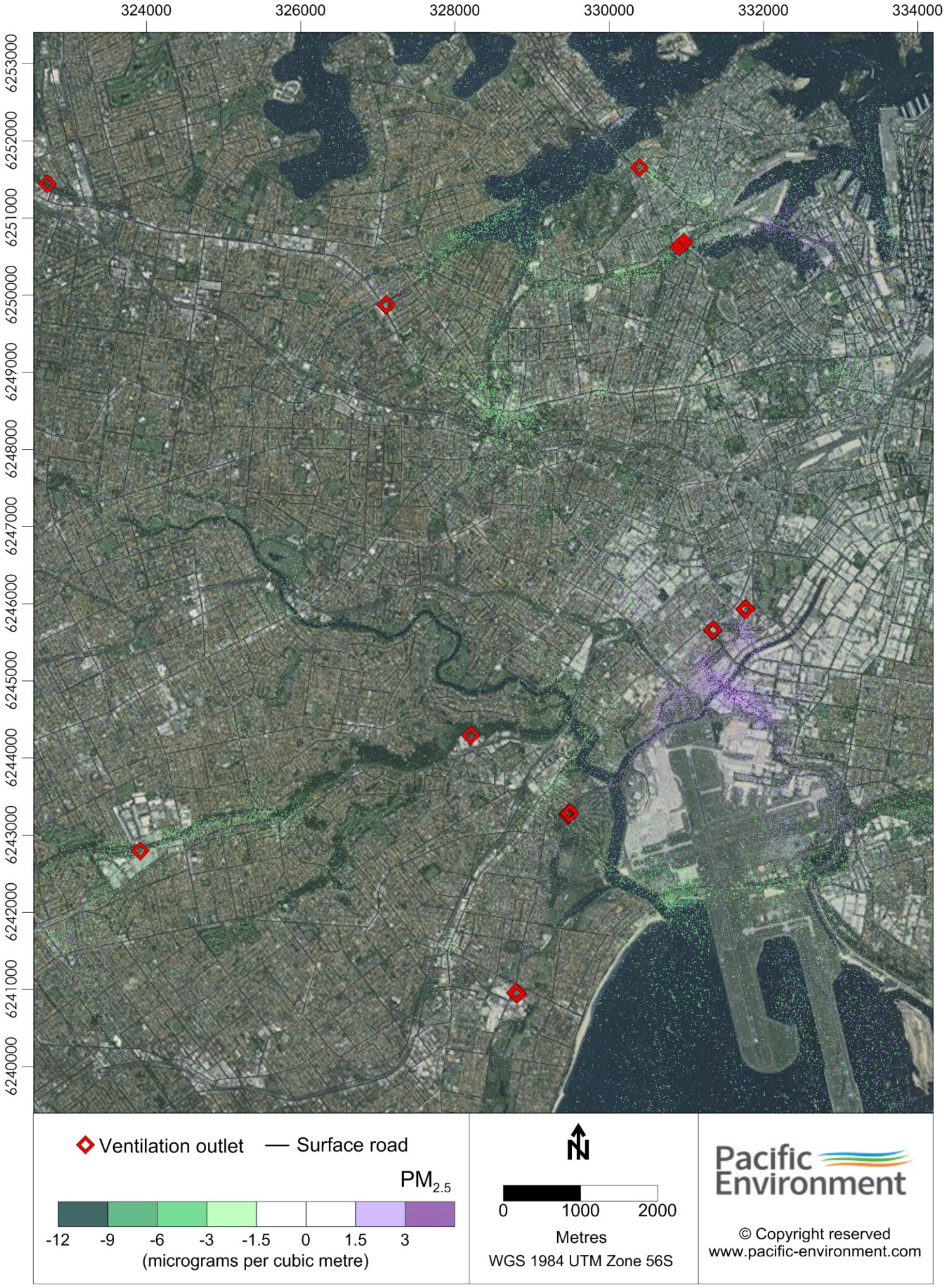


Figure 9-68 Contour plot for change in maximum 24 hour $PM_{2.5}$ concentration (2033-DSC minus 2033-DM, 10 metre receptor height)

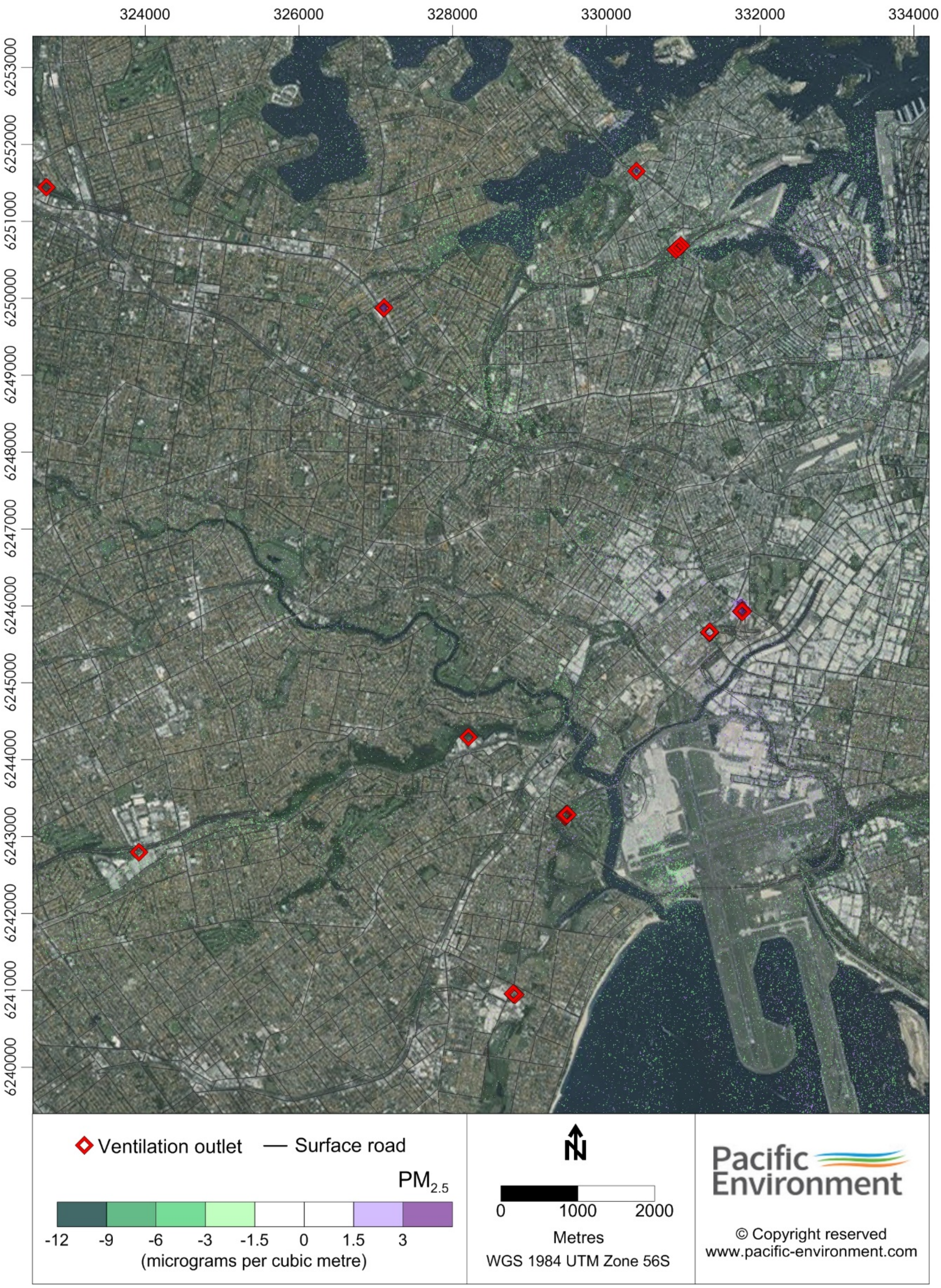


Figure 9-69 Contour plot for change in maximum 24 hour $PM_{2.5}$ concentration (2033-DSC minus 2033-DM, 30 metre receptor height)

Summary

The implications of the results for elevated receptors can be summarised as follows:

- For all receptor locations, the changes in $PM_{2.5}$ concentration at 10 metres are acceptable
- Future developments to the height of 10 metres should be possible at all locations in the study area. This assumes that the changes in $PM_{2.5}$ concentration for heights between ground level and 10 metres are also acceptable. This is a reasonable assumption because the influence of surface roads diminishes by 10 metres, so that the largest changes at 10 metres were smaller than the changes at ground level
- The predictions do not indicate the need for any restrictions on future developments to 30 metres height, except in the immediate vicinity of ventilation outlets, in particular at St Peters:
  - The ventilation outlets were predicted not to result in adverse air quality impacts at any existing receptors as there are no existing buildings 30 metres or higher located close to the proposed ventilation facilities at St Peters
  - Planning controls should be developed in the vicinity of St Peters to ensure future developments at heights 30 metres or higher are not adversely impacted by the ventilation outlets. Development of planning controls would need to be supported by detailed modelling addressing all relevant pollutants and averaging periods.

9.7.6 Results for regulatory worst case scenarios

The following sections highlight the results of these scenarios for the receptors with the largest impacts. As noted in the methodology, a more detailed approach was required for NO_2 than for the other pollutants. The objective of these scenarios was to demonstrate that compliance with the concentration limits for the tunnel ventilation outlets would deliver acceptable ambient air quality. The scenarios assessed emissions from the ventilation outlets only, with concentrations fixed at the limits. This represented the theoretical maximum changes in air quality for all potential traffic operations in the tunnel, including unconstrained and worst case traffic conditions from an emissions perspective, as well as vehicle breakdown situations.

Further detail of the regulatory worst case scenarios is in **Appendix I** (Technical working paper- Air Quality). The analysis was undertaken to assist regulatory authorities in assessing and determining potential ventilation outlet concentration limits that could be applied to the ventilation outlets through conditions of approval. Assuming that concentration limits are applied to the ventilation outlets, the results of the analysis would demonstrate the air quality performance of the project if it operates continuously at the limits. In reality, ventilation outlet concentrations would only occasionally approach the concentration limits under heavy traffic or incident conditions. Ventilation and traffic management would be used to avoid reaching concentration limits to avoid exceeding the limits. Experience in operating tunnels in Sydney shows that normal tunnel operations including congested traffic cases, are well below outlet limits.

CO and PM

The results for CO, PM_{10} and $PM_{2.5}$ in the regulatory worst case scenario (RWC-2033-DSC only) are given in **Table 9-27**. The table shows the maximum contribution of tunnel ventilation outlets at any of the RWR receptors in this scenario, as well as the maximum contribution at any residential receptor. For most of the pollutant metrics, the results were the same in both cases.

Table 9-27 Results of regulatory worst case assessment (RWR receptors) – CO and PM

Pollutant and period	Units	Maximum ventilation outlet contribution at any receptor					
		Regulatory worst case scenario (RWC-2033-DSC)		Expected traffic scenarios			
		All receptors	Residential receptors	2023-DS	2023-DSC	2033-DS	2033-DSC
CO (1 h)	(mg/m^3)	0.50	0.50	0.06	0.07	0.06	0.07
PM_{10} (annual)	($\mu g/m^3$)	1.01	1.01	0.24	0.37	0.24	0.30

Pollutant and period	Units	Maximum ventilation outlet contribution at any receptor					
		Regulatory worst case scenario (RWC-2033-DSC)		Expected traffic scenarios			
		All receptors	Residential receptors	2023-DS	2023-DSC	2033-DS	2033-DSC
PM_{10} (24 h)	(µg/m^3)	4.51	4.06	1.25	1.94	1.23	1.50
$PM_{2.5}$ (annual)[(a)]	(µg/m^3)	1.01	1.01	0.17	0.25	0.17	0.21
$PM_{2.5}$ (24 h)[(a)]	(µg/m^3)	4.51	4.06	0.81	1.23	0.81	1.01

Note:

(a) The same emission rates were used for PM_{10} and $PM_{2.5}$.

The concentrations in the regulatory worst case scenario were higher than those for the expected traffic scenarios in all cases, and the following points are noted for the former:

- The maximum one hour CO concentration was negligible, especially taking into account the fact that CO concentrations are well below the NSW impact assessment criterion. For example, the maximum one hour outlet contribution in the regulatory worst case scenario (0.50 mg/m^3) was a very small fraction of the criterion (30 mg/m^3). The maximum background one hour CO concentration (3.27 mg/m^3) was also well below the criterion. Exceedances of the criterion are therefore highly unlikely
- For PM_{10} the maximum contributions of the ventilation outlets are predicted to be small. For both the annual mean and maximum 24 hour metrics the outlet contributions were less than 10 per cent of the respective criteria
- The ventilation outlet contribution would be most important for $PM_{2.5}$, with the maximum contributions equating to 13 per cent and 18 per cent of the annual mean and 24 hour criteria respectively. Again, any exceedances of the criteria would be dominated by background concentrations.

NO_X and NO_2

The results of the more detailed assessment for NO_2 at the M4-M5 Link ventilation facilities are shown in **Appendix I** (Technical working paper: Air quality). The criterion was not exceeded in any of the project scenarios.

Total hydrocarbons and air toxics

The maximum outlet concentrations for the four specific air toxics considered in the regulatory worst-case assessment (scenario RWC-2033-DSC only) were determined using the THC predictions in conjunction with the speciation profiles stated in **Appendix I** (Technical working paper: Air quality). The results are given in **Table 9-28**. The Table shows the maximum contribution of tunnel ventilation outlets at any of the RWR receptors in this scenario (for most of the pollutant metrics these were residential receptors). The outlet contributions to the specific air toxics are well below the impact assessment criteria in the NSW EPA Approved Methods.

Table 9-28 Results of regulatory worst case assessment (RWR receptors) – air toxics (ventilation outlets only)

Pollutant and period	Units	Maximum ventilation outlet contribution at any receptor	
		Regulatory worst case scenario (RWC-2033 DSC)	Impact assessment criterion (µg/m^3)
THC (annual)	(µg/m^3)	3.65	-
THC (1 hour)	(µg/m^3)	55.29	-
Benzene (1 hour)	(µg/m^3)	2.20	29
PAH (BaP) (1 hour)	(µg/m^3)	0.016	0.4
Formaldehyde (1 hour)	(µg/m^3)	1.83	20
1,3-butadiene (1 hour)	(µg/m^3)	0.59	40

Table 9-29 shows that, even if the maximum outlet contribution is added to the maximum increase in concentration with the project (which implies some double counting), the results are still well below the impact assessment criteria.

Table 9-29 Results of regulatory worst case assessment (RWR receptors) – air toxics (ventilation outlets plus traffic)

Pollutant and period	Units	Maximum outlet contribution at any receptor	Maximum increase due to project (outlet + expected traffic)	Sum	Impact assessment criteria
THC (1 hour)	(µg/m^3)	55.29	-	-	-
Benzene (1 hour)	(µg/m^3)	2.20	3.08	5.28	*29*
PAH (BaP) (1 hour)	(µg/m^3)	0.016	0.035	0.051	*0.4*
Formaldehyde (1 hour)	(µg/m^3)	1.83	3.59	5.42	*20*
1,3-butadiene (1 hour)	(µg/m^3)	0.59	0.84	1.43	*40*

9.7.7 Sensitivity tests

In the EISs for the M4 East and New M5 projects, several sensitivity tests were conducted for various model inputs (Pacific Environment 2015). These included:

- The influence of ventilation outlet temperature
- The influence of ventilation outlet height
- The inclusion of buildings near tunnel ventilation outlets.

These tests were based upon a sub-area of the M4 East and New M5 GRAL domains of about two to three kilometres around the project ventilation outlets. Only the ventilation outlet contribution, and annual mean $PM_{2.5}$ and maximum 24 hour $PM_{2.5}$, were included in the tests. A sub-set of sensitive receptors was evaluated. The predicted concentrations were indicative, as the aim of the sensitivity tests was to assess the proportional sensitivity of the model to specific input parameters.

As the parameters for the tests from both the M4 East and New M5 projects were very similar to that for M4-M5 Link, the outcomes from those projects would also apply to the M4-M5 Link project.

The following sections present a summary of the tests.

Ventilation outlet temperature

The ventilation outlet temperatures for the M4 East and New M5 projects were around 25ºC. For this test, the effects of using outlet temperatures 10˚C below, and above, this value were modelled.

The results of the tests showed that the predicted concentrations for the ventilation outlets were higher for the lower temperature (by a factor of, on average, around 1.5). The predicted concentrations for both projects remained well below the standards for $PM_{2.5}$, and made up a very small proportion of the total combined results (for surface roads and ventilation outlets). Even with a significant change in ventilation outlet temperature, the total predicted concentration (roads and ventilation outlets) is unlikely to be significantly affected.

Ventilation outlet height

The height of the ventilation outlets for the M4 East and New M5 projects was around 30 metres. For this test, the effects of using outlet heights 10 metres below and above this value were modelled. The results for both projects were similar to those for the temperature sensitivity tests, with the lower outlet resulting in concentrations that were around 1.3 times greater, on average, than the higher outlet. Again, ventilation outlet height is unlikely to represent a large source of uncertainty in the overall predictions.

Buildings

The sensitivity of the inclusion of buildings to predicted concentrations was assessed in both the M4 East and New M5 projects. Modelling of the ventilation outlet was undertaken using inclusion and exclusion scenarios of the closest buildings.

The results showed that, when buildings were included, there was an average increase in concentrations associated with the ventilation outlet by a factor of about 1.3 to 1.5. Whilst these tests were not comprehensive, they indicated that the inclusion or exclusion of buildings is unlikely to represent a large source of uncertainty in the overall predictions. The total predicted concentrations, and the conclusions of the assessment, would not change significantly with the inclusion of buildings.

9.8 Regional air quality

The changes in the total emissions resulting from the project are shown in **Figure 9-70**, **Table 9-30** and **Table 9-31**.

These changes can be viewed as a proxy for the project's regional air quality impacts which, on the basis of the results, are likely to be negligible. For example:

- The increases in NO_X emissions for the assessed road network in a given year ranged from 71 to 174 tonnes per year. These values equate to a very small proportion (around 0.3 per cent) of anthropogenic NO_X emissions in the Sydney airshed in 2016 (around 53,700 tonnes)
- The increases in NOx in a given year are much smaller than the projected reductions in emissions between 2015 and 2033 (around 2,340 tonnes per year).

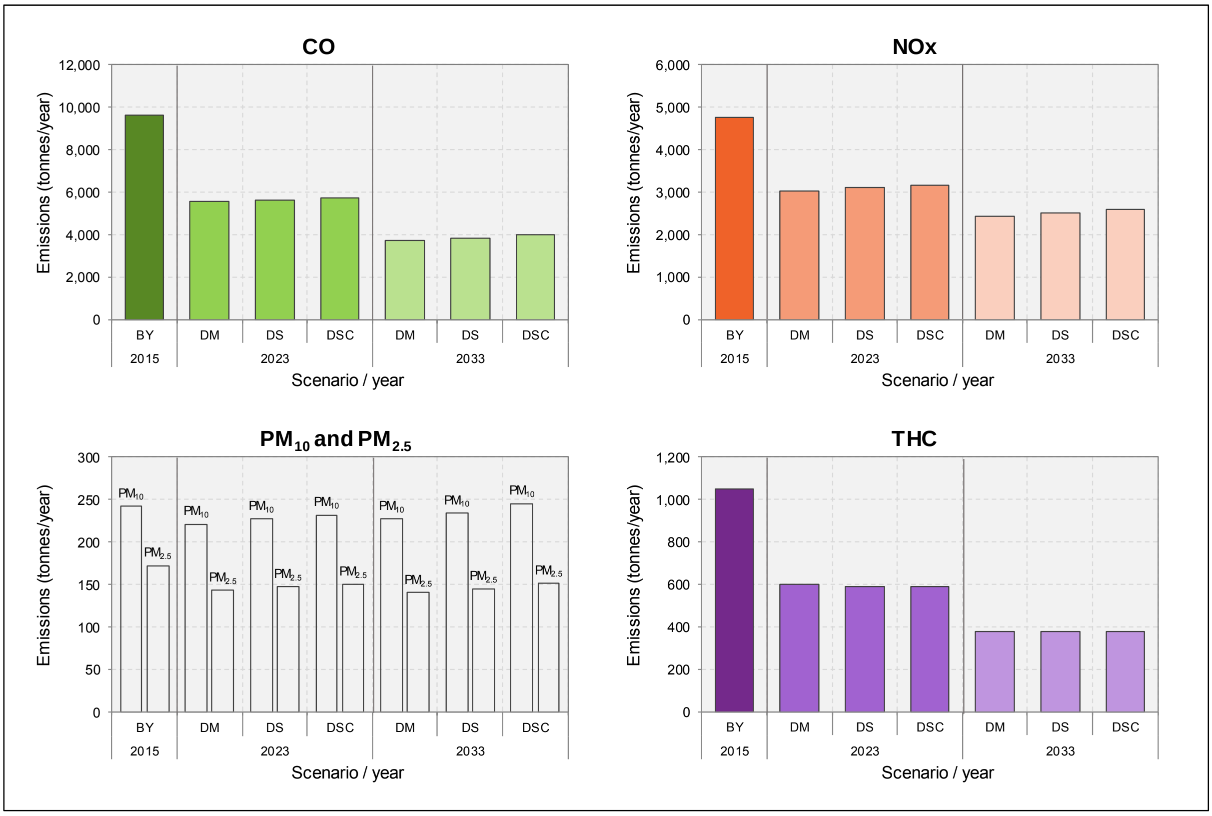


Figure 9-70 Total traffic emissions by pollutant in the WestConnex study area

Table 9-30 Total traffic emissions in the WestConnex study area

Scenario code	Scenario description	Total daily VKT[a] (million vehicle-km)	Total emissions (tonnes/year)				
			CO	NOx	PM_{10}	$PM_{2.5}$	THC
2015-BY	2015 – Base Year (existing conditions)	11.5	9,633	4,775	242	173	1,052
2023-DM	2023 – Do Minimum (no M4-M5 Link)	13.2	5,561	3,037	221	143	599
2023-DS	2023 – Do Something (with M4-M5 Link)	13.8	5,648	3,108	227	147	590
2023-DSC	2023 – Do Something Cumulative (with M4-M5 Link and some other projects)	14.3	5,737	3,164	232	150	589
2033-DM	2033 – Do Minimum (no M4-M5 Link)	14.5	3,719	2,434	227	140	380
2033-DS	2033 – Do Something (with M4-M5 Link)	15.2	3,837	2,506	234	145	376
2033-DSC	2033 – Do Something Cumulative (with M4-M5 Link and all other projects)	16.1	4,005	2,609	245	152	380

Note:

(a) VKT = vehicle kilometres travelled

Table 9-31 Absolute changes in total traffic emissions in the WestConnex study area

Scenario comparison	Change in total emissions (tonnes/year)				
	CO	NOx	PM_{10}	$PM_{2.5}$	THC
Underlying changes in emissions with time[a]					
2023-DM vs 2015-BY	-4,072	-1,738	-21	-30	-453
2033-DM vs 2015-BY	-5,914	-2,341	-15	-32	-672
Changes due to the project in a given year					
2023-DS vs 2023-DM	+87	+71	+6	+4	-9
2023-DSC vs 2023-DM	+176	+127	+11	+7	-10
2033-DS vs 2033-DM	+118	+72	+7	+4	-4
2033-DSC vs 2033-DM	+286	+174	+18	+11	-1

Note:

(a) The 2023-DM and 2033-DM scenarios include the M4-East and New M5 projects. The 2015-BY scenario does not.

The regional air quality impacts of a project can also be described in terms of its capacity to influence ozone production. NSW EPA has developed a *Tiered Procedure for Estimating Ground Level Ozone Impacts from Stationary Sources* (ENVIRON 2011). Although this procedure does not relate specifically to road projects, it was applied here to give an indication of the likely significance of the project's effect on ozone concentrations in the broader Sydney region.

The first step in the procedure involved the classification of the region within which the project is to be located as either an ozone 'attainment' or 'non-attainment' area, based on measurements from OEH monitoring stations over the past five years and criteria specified in the procedure. Following this approach, the project was identified as being in an ozone non-attainment area.

The second step involved the evaluation of the change in emissions due to the project against thresholds for NO_X and VOCs. For both attainment and non-attainment areas the procedure gives an emission threshold for NO_X and VOCs (separately) of 90 tonnes per year for new sources, above which a detailed modelling assessment for ozone may be required. Some lower thresholds are also specified for modified sources and for the scale of ozone non-attainment.

The results in **Table 9-32** show that for the 2023-DSC and 2033-DSC scenarios, the increases in NOX emissions with the project (127 and 174 tonnes per year respectively) were above the 90 tonnes per year threshold. In such cases, the procedure specifies that a ‘Level 1’ assessment is to be undertaken using a screening tool provided by the NSW EPA9. The tool estimates the increases in one hour and four hour ground level ozone concentrations, based on an input of emissions of CO, NO_x and VOC (THC) in tonnes per day. For sources located within ozone non-attainment areas, the incremental increases in ozone concentration predicted by the tool are compared against a screening impact level (SIL) of 0.5 ppb, and against a maximum allowable increment of one ppb. In cases where the maximum ozone increment is below the SIL and/or below the relevant maximum allowable increment, further ozone impact assessment is not required, but a best management practice (BMP) determination should be undertaken for the source. The results from the tool, shown in **Appendix I** (Technical working paper: Air quality) show that the project increment is below the SIL.

Table 9-32 Results from ozone screening tool

Scenario	Change in emissions with the project (tonnes per day)			Incremental O_3 concentration (ppb)		SIL (ppb)
	CO	NOx	THC	Max. 1 hour	Max. 4 hour	
2023-DSC	+0.483	+0.349	-0.026	0.13	0.11	0.50
2033-DSC	+0.784	+0.478	-0.002	0.17	0.15	

Overall, it is concluded that the regional impacts of the project would be negligible, and undetectable in ambient air quality measurements at background locations.

9.9 Odour

For each of the RWR receptors, the change in the maximum one hour THC concentration as a result of the project was calculated. The largest change in the maximum one hour THC concentration across all receptors was then determined, and this was converted into an equivalent change for three of the odorous pollutants identified in the NSW EPA Approved Methods (toluene, xylenes, and acetaldehyde). These pollutants were taken to be representative of other odorous pollutants from motor vehicles.

The changes in the levels of three odorous pollutants as a result of the project, and the corresponding odour assessment criteria from the NSW EPA Approved Methods, are given in **Table 9-33**.

Table 9-33 Comparison of changes in odorous pollutant concentrations with criteria in NSW EPA Approved Methods (RWR receptors)

Scenario	Largest increase in maximum one hour THC concentration relative to Do Minimum scenario (μg/m^3)	Largest increase in maximum one hour concentration for specific compounds		
		Toluene (μg/m^3)	Xylenes (μg/m^3)	Acetaldehyde (μg/m^3)
2023-DS	141.0	10.8	8.9	2.0
2023-DSC	137.1	10.5	8.6	1.9
2033-DS	110.8	7.0	5.8	2.0
2033-DSC	98.9	6.3	5.2	1.8
Odour criterion (μg/m^3)		360	190	42

The change in the maximum one hour concentration of each pollutant was well below the corresponding odour assessment criterion in the NSW EPA Approved Methods.

[9] http://www.epa.nsw.gov.au/air/appmethods.htm.

9.9.1 Overview

The SEARs for the project require details of, and justification for, the air quality management measures that have been considered. This section of the report firstly reviews the measures that are available for improving tunnel-related air quality, and then describes their potential application in the context of the project. The measures have been categorised as follows:

- Tunnel design
- Ventilation design and control
- Air treatment systems
- Emission controls and other measures.

9.10 Environmental management measures

9.10.1 Construction impacts

Mitigation and management measures for potential ambient air quality impacts during construction are shown in **Table 9-34**. Most of these measures are routinely employed as 'standard practice' on construction sites.

It is acknowledged there is potential for crystalline silica emissions to occur during tunnel excavation due to the high temperatures caused at the excavation face. The potential for crystalline silica to be released is primarily relevant to occupational exposure, and would be managed in accordance with relevant NSW and Australian guidelines. The controls would effectively eliminate its discharge into the atmosphere. Safe work method statements would be developed as part of the project safety management system. In relation to non-occupational exposures the World Health Organization (WHO 2000a) states 'there are no known adverse health effects associated with the non-occupational exposures to quartz' (where quartz is crystalline silica).

A Construction Air Quality Management Plan (CAQMP) will be produced (as a sub-plan to the Construction Environmental Management Plan) to address the construction impacts of the M4-M5 Link project. The CAQMP will contain details of the site-specific mitigation measures to be applied. Additional guidance on the control of dust at construction sites in NSW is provided as part of the NSW EPA Local Government Air Quality Toolkit[10]. Detailed guidance is also available from the United Kingdom (GLA 2006) and the United States of America (Countess Environmental 2006). Dust control procedures will be included as part of the CAQMP.

Table 9-34 Mitigation for all sites: communication

	Mitigation measure	All scenarios 1 – 7
1	Communication, notification and complaints handling requirements regarding air quality matters will be managed through the Community Communication Strategy (CCS).	Highly recommended

Table 9-35 Mitigation for all sites: dust management

	Mitigation measure	All scenarios 1 – 7
2	A Construction Air Quality Management Plan will be developed and implemented to monitor and manage potential air quality impacts associated with the construction for the project. The Plan will be implemented for the duration of construction.	Highly recommended

[10] http://www.epa.nsw.gov.au/air/lgaqt.htm.

	Mitigation measure	All scenarios 1 – 7
Site management		
3	Regular communication to be carried out with sites in close proximity to ensure that measures are in place to manage cumulative dust impacts.	Highly recommended
Monitoring		
4	Regular site inspections will be conducted to monitor for potential dust issues. The site inspection, and issues arising, will be recorded.	Highly recommended
Preparing and maintaining the site		
5	Construction activities with the potential to generate dust will be modified or ceased during unfavourable weather conditions to reduce the potential for dust generation.	Highly recommended
6	Measures to reduce potential dust generation, such as the use of water carts, sprinklers, dust screens and surface treatments, will be implemented within project sites as required.	Highly recommended
7	Unsealed access roads within project sites will be maintained and managed to reduce dust generation.	Highly recommended
8	Where reasonable and feasible, appropriate control methods will be implemented to minimise dust emissions from the project site.	Highly recommended
9	Storage of materials that have the potential to result in dust generation will be minimised within project sites at all times.	Highly recommended
Operating vehicle/machinery and sustainable travel		
10	All construction vehicles and plant will be inspected regularly and maintained to ensure that they comply with relevant emission standards.	Highly recommended
11	Engine idling will be minimised when plant is stationary, and plant will be switched off when not in use to reduce emissions.	Highly recommended
12	The use of mains electricity will be favoured over diesel or petrol-powered generators where practicable to reduce site emissions.	Highly recommended
13	Haul roads will be treated with water carts and monitored during earthworks operations, ceasing works if necessary during high winds where dust controls are not effective.	Highly recommended
Construction		
14	Suitable dust suppression and/or collection techniques will be used during cutting, grinding or sawing activities likely to generate dust in close proximity to sensitive receivers.	Highly recommended
15	The potential for dust generation will be considered during the handling of loose materials. Equipment will be selected and handling protocols developed to minimise the potential for dust generation.	Highly recommended
16	All vehicles loads will be covered to prevent escape of loose materials during transport.	Highly recommended

Table 9-36 Mitigation specific to demolition

	Mitigation measure	Scenario 1	2	3	4	5	6	7
17	Demolition activities will be planned and carried out to minimise the potential for dust generation.	Desirable	Highly recommended			Desirable	Highly recommended	Desirable
18	Adequate dust suppression will be applied during all demolition works required to facilitate the project.	Desirable	Highly recommended					
19	All potentially hazardous material will be identified and removed from buildings in an appropriate manner prior to the commencement of demolition.	Desirable	Highly recommended					

Table 9-37 Mitigation specific to earthworks

	Mitigation measure	Scenario 1	2	3	4	5	6	7
20	Areas of soil exposed during construction will be minimised at all times to reduce the potential for dust generation.	Not required	Desirable		Highly recommended			
21	Exposed soils will be temporarily stabilised during weather conditions conducive to dust generation and prior to extended periods of inactivity to prevent dust generation.	Not required	Desirable		Highly recommended			
22	Exposed soils will be permanently stabilised as soon as practicable following disturbance to minimise the potential for ongoing dust generation.	Not required	Desirable		Highly recommended			

Table 9-38 Mitigation specific to construction

	Mitigation measure	Scenario 1	2	3	4	5	6	7
23	Ensure sand and other aggregates are stored in bunded areas and are not allowed to dry out, unless this is required for a particular process, in which case ensure that appropriate additional control measures are in place.	Highly recommended						
24	Ensure fine materials are stored and handled to minimise dust.	Desirable			Highly recommended			

Table 9-39 Mitigation specific to track-out of loose material onto roads

	Mitigation measure	All scenarios 1 – 7
25	Deposits of loose materials will be regularly removed from sealed surfaces within and adjacent to project sites to reduce dust generation.	Highly recommended
26	During establishment of project ancillary facilities, controls such as wheel washing systems and rumble grids will be installed at site exits to prevent deposition of loose material on sealed surfaces outside project sites to reduce potential dust generation.	Highly recommended

9.10.2 Operational impacts

The SEARs for the project require details of, and justification for, the air quality management measures that were considered for the project. This section reviews the environmental management measures that are available for improving tunnel-related air quality, and then describes their potential application in the context of the project. The measures are categorised as follows:

- Tunnel design
- Ventilation design and control
- Air treatment systems
- Emission controls and other measures.

Tunnel design

Tunnel infrastructure is designed in such a way that the generation of pollutant emissions by the traffic using the tunnel is minimised. The main considerations are minimising gradients and ensuring that lane capacity remains constant or increases from entry to exit point. Traffic management can also be used to improve traffic flows, which results in reduced overall emissions.

Ventilation design and control

There are several reasons why a tunnel needs to be ventilated. The main reasons are:

- Control of the internal environment. It must be safe and comfortable to drive through the tunnel. Vehicle emissions must be sufficiently diluted so as not to be hazardous during normal operation, or when traffic is moving slowly or stationary
- Protection of the external environment. Ventilation, and the dispersion of pollutants, is the most widely used method for minimising the impacts of tunnels on ambient air quality. Collecting emissions and venting them via elevated ventilation outlets is a very efficient way of dispersing pollutants. Studies show that the process of removing surface traffic from heavily trafficked roads and releasing the same amount of pollution from an elevated location results in substantially lower concentrations at sensitive receptors (PIARC 2008)

- Emergency situations. When a fire occurs in a tunnel, the ventilation system is able to control the heat and smoke in the tunnel so as to permit safe evacuation of occupants, and to provide the emergency services with a safe route to deal with the fire and to rescue any trapped or injured persons.

The ventilation system design options that were considered for the project are discussed in **Chapter 4** (Project development and alternatives) and the system adopted for the project is described in **Chapter 5** (Project description).

Air treatment systems

There are several air treatment options for mitigating the effects of tunnel operation on both in-tunnel and ambient air quality. Where in-tunnel treatment technologies have been applied to road tunnels, these technologies have focused on the management and treatment of PM. The most common of these is the electrostatic precipitator (ESP), and this is discussed in detail in **Appendix I** (Technical working paper: Air quality). Information is provided on the method of operation, the international experience with ESPs in tunnels, and the effectiveness of systems. Other techniques include filtering, denitrification and biofiltration, agglomeration and scrubbing. These are described in **Appendix I** (Technical working paper: Air quality).

Emission controls and other measures

Various operational measures are available to manage in-tunnel emissions and ambient air quality. These include the following:

- Traffic management. Traffic management will be employed by tunnel operators to control exposure to vehicle-derived air pollution. Measures can include (PIARC 2008):
  - Allowing only certain types of vehicle
  - Regulating time of use
  - Tolling (including differential tolling by vehicle type, emission standard, time of day, occupancy)
  - Reducing traffic throughput
  - Lowering the allowed traffic speed
- Incident detection. Early detection of incidents and queues is essential to enable tunnel operators and the highway authority to put effective traffic management in place. Monitoring via CCTV cameras is normally a vital part of the procedure for minimising congestion within tunnels and allowing timely operator response to changes in traffic flow
- Public information and advice. Traffic lights, barriers, variable message signs, radio broadcasts, public address systems (used in emergencies) and other measures can help to provide driver information and hence influence driver behaviour in tunnels
- Cleaning the tunnel regularly assists in reducing concentrations of small particles (PIARC 2008), as is common practice in Sydney tunnels.

Detailed design of the In-tunnel monitoring system will be undertaken during future project development phases and will include the following:

- NO_x, NO_2, CO and visibility. Monitoring of each pollutant will be undertaken throughout the tunnel. The locations of monitoring equipment will generally be at the beginning and end of each ventilation section. This would include, for example, monitors at each entry ramp, exit ramp, merge point and ventilation exhaust and supply point. The location of monitors will be governed by the need to meet the in-tunnel air quality criteria for all possible journeys through the tunnel system, especially for NO_2. This will require sufficient, appropriately placed monitors to calculate a journey average
- Velocity monitors will be placed in each tunnel ventilation section and at portal entry and exit points. The velocity monitors in combination with the air quality monitors will be used to modulate the ventilation within the tunnel to manage air quality and to ensure net air inflow at all tunnel portals.

10 Noise and vibration

This chapter outlines the potential noise and vibration impacts associated with the M4-M5 Link project (the project). A detailed noise and vibration assessment has been prepared for the project and is included in **Appendix J** (Technical working paper: Noise and vibration).

The Secretary of the NSW Department of Planning and Environment (DP&E) has issued environmental assessment requirements for the project. These are referred to as Secretary's Environmental Assessment Requirements (SEARs). **Table 10-1** sets out these requirements and the associated desired performance outcomes as they relate to noise and vibration, and identifies where they have been addressed in this environmental impact statement (EIS).

Table 10-1 SEARs – Noise and vibration

Desired performance outcome	SEARs	Where addressed in the EIS
4. Noise and Vibration – Amenity Construction noise and vibration (including airborne noise, ground-borne noise and blasting) are effectively managed to minimise adverse impacts on acoustic amenity. Increases in noise emissions and vibration affecting nearby properties and other sensitive receivers during operation of the project are effectively managed to protect the amenity and well-being of the community.	1. The Proponent must assess construction and operational noise and vibration impacts in accordance with relevant NSW noise and vibration guidelines. The assessment must address the redistribution of traffic and include consideration of impacts to sensitive receivers (on affected floors of residential buildings), include consideration of sleep disturbance and, as relevant, the characteristics of noise and vibration (for example, low frequency noise).	Sensitive receivers identified in the study area are outlined in **section 10.2**. Construction noise and vibration impacts are assessed in **section 10.3**. Operational noise impacts are assessed in **section 10.4**. Cumulative impacts are summarised in **Chapter 26** (Cumulative impacts). Assessments of impact to the heritage significance of items is included in **Chapter 20** (Non-Aboriginal Heritage) and **Appendix U** (Technical working paper: Non-Aboriginal Heritage).
	2. An assessment of construction noise and vibration impacts which must address: a) the nature of construction activities (including transport, tonal or impulsive noise-generating works and the removal of operational noise barriers, as relevant); b) the intensity and duration of noise and vibration impacts (both air and ground borne); c) the nature, sensitivity and impact to receivers; d) the need to balance timely conclusion of noise and vibration-generating works with periods of receiver respite, and other factors that may influence the timing and duration of construction activities (such as traffic management); e) the potential for works outside standard construction hours, including estimated duration and timing, predicted levels, exceedances and number of potentially affected receivers and justification for the activity in terms of the Interim Construction Noise Guideline (DECCW 2009); f) potential noise and vibration mitigation measures, including timing of implementation; g) figures illustrating the existing and predicted noise levels;	

Desired performance outcome	SEARs	Where addressed in the EIS
	h) a cumulative noise and vibration assessment inclusive of impacts from the project (including concurrent project construction activities); and i) a cumulative noise and vibration assessment inclusive of impacts from other key infrastructure projects including, but not limited to, the New M5 and M4 East.	
5. Noise and Vibration – Structural Construction noise and vibration (including airborne noise, ground-borne noise and blasting) are effectively managed to minimise adverse impacts on the structural integrity of buildings and items including Aboriginal places and environmental heritage. Increases in noise emissions and vibration affecting environmental heritage as defined in the *Heritage Act 1977* during operation of the project are effectively managed.	1. The Proponent must assess construction and operation noise and vibration impacts in accordance with relevant NSW noise and vibration guidelines. The assessment must include consideration of impacts to the structural integrity and heritage significance of items (including Aboriginal places and items of environmental heritage). 2. The Proponent must demonstrate that blast impacts are capable of complying with the current guidelines, if blasting is required.	Sensitive receivers identified in the study area are outlined in **section 10.2**. Construction noise and vibration impacts are assessed in **section 10.3**. Operational noise impacts are assessed in **section 10.4**. Potential impacts on non-Aboriginal heritage items are assessed in **Chapter 20** (Non-Aboriginal heritage) and **Appendix U** (Technical working paper: Non-Aboriginal heritage).

10.1 Assessment methodology

10.1.1 Overview

The assessment methodology for noise and vibration impacts has been carried out by undertaking the following key tasks:

- Identification of noise catchment areas (NCAs)
- Identification and classification of sensitive receivers
- Background noise monitoring, including attended and unattended noise monitoring undertaken to establish the existing noise levels in a particular area. This was undertaken at a total of 23 locations throughout the study area supplemented by a further 11 noise measurements undertaken previously for the M4 East and New M5 projects
- Validation and, where necessary, calibration of noise models based on background data
- Review of construction methodology and machinery and equipment needed for construction
- Modelling of construction and operational noise

- Assessment of airborne and ground-borne noise model predictions against relevant noise criteria for construction works, construction and operational traffic, and operational infrastructure
- Assessment of vibration impacts with reference to human comfort and cosmetic damage thresholds, and with respect to identified heritage items, where relevant
- Identification of feasible and reasonable mitigation and management measures to reduce noise impacts upon sensitive receivers throughout the study area.

Where guidelines require consideration of ‘feasible’ and ‘reasonable’ noise mitigation and management measures, the *Interim Construction Noise Guideline* (ICNG) (NSW Department of Environment and Climate Change (DECC) 2009) describes these terms as:

- Feasible – a work practice or abatement measure is feasible if it is capable of being put into practice or of being engineered and is practical to build given project constraints such as safety and maintenance requirements
- Reasonable – selecting reasonable measures from those that are feasible involves making a judgment to determine whether the overall noise benefits outweigh the overall adverse social, economic and environmental effects of implementing the measure, including consideration of the cost of the measure.

10.1.2 Study area

The study area for the noise and vibration impact assessment was developed according to the impacts likely to arise from project activities, including those related to construction, operation and cumulative scenarios. This included the following key elements:

- Identification of the location of all construction activities, construction sites and haulage routes with the potential to generate noise. These include:
  - Wattle Street civil and tunnel site (C1a)
  - Haberfield civil and tunnel site (C2a)
  - Northcote Street civil site (C3a)
  - Parramatta Road West civil and tunnel site (C1b)
  - Haberfield civil site (C2b)
  - Parramatta Road West civil and tunnel site (C3b)
  - Darley Road civil and tunnel site (C4)
  - Rozelle civil and tunnel site (C5)
  - The Crescent civil site (C6)
  - Victoria Road civil site (C7)
  - Iron Cove Link civil site (C8)
  - Pyrmont Bridge Road tunnel site (C9)
  - Campbell Road civil and tunnel site (C10)
  - The mainline tunnel alignment
  - Construction areas for local road upgrades
- Identification of receivers along the alignment and around construction sites that are potentially sensitive to noise and vibration. Noise sensitive receivers were identified through aerial photography and all structures in the project footprint, except for those to be acquired and demolished, were subject to visual ground-truthing. This exercise, in conjunction with cadastral information, was used to determine the classification of buildings into residential dwellings, commercial and industrial properties, education institutions, child-care centres, medical (hospital wards or other uses including medical centres), places of worship and outdoor open areas (passive and active recreation)

- Identification of NCAs. A total of 56 NCAs have been identified to reflect the land uses surrounding the project and assist in the identification of impacts upon groups of receivers likely to be affected by the same works. The NCAs have been designed around the nature of the receivers and local conditions (such as topography and proximity to other major noise sources) and the anticipated extent of discernible noise impacts around each construction and operational activity/site
- The 56 NCAs together form the noise study area for construction and operational sites. Further detail on these NCAs is provided in **section 10.2.2**. A map of all NCAs is shown in **Figure 10-1**, **Figure 10-2** and **Figure 10-3**.

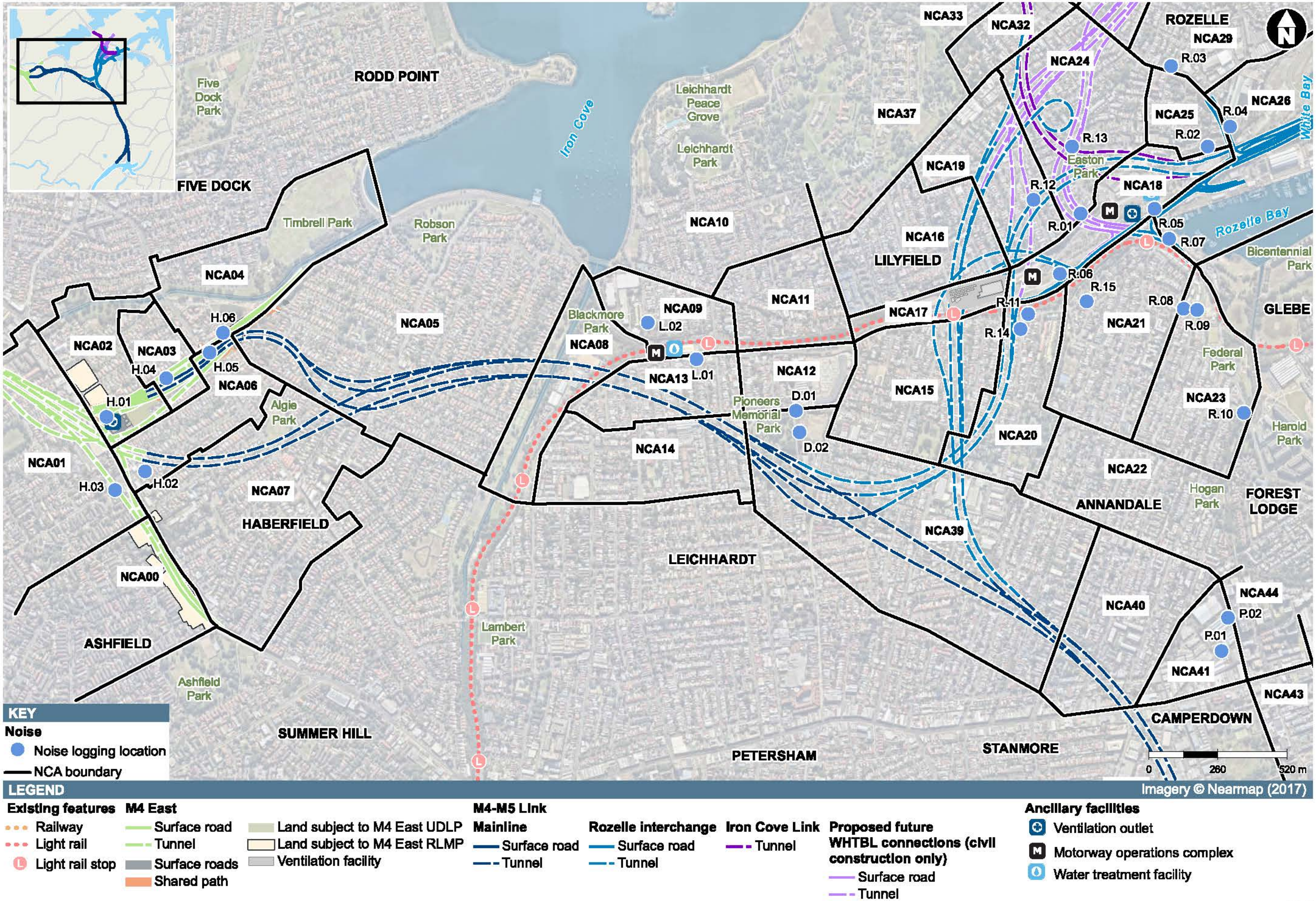


Figure 10-1 Project footprint, noise catchment areas and noise logging locations (western section)

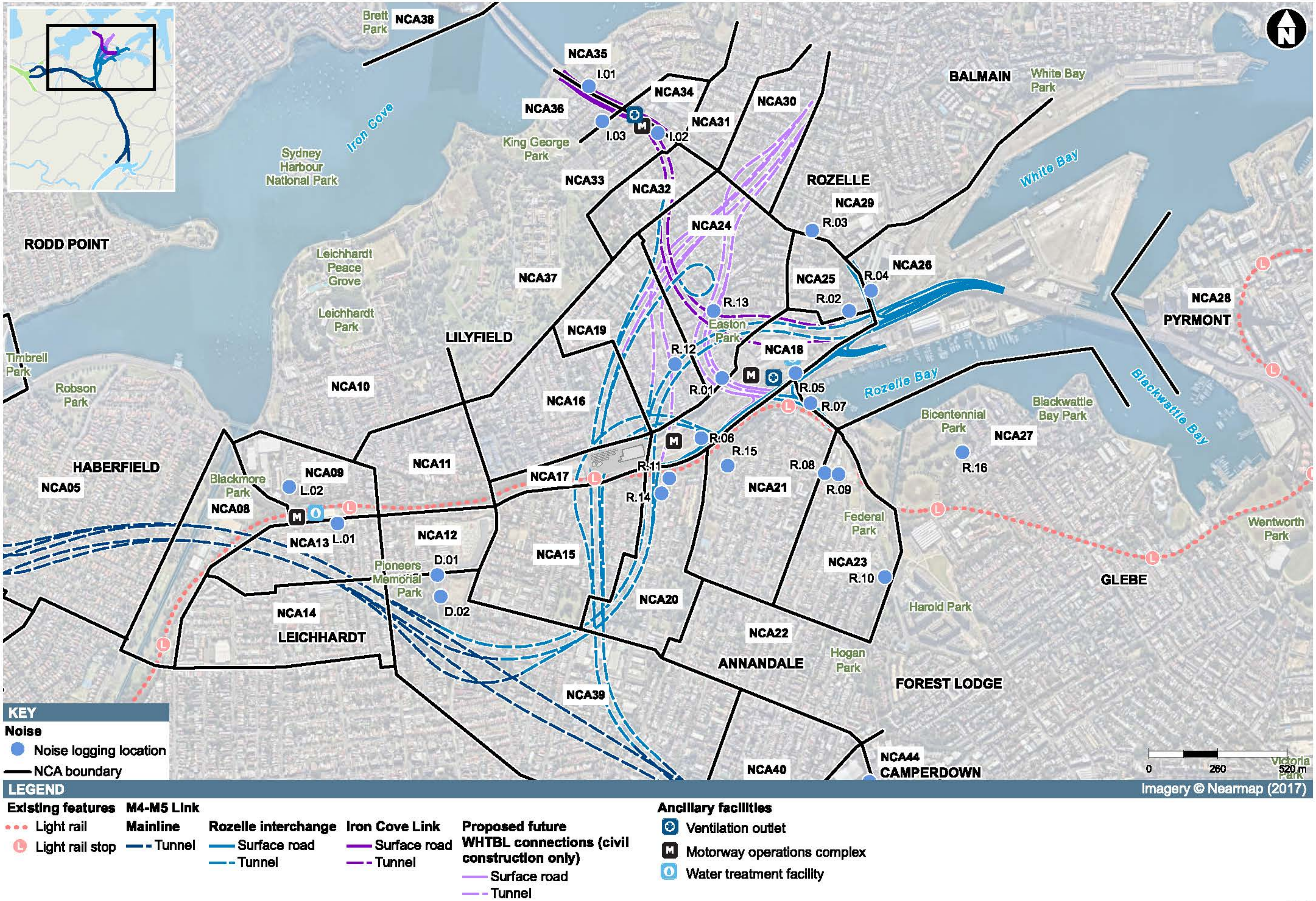


Figure 10-2 Project footprint, noise catchment areas and noise logging locations (northern section)

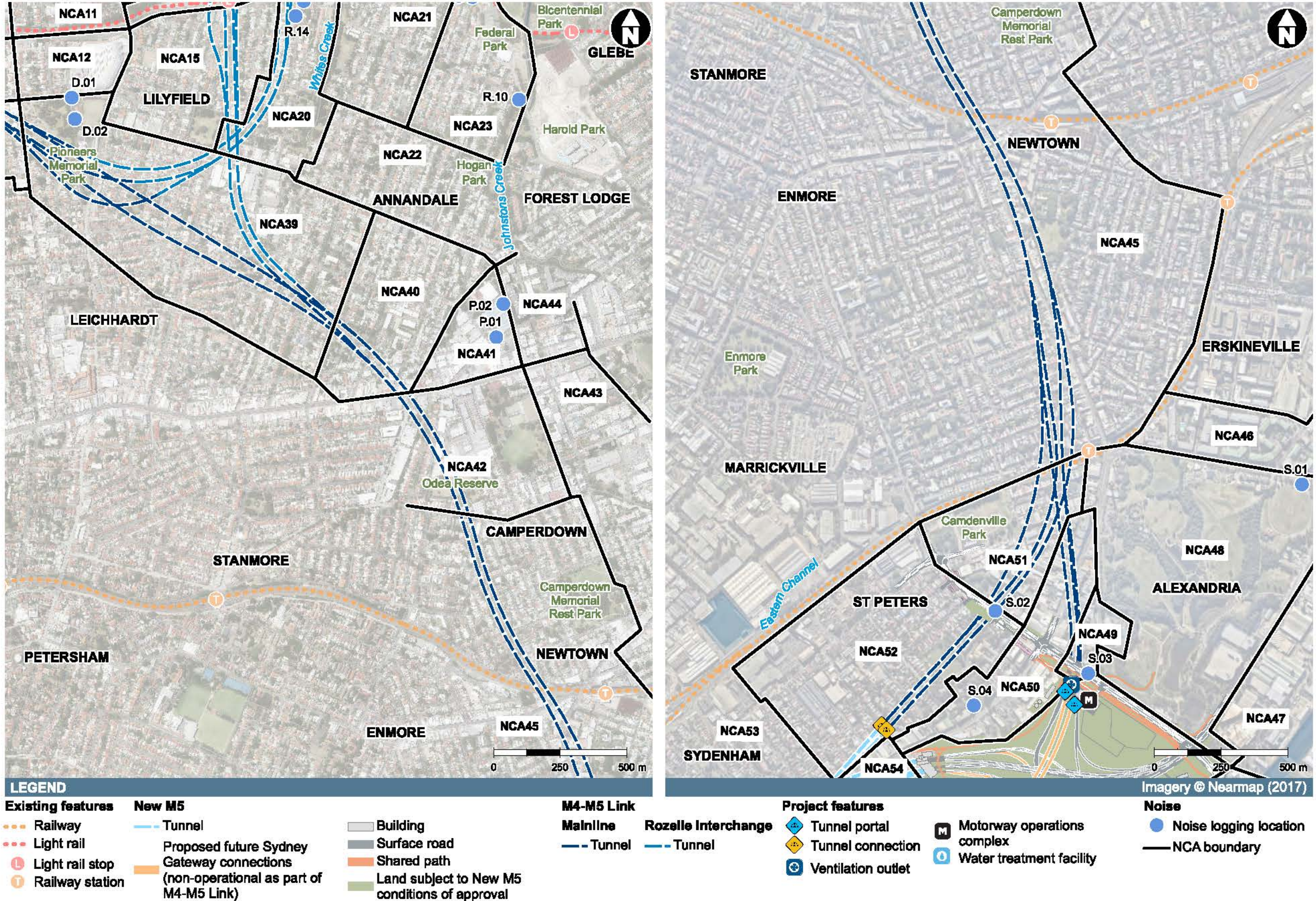


Figure 10-3 Project footprint, noise catchment areas and noise logging locations (southern section)

The study area for the assessment of noise associated with construction and operational traffic was determined through the:

- Identification of traffic routes for construction and operational phases of the project:
  - For construction traffic, proposed construction traffic routes to and from each construction site are described in **Chapter 8** (Traffic and transport)
  - For operational traffic, relevant traffic routes were those new or upgraded roads within the scope of the project. Relevant operational traffic routes were broadly located around the proposed surface elements of the project including Haberfield, Iron Cove, Darley Road, Rozelle, Pyrmont Bridge Road and St Peters
- Identification of a boundary up to the physical extent of the works. Note that while not required under the NSW Roads and Maritime Services (Roads and Maritime) *Noise Criteria Guideline* (2015a), due to the relatively small gap between the Rozelle interchange area and the Iron Cove Link, the boundary areas have been extended in order to include receivers on Victoria Road located between the two assessment areas
- Identification of a boundary of 600 metres either side of the main project construction and operational traffic routes, as recommended in the *NSW Road Noise Policy* (NSW Department of Environment, Climate Change and Water (DECCW) 2001)
- Modelling of adjacent collector roads, sub-arterial and arterial roads in order to identify the contributions from project and non-project existing roads separately. Roads where design or engineering changes are proposed have generally been considered as project roads.

The combined noise and vibration study area is predominantly a suburban noise environment in the west and an urban noise environment in the east, incorporating a mix of noise and vibration sensitive receivers (ie residential properties, educational establishments, hospitals and recreational areas), commercial and industrial properties, as well as major arterial and local roads.

10.1.3 Policy framework

The following guidelines have been used in the noise and vibration assessment:

- Construction noise:
  - *Construction Noise and Vibration Guideline* (CNVG) (Roads and Maritime 2016)
  - *Interim Construction Noise Guideline* (ICNG) (DECC 2009)
- Construction vibration:
  - *Assessing Vibration: a technical guideline* (NSW Department of Environment and Conservation (DEC) 2006a)
  - DIN 4150:Part 2-1999 Structural vibration – Effects of vibration on structures (*Deutsches Institut für Normung* 1999)
  - DIN 4150:Part 3-1999 Structural vibration – Effects of vibration on structures (*Deutsches Institut für Normung* 1999)
  - Evaluation and Measurement for Vibration in Buildings Part 2, (British Standard (BS) 7385:Part 2-1993) (BS 7385)
  - Explosives − Storage and Use − Part 2: Use of Explosives (Australian Standard (AS) 2187:Part 2-2006) (AS 2187)

- Construction and operational traffic noise:
  - *NSW Road Noise Policy* (RNP) (DECCW 2011)
  - *Noise Criteria Guideline* (NCG) (Roads and Maritime 2015a)
  - *Noise Mitigation Guideline* (NMG) (Roads and Maritime 2015b)
  - *Model Validation Guideline* (Roads and Maritime 2016)
  - *Application Notes – Noise Criteria Guideline* (Roads and Maritime 2015a)
  - *Environmental Noise Management Manual* (Roads and Maritime 2001)
  - *Procedure for Preparing an Operational Noise and Vibration Assessment* (Roads and Maritime 2011b)
- Noise from operational ancillary facilities:
  - *NSW Industrial Noise Policy* (INP) (NSW Environment Protection Authority (NSW EPA) 1999)
- Sleep disturbance during construction and operation:
  - *NSW Road Noise Policy* (DECCW 2011)
  - *Application notes – NSW industrial noise policy* (NSW EPA).

The above policies and guidelines are detailed further in the following sections, including how they have been employed for the purposes of this assessment.

Construction noise and vibration guidelines and policies

Airborne noise

The ICNG sets out ways to assess and manage the impacts of demolition and construction noise on residences and other sensitive land uses. This guideline requires project specific Noise Management Levels (NMLs) to be established for noise affected receivers. In the event construction noise levels are predicted to be above the NMLs, feasible and reasonable work practices are to be investigated to minimise noise emissions.

Residential receivers

The ICNG provides an approach for determining $L_{Aeq(15\text{-}minute)}$[1] NMLs at adjacent residential properties based on measured $L_{A90(15\text{-}minute)}$[2] rating background noise levels (RBL), as described in **Table 10-2**.

[1] $L_{Aeq(15\text{-}minute)}$ is the 'energy average noise level' evaluated over a 15-minute period. This parameter is used to assess the potential construction noise impacts.

[2] $L_{A90(15\text{-}minute)}$ is the noise level exceeded for 90% of the measurement period, A-weighted and calculated by statistical analysis.

Table 10-2 Determination of NMLs for residential receivers

Time of day	NML $L_{Aeq(15\ minute)}$	How to apply the ICNG
Standard construction hours: • Monday to Friday 7:00am to 6:00pm • Saturday 8:00am to 1:00pm • No work on Sundays or public holidays	Noise affected level RBL[1] + 10 dBA	Above the noise affected level, some community reaction to noise would be expected. Where the predicted or measured $L_{Aeq(15\text{-}minute)}$ is greater than the noise affected level, the proponent should apply all feasible and reasonable work practises to meet the noise affected level. The proponent should also inform all potentially impacted residents of the nature of works to be carried out, the expected noise levels and duration, as well as contact details.
	Highly noise affected 75 dBA	Above the 'highly noise affected level' a strong community reaction to noise would be expected. Where noise is above this level, the relevant authority (consent, determining or regulatory) may require respite periods by restructuring the hours during which very noise intensive activities can occur, taking into account: • Times identified by the communities when they are less sensitive to noise (such as before and after school for works near schools or mid-morning or mid-afternoon for works near residences) • If a community is prepared to accept a longer period of construction in exchange for restrictions on construction times.
Outside standard construction hours	RBL[1] + 5 dBA	A strong justification would typically be required for works outside the recommended standard hours. The proponent should apply all feasible and reasonable work practices to meet the noise affected level. Where all feasible and reasonable practises have been applied and noise is more than 5 dBA above the noise affected level, the proponent should negotiate with the community.

Note :

1 The RBL is the overall single-figure background noise level measured in each relevant assessment period (during or outside the recommended standard hours) as described in the NSW Industrial Noise Policy (NSW EPA 1999).

Commercial receivers

The ICNG notes that due to the broad range of sensitivities that commercial or industrial receivers can have to noise from construction, the process of defining management levels is separated into three categories:

- Industrial premises: external $L_{Aeq(15\text{-}minute)}$ 75 dBA
- Offices, retail outlets: external $L_{Aeq(15\text{-}minute)}$ 70 dBA
- Other businesses that may be very sensitive to noise, where the noise level is project specific, as discussed below.

The external noise levels should be assessed at the most-affected occupied point of the premises.

Other sensitive land uses

The ICNG's quantitative assessment method provides NMLs for other sensitive land uses, such as educational institutions, hospitals, medical facilities and outdoor recreational areas. These land uses are considered potentially sensitive to construction noise only when the properties are in use.

The project specific $L_{Aeq(15\text{-}minute)}$ NMLs for other non-residential noise sensitive receivers from the ICNG are provided in **Table 10-3**.

Table 10-3 NMLs for other sensitive receivers

Land use	NML $L_{Aeq(15\ minute)}$ (Applied when the property is in use)
Classrooms at schools and other education institutions	Internal noise level 45 dBA
Hospital wards and operating theatres	Internal noise level 45 dBA
Places of Worship	Internal noise level 45 dBA
Active recreation areas (characterised by sporting activities and activities which generate their own noise or focus for participants, making them less sensitive to external noise intrusion)	External noise level 65 dBA
Passive recreation areas (characterised by contemplative activities that generate little noise and where benefits are compromised by external noise intrusion, eg reading, meditation)	External noise level 60 dBA
Community centres	Depends on the intended use of the centre. Refer to the recommended 'maximum' internal levels in AS 2107-1987. Acoustics - Recommended design sound levels and reverberation times for building interiors (AS 2107) for specific uses.

For sensitive receivers such as schools and places of worship, the NMLs presented in **Table 10-3** are based on internal noise levels. For the purpose of this assessment, it is conservatively assumed that all schools and places of worship have windows that can be opened. On the basis that external noise levels are typically 10 dBA higher than internal noise levels when windows are open, an external NML of 55 dBA $L_{Aeq(15\text{-}minute)}$ has been adopted.

Other noise-sensitive receivers require separate project-specific noise goals and, as per the guidance in the ICNG, NMLs for these receivers have been derived from the internal levels presented in AS 2107.

The ICNG and AS 2107 do not provide specific guideline noise levels for childcare centres. Childcare centres generally have internal play areas and sleeping areas. For internal play areas an internal NML of 55 dBA $L_{Aeq(15\text{-}minute)}$ has been adopted together with an internal NML of 40 dBA $L_{Aeq(15\text{-}minute)}$ (when in use) for sleeping areas.

On the assumption that windows and doors of childcare centres may be opened, an external NML of 65 dBA $L_{Aeq(15\text{-}minute)}$ for play areas has been applied at the façade and would also be applicable to external play areas. For sleeping areas (on the assumption that windows are open), an external NML is 50 dBA $L_{Aeq(15\text{-}minute)}$ has been applied. Given specific layouts for childcare centres are unknown during the preparation of the EIS, a NML of 50 dBA has been used to assess construction noise impacts on these centres.

Sleep disturbance

The most recent NSW guidance in relation to sleep disturbance is contained in the NSW EPA's online *Application notes – NSW industrial noise policy*[3]. For the purposes of this assessment a night-time sleep disturbance 'screening criterion' noise goal of RBL +15 dBA has been used.

The term 'screening criterion' indicates a noise level that is intended as a guide to identify the likelihood of sleep disturbance. While it is not a firm criterion to be met, where the criterion is met sleep disturbance is not likely. When the screening criterion is not met, a more detailed analysis is required.

With regard to reaction to potential sleep awakening events, the RNP gives the following guidance:

'From the research on sleep disturbance to date it can be concluded that:

- *maximum internal noise levels below 50–55 dBA are unlikely to awaken people from sleep*
- *one or two noise events per night, with maximum internal noise levels of 65–70 dB(A), are not likely to affect health and wellbeing significantly'.*

Road traffic noise

When trucks and other vehicles are operating within the boundaries of construction sites, road vehicle noise contributions are included in the predicted $L_{Aeq(15\text{-}minute)}$ noise emissions and assessed against the criteria in **Table 10-4**.

When construction related traffic moves onto the public road network a different noise assessment methodology is appropriate, as vehicle movements are regarded as 'additional road traffic' rather than as part of the construction works and as such would be assessed using Roads and Maritime's NCG (2015a). The NCG documents Roads and Maritime's approach to implementing the RNP.

The NCG requires that an initial screening test should be applied by evaluating whether noise levels would increase by more than 2 dBA (an increase in the number vehicles of approximately 60 per cent) due to construction traffic or a temporary reroute due to a road closure. Where increases are 2 dBA or less, then no further assessment is required as noise level changes would most likely not be perceptible to most people.

Where noise levels increase by more than 2 dBA (ie 2.1 dBA or greater) further assessment is required using criteria presented in the NCG (see **Table 10-4**).

Table 10-4 NCG criteria for assessing construction vehicles on public roads

Road category	Type of project/land use	Assessment criteria (dBA)	
		Daytime (7 am – 10 pm)	Night-time (10 pm – 7 am)
Freeway/arterial/ sub-arterial roads	Existing residences affected by additional traffic on existing freeways/arterial/sub-arterial roads generated by land use developments	$L_{Aeq(15\text{-}hour)}$ 60 (external)	$L_{Aeq(9\text{-}hour)}$ 55 (external)
Local roads	Existing residences affected by additional traffic on existing local roads generated by land use developments	$L_{Aeq(1\text{-}hour)}$ 55 (external)	$L_{Aeq(1\text{-}hour)}$ 50 (external)

[3] http://www.epa.nsw.gov.au/noise/applicnotesindustnoise.htm

Ground-borne noise

Ground-borne noise is that generated by vibrations arising from a ground-based source, typically underground mechanical equipment. These vibrations are transmitted to a structure, such as a building, where the vibration of the floors and walls may cause vibration and rattling of items and/or a low rumble, all of which may be perceptible by the occupants. This rumbling noise is derived from the motion of the walls and floors, causing the building to effectively act as a loudspeaker for the transmitted vibration. For this reason, ground-borne noise is only an issue for occupants within buildings, with outdoor spaces being unaffected.

It should be noted that ground-borne noise is different to ground-borne vibration. Ground-borne vibration refers to vibration effects that are transmitted via the ground as small physical movements can be 'felt' and may create audible (ground-borne) noise. As such ground-borne noise is a by-product of ground-borne vibration.

The CNVG provides residential NMLs for ground-borne noise, which are applicable when ground-borne noise levels are higher than the corresponding airborne construction noise levels. The CNVG provides ground-borne noise levels at residences for evening and night-time periods only, as the objectives aim to protect amenity and minimise potential sleep disturbance. The following ground-borne noise levels are applicable for residences:

- Evening (6.00pm to 10.00pm weekdays): 40 dBA $L_{Aeq(15\text{-}minute)}$
- Night-time (10:00pm to 7am): 35 dBA $L_{Aeq(15\text{-}minute)}$.

For commercial receivers such as offices and retail areas, the CNVG does not provide guidance in relation to acceptable ground-borne noise levels. For the purpose of this assessment, an internal NML of 60 dBA $L_{Aeq(15\text{-}minute)}$ has been adopted to assist in identifying potential impacts. This level has been selected with guidance taken from AS 2107 as well as recognising that ground borne noise impacts are generally only for a relatively short period of time. A level of 60 dBA is also consistent to what has been applied on previous large infrastructure projects.

These NMLs are applicable to residences and commercial receivers located above tunnelling works, and could also apply to other construction activities such as rock breaking in an adjoining building where ground-borne noise levels may be higher than airborne noise levels. This situation may occur at construction sites where airborne noise impacts are shielded by noise barriers or other structures, or noise sensitive areas within residential or commercial buildings which are not directly affected by the airborne noise component of nearby construction works.

Vibration

The effects of vibration on buildings can be divided into three main categories:

- Those in which the occupants or users of the building are inconvenienced or possibly disturbed
- Those where the building contents may be affected
- Those in which the integrity of the building or the structure itself may be compromised.

Human comfort vibration

Assessing Vibration: a technical guideline (NSW EPA 2006) provides guideline values for continuous, transient and intermittent events that are based on a Vibration Dose Value (VDV) rather than a continuous vibration level. The VDV is dependent upon the level and duration of the vibration event, as well as the number of events occurring during the daytime or night-time period.

The VDVs recommended in the guideline for intermittent vibration are presented in **Table 10-5**.

Table 10-5 Acceptable vibration dose values for intermittent vibration ($m/s^{1.75}$)

Human comfort (as per Assessing Vibration: a technical guideline) Location	Daytime[1]		Night time[1]	
	Preferred value	Maximum value	Preferred value	Maximum value
Critical areas[2]	0.10	0.20	0.10	0.20
Residences	0.20	0.40	0.13	0.26
Offices, school, educational institutions and places of worship	0.40	0.80	0.40	0.80
Workshops	0.80	1.60	0.80	1.60

Note:

1: Daytime is 7.00 am to 10.00 pm and night-time is 10.00 pm to 7.00 am.

2: Examples include hospital operating theatres and precision laboratories where operations are occurring. These criteria are only indicative, and there may be a need to assess intermittent values against the continuous or impulsive criteria for critical areas. Source BS 6472-1992.

Effects on building contents

People can perceive floor vibration at levels well below those likely to cause damage to building contents or affect the operation of typical equipment found in most buildings that is not particularly vibration sensitive. For most receivers, the controlling vibration criterion is the human comfort criterion, and it is therefore not normally required to set separate criteria in relation to the effect of construction vibration on typical building contents.

Where appropriate, objectives for the satisfactory operation of vibration sensitive critical instruments or manufacturing processes should be sourced from manufacturer's data and/or other published objectives.

Structural damage vibration

Structural damage vibration limits are based on AS 2187 and BS 7385. These standards provide frequency-dependent vibration limits related to cosmetic damage, noting that cosmetic damage is very minor in nature, is readily repairable and does not affect the structural integrity of the building.

The recommended vibration limits from BS 7385 for transient vibration for minimal risk of cosmetic damage to residential and industrial buildings are shown in **Table 10-6**.

Table 10-6 Transient vibration guide values for minimal risk of cosmetic damage (BS 7385)

Structural damage vibration criteria Line	Type of building	Peak component particle velocity in frequency range of predominant pulse	
		4 Hz to 15 Hz	15 Hz and above
1	Reinforced or framed structures; industrial and heavy commercial buildings	50 mm/s at 4 Hz and above	
2	Unreinforced or light framed structures; residential or light commercial type buildings	15 mm/s at 4 Hz increasing to 20 mm/s at 15 Hz	20 mm/s at 15 Hz increasing to 50 mm/s at 40 Hz and above

Note:

The guide values relate predominantly to transient vibration which does not give rise to resonant responses in structures and low-rise buildings. In the event continuous vibration gives rise to magnification of vibration by resonance (under specific conditions where the structure can readily store and transfer vibration energy), then the guide values may need to be reduced by up to 50 per cent.

Heritage and vibration sensitive structures

The Roads and Maritime CNVG notes that separate guidance for assessment of heritage structures is contained in the German Standard DIN 4150: Part 3-1999 Structural vibration – Effects of vibration on structures (*Deutsches Institut für Normung* 1999) (DIN 4150).

For continuous, long-term vibration or repetitive vibration with the potential to cause fatigue effects, DIN 4150 provides the following Peak Particle Velocity (PPV) values as safe limits, below which superficial cosmetic damage is not expected:

- 10 millimetres per second for commercial buildings and buildings of similar design
- Five millimetres per second for dwellings and buildings or similar design
- 2.5 millimetres per second for buildings of particular sensitivity (structurally unsound).

For short-term vibration events (ie those unlikely to cause resonance or fatigue), DIN 4150 provides the criteria shown in **Table 10-7**. These are maximum levels measured in any direction at the foundation or in the horizontal axes in the plane of the uppermost floor.

Table 10-7 DIN 4150 structural damage – safe limits for short-term building vibration

Group	Type of structure	Peak particle velocity (mm/s) At foundation			Plane of floor of uppermost storey
		1 Hz to 10 Hz	10 Hz to 50 Hz	50 Hz to 100 Hz[1]	All frequencies
1	Buildings used for commercial purposes, industrial buildings and buildings of similar design	20	20 at 10 Hz increasing to 40 at 50 Hz	40 at 50 Hz increasing to 50 at 100 Hz	40
2	Dwellings and buildings of similar design and/or use	5	5 at 10 Hz increasing to 15 at 50 Hz	15 at 50 Hz increasing to 20 at 100 Hz	15
3	Structures that because of their particular sensitivity to vibration (structurally unsound), do not correspond to those listed in Lines 1 or 2 (see **Table 10-6**)	3	3 at 10 Hz increasing to 8 at 50 Hz	8 at 50 Hz increasing to 10 at 100 Hz	8

Note:

1: For frequencies above 100 Hertz the upper value in this column should be used.

The minimum 'safe limit' of peak vibration velocity at low frequencies for commercial buildings and buildings of similar design is 20 millimetres per second (Group 1). For dwellings and buildings of similar design and/or use, the safe limit is five millimetres per second (Group 2) and for structures which may be particularly sensitive to ground vibration, such as historic buildings which are structurally unsound (Group 3), the safe limit is three millimetres per second. This latter criterion could also be applied to buried archaeological artefacts. Potential impacts on historic buildings and archaeological artefacts are discussed in **Chapter 20** (Non-Aboriginal heritage).

As opposed to the 'minimal risk of cosmetic damage' approach adopted in BS 7385 (95 per cent probability of no effect), the 'safe limits' given in DIN 4150 are the levels up to which no damage due to vibration effects has been observed for the particular class of building.

'Damage' is defined by DIN 4150 to include even minor, non-structural effects such as superficial cracking in cement render, the enlargement of cracks already present, and the separation of partitions or intermediate walls from load bearing walls.

Project blasting criteria (human comfort)

Guidance in relation to acceptable airblast overpressure (high energy impulse noise) and ground vibration from blasting is provided in the ICNG, which specifies that the assessment should be based on the levels in the *Technical Basis for Guidelines to Minimise Annoyance Due to Blasting Overpressure and Ground Vibration* (Australian and New Zealand Environment and Conservation Council (ANZECC) 1990).

For airblast overpressure the criteria are stated as:

- Recommended maximum level of 115 dBL (linear peak). This may be exceeded on up to five per cent of the total number of blasts over a period of 12 months
- A maximum level of 120 dBL (linear peak) should not be exceeded at any time.

For ground vibration the criteria are stated as:

- Recommended maximum level of five millimetres per second (peak particle velocity). This may be exceeded on up to five per cent of the total number of blasts over a period of 12 months
- A maximum level of 10 millimetres per second (peak particle velocity) should not be exceeded at any time.

These criteria relate to sensitive sites (including houses and low rise residential buildings, theatres, schools, and other similar buildings occupied by people).

The blast vibration criteria identified in ANZECC 1990 are considered conservative and were originally developed to protect communities exposed to long-term blasting operations such as near to mining sites. For projects with a shorter duration of blasting (12 months or less, such as this one), a higher vibration criterion may be reasonable. For this project the location of any potential blasting within the tunnel would move along the alignment such that any one receiver would be affected for only a short proportion of the overall construction program.

AS 2187 presents vibration limits designed to safeguard human comfort in relation to blasting. These have been used by some authorities as they provide a clearer definition of vibration limits which are dependent on the specific duration of the project. Based on the limitations of ANZECC 1990 and further guidance in AS 2187, it is recommended that a human comfort vibration limit of 10 millimetres per second (peak particle velocity) for blasting operations lasting less than 12 months be applied to this project, which is consistent with recommendations for previous WestConnex projects.

Project blasting criteria (control of damage)

In terms of the most recent relevant vibration damage criteria, AS 2187 recommends the frequency dependent guideline values and assessment methods given in BS 7385 Part 2-1993 as they ‘are applicable to Australian conditions’. The criteria are presented in **Appendix J** (Technical working paper: Noise and vibration).

It should be noted that BS 7385 states that ‘a building of historical value should not (unless it is structurally unsound) be assumed to be more sensitive’. Nominating appropriate criteria for heritage buildings generally requires site inspections and should be confirmed during detailed design.

In relation to damage from airblast, AS 2187 notes that from Australian and overseas research, damage (even of a cosmetic nature) has not been found to occur at airblast levels below 133 dBL.

Recommended blasting hours

For blasting, the standard hours of construction in NSW as recommended by the ICNG are applicable:

- 9.00 am to 5.00 pm Monday to Friday
- 9.00 am to 1.00 pm Saturday
- No blasting on Sundays and public holidays.

Other hours may be worked if approved by the relevant authority.

Operational noise guidelines and policies

Operational road traffic noise

This assessment has been prepared under the guidance of the NCG which documents Roads and Maritime's interpretation of the RNP and provides a consistent approach to identifying road noise criteria for Roads and Maritime projects. Although it is not mandatory to achieve the noise assessment criteria in the NCG, project proponents need to provide justification if it is not considered feasible or reasonable to achieve them.

The NCG recognises that there are generally more opportunities to minimise noise impacts from new roads and road corridors, especially those in greenfield locations, through judicious road design and land use planning. The scope to reduce noise impacts from existing/upgraded roads and corridors in established areas is typically more limited. The NCG criteria are applicable both at the time of project opening and also in a future design year, typically taken to be 10 years after project completion.

The NCG sets out four key principles to guide assessment. These are:

- Criteria are based on the type of road development that a residence is affected by
- Adjacent and nearby residences should not have significantly different criteria for the same road
- Criteria for the surrounding road network are assessed where a road project generates an increase in traffic noise greater than 2 dBA on the surrounding road network
- Existing quiet areas should be protected from excessive changes in amenity due to traffic noise.

Noise assessment criteria

Noise criteria are assigned to sensitive receivers using the NCG. The assessment timeframe for the criteria are in the year of opening (for this project 2023 is used) and 10 years after opening (for this project 2033 is used).

Residences are categorised depending on how the project would influence noise levels. Each category is then given a set of related criteria. Residences may be assigned new, redeveloped, transition zone or relative increase criteria depending on how the project would influence noise levels. For each façade of the residence the most stringent applicable criteria are to be used in the assessment.

In some instances, residences may be exposed to noise from both new and redeveloped roads. In this instance the proportion of noise from each road is used to establish transition zone criteria. A further check is made to prevent large increases in noise levels using the relative increase criteria.

Assessment scenarios

The RNP requires the following four assessment scenarios to be assessed (years relevant to the project):

- 2023 No Build (ie at opening, without the project)
- 2023 Build (ie at opening, with the project)
- 2033 No Build (ie 10 years after opening, without the project)
- 2033 Build (ie 10 years after opening, with the project).

Criteria by road type

The project consists of multiple new and redeveloped road segments, with transition zones at the Iron Cove Link and the Rozelle interchange.

Note that a road is new where the road is a tunnel/bypass or has been substantially realigned (more than six times the existing lane width tolerance band and/or existing grade). However, consideration can be given to whether a road has been substantially realigned for distances less than six times the existing lane width using local context for guidance. This is consistent with the NCG.

The above situation occurs in the vicinity of Iron Cove Bridge, where the upgraded section of Victoria Road (around the Iron Cove Link portals) has been moved to a new location within the tolerance band but over the existing housing footprint to accommodate new tunnel portals. The criteria for residences are summarised in **Table 10-8**.

Table 10-8 NCG criteria – residential

Road category	Type of project/land use	Assessment criteria (dB)	
		Daytime (7:00 am – 10:00 pm)	**Night-time (10:00 pm – 7:00 am)**
Freeway/ arterial/ sub-arterial roads	1. Existing residences affected by noise from new freeway/arterial/sub-arterial road corridors	$L_{Aeq(15\text{-}hour)}$ 55 (external)	$L_{Aeq(9\text{-}hour)}$ 50 (external)
	2. Existing residences affected by noise from redevelopment of existing freeway/arterial/sub-arterial roads 3. Existing residences affected by additional traffic on existing freeways/arterial/sub-arterial roads generated by land use developments	$L_{Aeq(15\text{-}hour)}$ 60 (external)	$L_{Aeq(9\text{-}hour)}$ 55 (external)
	4. Existing residences affected by both new roads and the redevelopment of existing freeway/arterial/sub-arterial roads in a Transition Zone[1]	Between $L_{Aeq(15\text{-}hour)}$ 55-60 (external)	Between $L_{Aeq(9\text{-}hour)}$ 50-55 (external)
	5. Existing residences affected by increases in traffic noise of 12 dBA or more from new freeway/arterial/sub-arterial roads[2]	Between $L_{Aeq(15\text{-}hour)}$ 42-55 (external)	Between $L_{Aeq(9\text{-}hour)}$ 42-50 (external)
	6. Existing residences affected by increases in traffic noise of 12 dBA or more from redevelopment of existing freeway/arterial/sub-arterial roads[2]	Between $L_{Aeq(15\text{-}hour)}$ 42-60 (external)	Between $L_{Aeq(9\text{-}hour)}$ 42-55 (external)
Local roads	7. Existing residences affected by noise from new local road corridors.	$L_{Aeq(1hour)}$ 55 (external)	$L_{Aeq(1hour)}$ 50 (external)
	8. Existing residences affected by noise from redevelopment of existing local roads		
	9. Existing residences affected by additional traffic on existing local roads generated by land use developments		

Note

1: The criteria assigned to the entire residence depend on the proportion of noise coming from the new and redeveloped road. Please refer to Roads and Maritimes' NCG for further information.

2: The criteria at each facade are determined from the existing traffic noise level plus 12 dBA.

Table 10-9 NCG criteria – other sensitive land uses

Existing sensitive land use	Assessment criteria (dBA)[1]		Additional considerations
	Daytime (7.00 am – 10.00 pm)	**Night-time (10.00 pm – 7.00 am)**	
School classrooms	$L_{Aeq(1\text{-}hour)}$ 40 (internal)	-	In the case of buildings used for education or health care, noise level criteria for spaces other than classrooms and wards may be obtained by interpolation from the 'maximum' levels shown in AS 2107.
Places of worship	$L_{Aeq(1\text{-}hour)}$ 40 (internal)	$L_{Aeq(1\text{-}hour)}$ 40 (internal)	The criteria are assessed inside of the place of worship. Areas outside the place of worship, such as a churchyard or cemetery, may also be deemed 'places of worship'. Therefore, in determining appropriate criteria for such external areas, the assessment should establish which activities in these areas may be affected by road traffic noise.
Open space (active use)	$L_{Aeq(15\text{-}hour)}$ 60 (external) when in use	-	Active recreation is characterised by sporting activities and activities which generate their own noise or focus for participants, making them less sensitive to external noise intrusion.
Open space (passive use)	$L_{Aeq(15\text{-}hour)}$ 55 (external) when in use	-	Passive recreation is characterised by contemplative activities that generate little noise and where benefits are compromised by external noise intrusion, eg playing chess, reading.
Childcare facilities	Sleeping rooms $L_{Aeq(1\text{-}hour)}$ 35 (internal) Indoor play areas $L_{Aeq(1\text{-}hour)}$ 40 (internal) Outdoor play areas $L_{Aeq(1\text{-}hour)}$ 55 (external)	-	Multi-purpose spaces, eg shared indoor play/sleeping rooms should meet the lower of the respective criteria. Measurements for sleeping rooms should be taken during designated sleeping times for the facility, or if these are not known, during the highest hourly traffic noise level during the opening hours of the facility.
Aged care facilities	-	-	Residential land use noise assessment criteria should be applied to these facilities, see Table 10-8.
Hospital wards	$L_{Aeq(1\text{-}hour)}$ 35 (internal)	$L_{Aeq(1\text{-}hour)}$ 35 (internal)	N/A

Note:
1: Internal NCG noise criteria has been converted to an external noise criteria for the purposes of assessment using external noise level predictions. Where detailed information relating to building construction is not available, the NSW EPA recommends a 10 dBA factor to convert internal to external noise levels on the basis that façades with windows open

typically provide approximately 10 dBA attenuation from inside to outside (refer to guidance contained in the ICNG and INP).

For sensitive receivers such as schools, places of worship and childcare facilities, the NCG criteria presented in **Table 10-9** are based on internal noise levels.

Potential road traffic noise impacts on the surrounding road network

The NCG criteria require consideration of the surrounding road network where the proposed project is predicted to increase noise levels by more than 2 dBA at receivers from the No Build to Build scenarios. The impacted surrounding road network is then assessed as a project road where noise levels have increased by more than 2 dBA.

This assessment considers potential increases in traffic noise on the surrounding road network within the extent of works of the project. This approach meets the principles of the NCG.

Noise mitigation

The NMG provides guidance in managing and controlling road traffic generated noise and describes the principles to be applied when reviewing noise mitigation. The NMG recognises that the criteria recommended by the NCG are not always practicable and that it is not always feasible or reasonable to expect that they should be achieved.

The NMG provides three triggers where a receiver may qualify for consideration of noise mitigation (beyond the adoption of road design and traffic management measures). These are:

- **Trigger 1:** The predicted Build noise level exceeds the NCG controlling criterion and the noise level increase due to the project (ie the noise predictions for the Build minus the No Build) is greater than 2 dBA
- **Trigger 2:** The predicted Build noise level is 5 dBA or more above the NCG controlling criterion (exceeds the cumulative limit) and the receiver is significantly influenced by project road noise, regardless of the incremental impact of the project
- **Trigger 3:** The noise level contribution from the road project is acute (daytime $L_{Aeq(15\text{-hour})}$ 65 dBA or higher, or night-time $L_{Aeq(9\text{-hour})}$ 60 dBA or higher) even if noise levels are dominated by a non-project road.

As highlighted in the NMG, once noise has been minimised by feasible and reasonable methods during the corridor planning and road design stages, triggered receivers with residual exceedances of the NCG controlling criteria shall be assessed to determine if they qualify for noise mitigation. The NMG defines what feasible and reasonable factors may be considered when investigating noise mitigation measures.

Selecting reasonable measures from those that are ‘feasible’ involves judging whether the overall noise benefits outweigh the overall adverse social, economic and environmental effects, including the cost of the abatement measure. To make such a judgement, consideration may be given to noise impacts, noise mitigation benefits, the cost effectiveness of noise mitigation and community views.

Maximum noise levels

A maximum noise level assessment has been conducted in accordance with the procedure *Preparing an Operational Noise and Vibration Assessment* (Roads and Maritime 2011) using guidance contained in Practice Note iii of the Environmental Noise Management Manual (ENMM). The objective of the maximum noise level assessment is to determine whether maximum noise levels are likely to increase or decrease as a result of the project.

Maximum noise level events were measured as part of the background noise study described in **section 10.2**. The maximum noise level assessment includes an evaluation of the number and distribution of night-time passby events in accordance with the ENMM (Roads and Traffic Authority 2001). A maximum noise level event is defined within the ENMM as being any passby where:

- The maximum noise level of the event is greater than 65 dBA L_{AFmax}[4]
- The $L_{AFmax} – L_{Aeq(1\text{-hour})}$ is greater than or equal to 15 dBA.

Strategies are currently being implemented by Roads and Maritime to reduce road traffic noise across the state road network: this may reduce the number of maximum noise level events associated with the project over the longer term.

Operational fixed facilities

Industrial noise from fixed facilities associated with the operation of the project have the potential to adversely affected nearby receivers. The following fixed facilities have been considered as part of this assessment:

- In-tunnel jet fans
- Ventilation facilities
- Substations
- Water treatment plants.

The locations of these facilities are shown in **Figure 10-4** to **Figure 10-6**.

[4] L_{AFmax} is the maximum level with A-weighted frequency response and Fast time constant

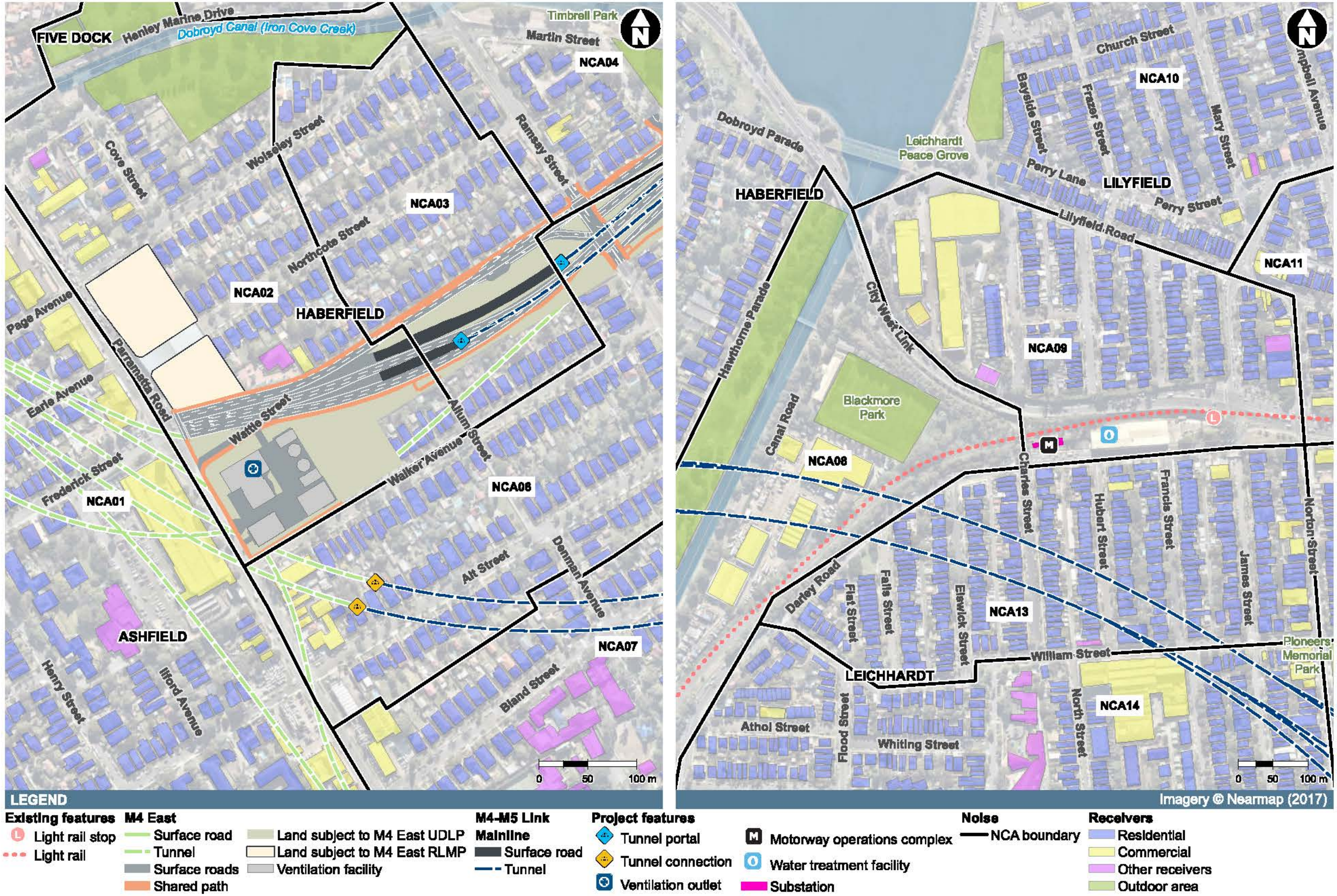


Figure 10-4 Location of fixed facilities - Haberfield (left) and Darley Road (right)

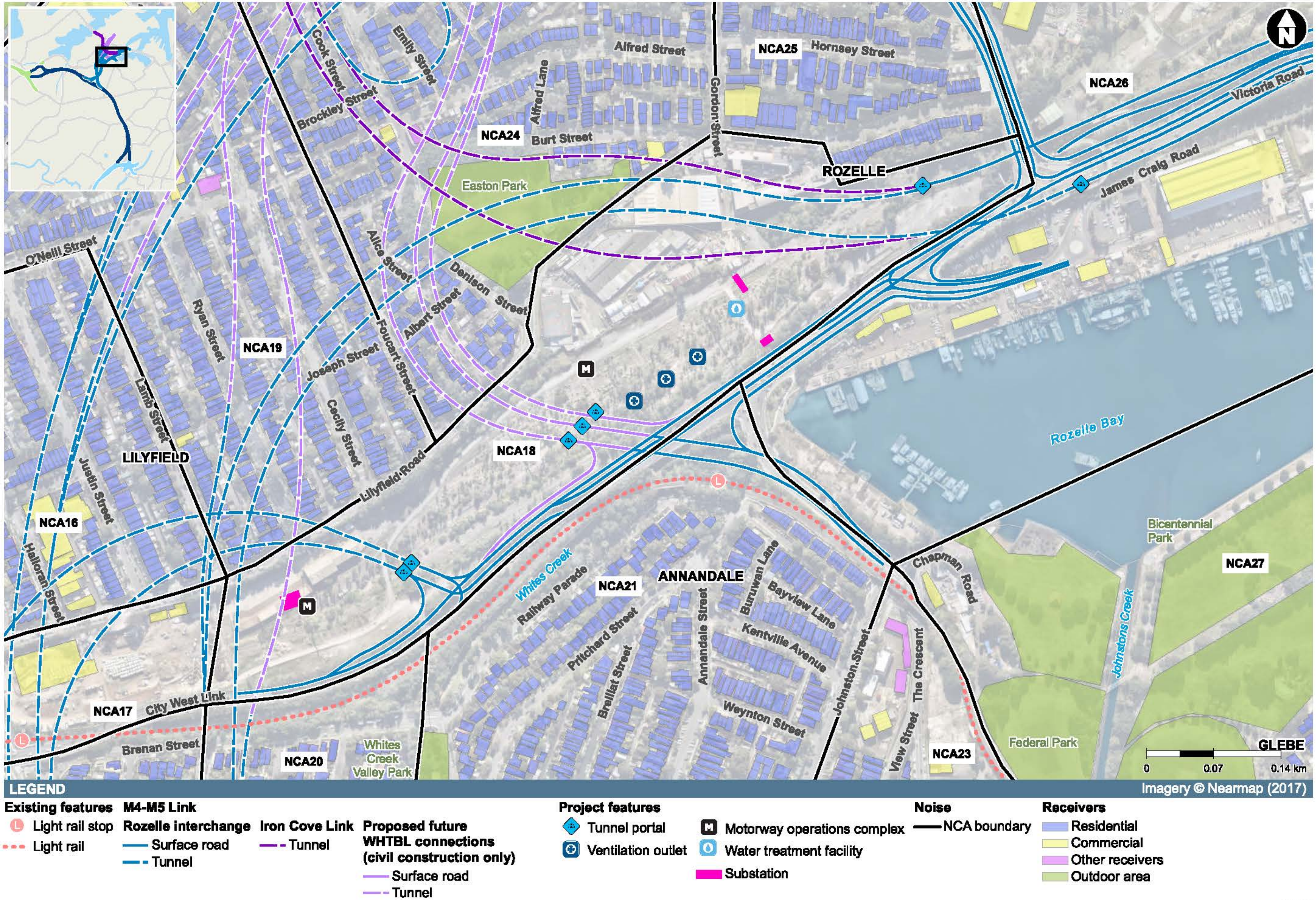
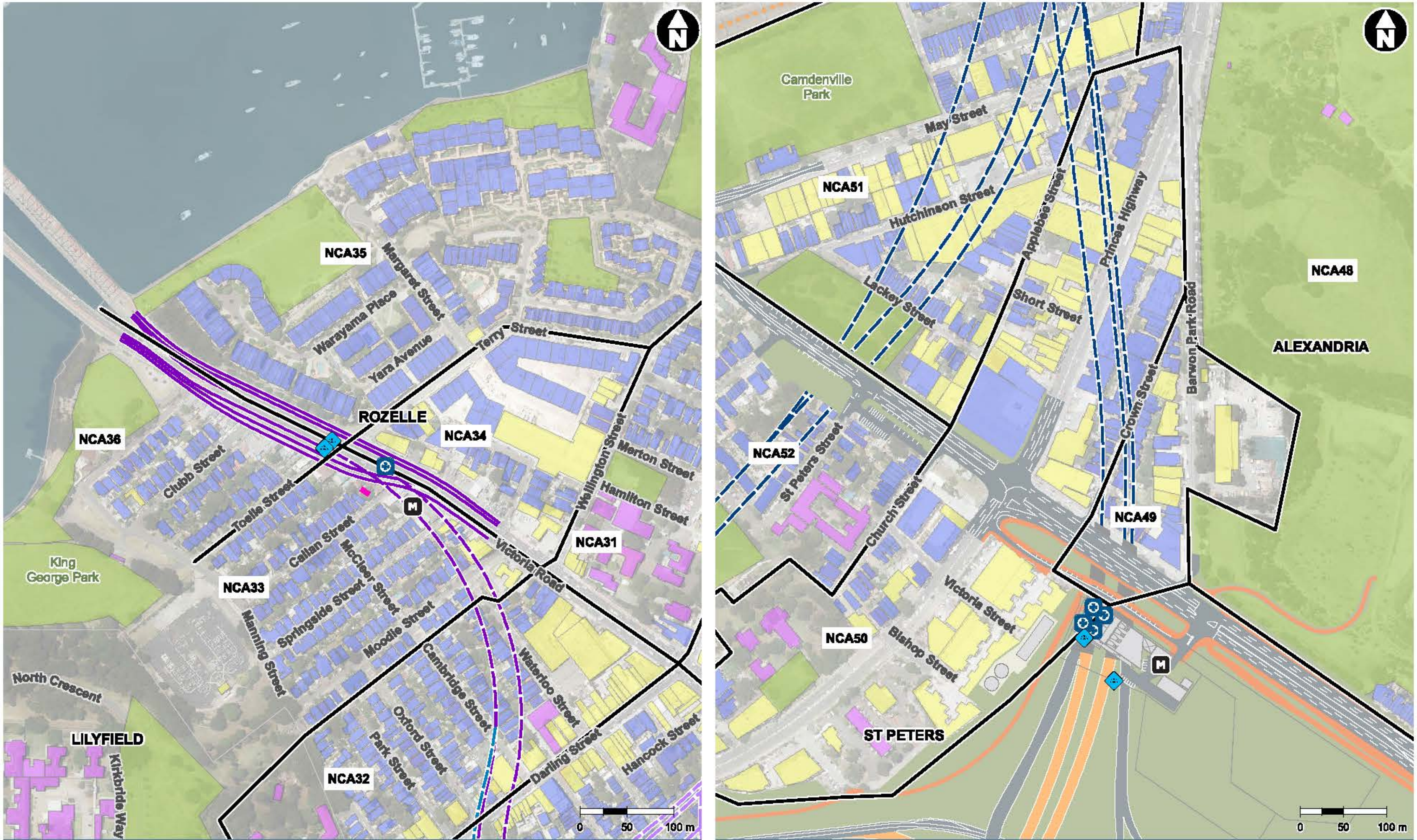


Figure 10-5 Location of fixed facilities - Rozelle



LEGEND Imagery © Nearmap (2017)

New M5
- Building
- Surface road
- Shared path
- Land subject to New M5 conditions of approval
- Proposed future Sydney Gateway connections (non-operational as part of M4-M5 Link)

M4-M5 Link

Mainline
- Surface road
- Tunnel

Iron Cove Link
- Surface road
- Tunnel

Project features
- Tunnel portal
- Motorway operations complex
- Water treatment facility
- Substation

Receivers
- Residential
- Commercial
- Other receivers
- Outdoor area

Figure 10-6 Location of fixed facilities - Iron Cove (left) and St Peters (right)

Fixed facilities noise criteria

The *NSW Industrial Noise Policy* (INP) (NSW EPA 1999) sets two separate noise criteria to meet environmental noise objectives: one to account for intrusive noise and the other to protect the amenity of particular land uses. These criteria are to be met at the most affected boundary of the receiver property. The more stringent of these two criteria usually defines the project specific noise levels. For both amenity and intrusiveness, night-time criteria are typically more stringent than daytime or evening criteria.

In addition to intrusiveness and amenity, the risk of sleep disturbance must also be assessed. Sleep disturbance is assessed in accordance with the screening criterion described in the NSW EPA's online *Application notes – NSW industrial noise policy* and the more detailed review of sleep disturbance contained in the RNP.

INP criteria for intrusive noise

To provide for protection against intrusive noise, the INP states that the L_{Aeq} noise level of the source, measured over a period of 15 minutes, should not be more than 5 dBA above the ambient (background) L_{A90} noise level (or RBL), measured during the daytime, evening and night-time periods at the nearest sensitive receivers.

The intrusiveness criteria are determined from the RBLs in **Figure 10-4** from sensitive receiver locations nearest to the facilities.

INP criteria for amenity

To provide protection against impacts on amenity, the INP specifies suitable maximum L_{Aeq} period noise levels for particular land uses and activities during the daytime, evening and night-time periods.

For this assessment, the existing residences potentially affected by noise from ventilation facilities are considered to be 'urban'. According to the INP, an 'urban' area is characterised by an acoustic environment dominated by 'urban hum' or industrial source noise, through traffic with characteristically heavy and continuous traffic flows during peak hours, located near commercial districts or industrial districts. The relevant INP amenity criteria are presented in **Table 10-10**.

Table 10-10 INP amenity noise levels

Type of receiver	Indicative noise amenity area	Period	Recommended L_{Aeq} noise level (dBA)	
			Acceptable	Recommended maximum
Residence	Urban	Day	60	65
		Evening	50	55
		Night	45	50

According to the INP, where existing transportation L_{Aeq} noise levels exceed the 'acceptable' noise level by 10 dBA, and the existing noise level is unlikely to decrease in future, the noise criteria should be taken to be the existing noise level minus 10 dBA. This approach may be applicable to areas with high traffic noise. For this assessment, however, the more stringent intrusiveness and amenity criteria have been adopted.

INP modifying factor adjustments

Where a noise source contains certain characteristics, such as tonality, impulsiveness, intermittency, irregularity or dominant low-frequency content, there is evidence to suggest that it can cause greater annoyance than other less-obtrusive noise sources at the same level.

To address this additional annoyance, the INP describes modifying factors to be applied when assessing amenity and intrusiveness. The definition of the modifying factors is described in **Table 10-11**.

Table 10-11 INP amenity noise levels

Factor	Assessment/ measurement	When to apply	Correction[1]	Comments
Low Frequency Noise	Measurement of C-weighted and A-weighted level	Measure/assess C- and A-weighted levels over same time period. Correction to be applied if the difference between the two levels is 15 dB or more.	5 dB[2]	C-weighting is designed to be more responsive to low-frequency noise
Tonal noise	One-third octave or narrow band analysis	Level of one-third octave band exceeds the level of the adjacent bands on both sides by: • 5 dB or more if the centre frequency of the band containing the tone is above 400 Hz • 8 dB or more if the centre frequency of the band containing the tone is 160 to 400 Hz inclusive • 15 dB or more if the centre frequency of the band containing the tone is below 160 Hz.	5 dB[2]	Narrow-band frequency analysis may be required to precisely detect occurrence

Note:

1: Corrections to be added to the measured or predicted levels.

2: Where a source emits tonal and low-frequency noise, only one 5 dB correction should be applied if the tone is in the low-frequency range.

10.1.4 Background noise monitoring

Noise monitoring surveys were undertaken between July 2016 and November 2016 at 23 locations within the study area. These surveys were supplemented by 11 noise measurements undertaken previously for the M4 East[5] and New M5[6] projects. Locations, dates and purposes of each background monitoring event are outlined in Table 3-2 of **Appendix J** (Technical working paper: Noise and vibration).

Unattended noise loggers were deployed to continuously measure ambient noise levels in 15-minute sampling periods to determine the existing L_{Aeq}, L_{A90} and other relevant statistical noise levels during the daytime, evening and night-time periods.

The results of the noise monitoring were processed to exclude noise identified as extraneous and/or data affected by adverse weather conditions (such as strong wind or rain) so as to establish representative noise levels in each area.

[5] WestConnex M4 East EIS – Construction and Operational Noise and Vibration Impact Assessment.

[6] WestConnex New M5 EIS – Technical working paper: Noise and vibration.

The measured noise levels within the study area are used to identify the existing levels of environmental noise. These measured noise levels inform the following key aspects of this assessment:

- Validation of the noise model. Due to the large number of noise sensitive receivers considered in this assessment, it is not practicable to measure noise at each receiver. Representative locations suitable for validation of a prediction model are therefore required. Noise loggers installed at these locations are used to quantify existing road traffic noise levels, generally near the roads, to minimise the influence of other ambient noise sources
- Estimation of existing maximum road traffic noise events. Noise loggers at these locations are used to quantify existing maximum noise levels representative of the immediately adjacent receivers
- Determine noise goals for fixed facilities and construction activities at the most exposed locations. Noise loggers at these locations are used to quantify existing background noise levels representative of the immediately adjacent receivers
- Spot checks to assess the suitability of construction noise mitigation measures for receivers located further back than the nearest receivers in key NCAs. Noise loggers at these locations are used to quantify existing background noise levels and establish noise goals, so that impacts can be predicted and compared to those for the most affected receivers.

Operator attended measurements of ambient noise were completed during the noise logging surveys to determine the various noise sources that influence the existing noise environment.

10.1.5 Construction noise prediction methodology

Airborne noise

Modelling

Identifying scenarios

As construction noise emissions are temporary, acceptable noise levels are normally higher during construction than during operations. Construction often requires the use of heavy machinery which can generate high noise levels at nearby buildings and receivers. For some equipment, there is limited opportunity to mitigate the noise and vibration levels in a cost-effective manner and, as a result, the potential impacts should be minimised by using feasible and reasonable management techniques.

At any particular location, the potential impacts can vary greatly depending on factors such as the relative proximity of sensitive receivers, the overall duration of the construction works, the intensity of the noise levels, the time at which the construction works are undertaken, and the character of the noise or vibration emissions.

A number of construction scenarios have been developed to assess the likely impacts associated with the project. These scenarios, shown in **Table 10-12**, are based on construction methodology outlined in **Chapter 6** (Construction work) and have been used to group a number of similar construction activities. These are referenced throughout the assessment of construction impacts (see **section 10.3**). It should be noted that these scenarios may change during detailed design when additional information regarding construction activities and staging is available.

Table 10-12 Summary of work scenarios and associated activities

Scenario	Typical activities
Site establishment and enabling works	• Vegetation clearing • Utility works • Traffic management changes and measures • Install safety and environmental controls • Install site fencing and hoarding • Demolition of buildings and structures and site clearing • Heritage salvage or conservation works (if required) • Establish construction ancillary facilities and access • Supply utilities (including construction power) to construction facilities • Establish temporary pedestrian and cyclist diversions
Tunnelling	• Construct temporary access tunnels • Excavation of mainline tunnels, ramps and associated tunnelled infrastructure • Spoil management and haulage • Finishing works in tunnel and provision of permanent tunnel services • Testing of plant and equipment
Surface earthworks and structures	• Vegetation clearance and topsoil stripping • Excavate new cut and fill areas • Construct dive and cut-and-cover tunnel structures • Construct required retaining structures • Excavate new road levels
Bridge works	• Construct piers and abutments • Construct headstock • Construct bridge deck, slab and girders • Demolish and remove redundant bridges
Drainage	• Construct new pits and pipes • Construct new groundwater drainage system • Connect drainage to existing network • Construct sumps in tunnels as required • Construct water quality basins, constructed wetlands and bioretention facility • Construct drainage channels • Construct spill containment basin • Construct onsite detention tanks • Adjustments to existing drainage infrastructure where impacted • Carry out widening and naturalisation of a section of Whites Creek • Demolish and remove redundant drainage
Pavement	• Lay select layers and base • Lay road pavement surfacing • Construct pavement drainage

Scenario	Typical activities
Operational ancillary facilities	• Install ventilation systems and facilities • Construct water treatment facilities • Construct fire pump rooms and install water tanks • Test and commission plant and equipment • Construction electrical substation to supply permanent power to the project
Finishing works	• Line marking of new road surfaces • Erect directional and other signage and other roadside furniture such as street lighting • Erect toll gantries and other control systems • Construct pedestrian and cyclist paths and walkways • Earthworks at disturbed areas to establish the finished landform • Landscaping works • Site demobilisation and preparation of the site for a permissible future use

Source location

Consistent with the requirements of the ICNG, this assessment provides a 'realistic worst case' noise impact assessment for construction scenarios based on proposed works within a 15-minute period. This is typically associated with works located within the nearest site area to a particular receiver.

In reality at any particular location, the potential construction noise impacts can vary greatly depending on factors including:

- The position of the works within the construction site and distance to the nearest sensitive receiver
- The overall duration of the works
- The intensity of the noise levels
- The time at which the works are undertaken
- The number of concurrent activities underway at the same time
- The character of the noise.

Noise levels at sensitive receivers can be significantly lower than the worst case scenario when the construction works move to a more distant location within a works area. This concept is shown in **Figure 10-7**.

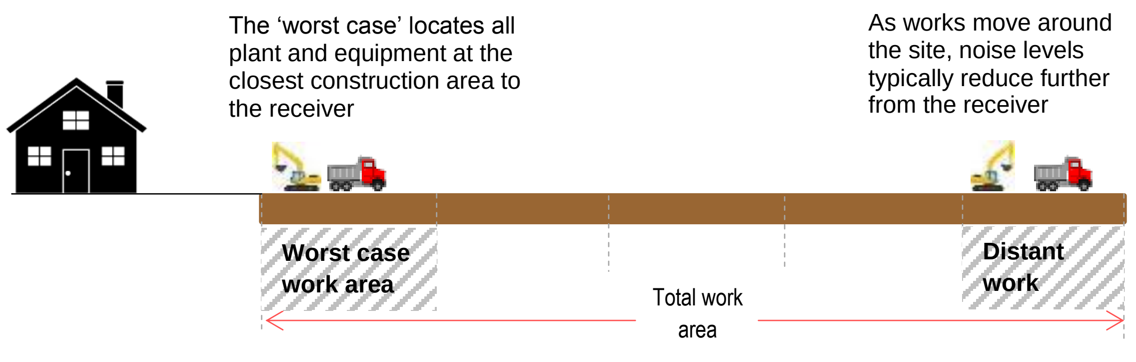


Figure 10-7 Conceptual illustration of work areas

Calculation type

To quantify noise levels from construction activities, a computer noise prediction model based on the ISO 9613 algorithms was developed, using SoundPLAN software. Local terrain, receiver buildings and structures were digitised in the noise model to develop a three-dimensional representation of the construction sites and surrounding environment. In accordance with the Roads and Maritime CNVG, noise levels are predicted for all receivers in the catchment areas surrounding the works.

Working hours

The majority of above ground construction works would be undertaken during standard construction hours:

- 7.00 am and 6.00 pm Monday to Friday
- 8.00 am and 1.00 pm on Saturdays.

There would generally be no above ground construction works on Sundays or public holidays, with the exception of those activities required to be undertaken outside of standard construction hours (outlined below).

Proposed construction hours are summarised in **Table 10-13**. Construction activities required for the project would be managed in six broad categories.

Table 10-13 Summary of anticipated out-of-hours works

Component	Construction hours	Comments or exception
Tunnelling, tunnelling support and underground construction activities		
Tunnelling and underground excavation	24 hours a day, up to seven days a week.	• Tunnelling and activities that support tunnelling works may need to occur 24 hours a day, up to seven days a week
Underground construction and tunnel fitout	24 hours a day, up to seven days a week.	• Activities that support underground construction and tunnel fitout may need to occur 24 hours a day, up to seven days a week • Deliveries for underground construction and tunnel fitout may need to occur 24 hours a day, up to seven days a week (see **Table 10-14**)
Surface construction activities		
Demolition and surface construction activities	7.00 am to 6.00 pm on weekdays, 8.00 am to 1.00 pm on Saturdays, no works on Sundays or public holidays.	• Aboveground work supporting underground construction activities (eg concrete pumping, truck loading) are expected to be required 24 hours a day, up to seven days a week where noise mitigation is in place • Non-disruptive preparatory work, repairs or maintenance may be carried out outside standard daytime construction hours • Activities requiring the temporary possession of roads or to accommodate road network requirements may need to be carried out outside the standard daytime construction hours during periods of low demand to minimise safety impacts and inconvenience to commuters
Construction traffic for material supply and spoil handling		
Construction traffic for material supply to, and spoil handling from, tunnelling and underground excavation	24 hours a day, up to seven days a week.	• Spoil handling from the Darley Road civil and tunnel site (C4) would only occur during standard construction hours. No spoil would be removed from this site on Sundays or public holidays

Component	Construction hours	Comments or exception
Blasting and rock breaking		
Blasting	Between 9.00 am and 5.00 pm, Mondays to Fridays and 9.00 am to 1.00 pm on Saturdays	• Blasting would occur up to six days a week (Monday to Saturday). Blasts would be limited to one detonation in any one day per receiver group, unless otherwise agreed by the Secretary or the NSW EPA
Rock breaking (with potential for impulsive or tonal noise impact at a sensitive receiver)	Between 8.00 am and 6.00 pm Monday to Friday and between 8.00 am and 1.00 pm Saturdays, with respite periods.	• Respite periods would be scheduled to minimise the frequency and duration of extended rock breaking activities with potential for impulsive or tonal noise emissions • Rock breaking and other high impact noise activities could also occur outside these standard day time construction hours if authorised by an environmental protection licence
Minor or EPL-authorised activities		
Minor activities	At any time	• Minor activities would include activities that do not lead to an exceedance of the applicable noise management level at an affected receiver
Activities authorised by an Environment Protection Licence	As specified in the environment protection licence.	• Construction activities would be managed as required by the Environment Protection Licence
Emergency or directed activities		
Emergency or directed activities	At any time	• Activities would be carried out as directed by a relevant authority • Activities would be carried out if required to prevent an imminent loss of life or environmental damage

A summary of the proposed construction work hours at each construction ancillary facility is provided in **Table 10-14**.

Table 10-14 Construction work hours at construction ancillary facilities

Construction ancillary facility	Type of construction activity	Construction work hours
Wattle Street civil and tunnel site (C1a)	Tunnelling and spoil handling	• 24 hours a day, seven days a week
	Civil construction[1]	• 7.00 am to 6.00 pm Monday to Friday • 8.00 am to 1.00 pm Saturdays
Haberfield civil and tunnel site (C2a)	Tunnelling and spoil handling	• 24 hours a day, seven days a week
	Civil construction[1]	• 7.00 am to 6.00 pm Monday to Friday • 8.00 am to 1.00 pm Saturdays
Northcote Street civil site (C3a)	Civil construction[1]	• 7.00 am to 6.00 pm Monday to Friday • 8.00 am to 1.00 pm Saturdays
	Construction workforce parking	• 24 hours a day, seven days a week
Parramatta Road	Tunnelling and spoil handling	• 24 hours a day, seven days a week

Construction ancillary facility	Type of construction activity	Construction work hours
West civil and tunnel site (C1b)	Civil construction[1]	• 7.00 am to 6.00 pm Monday to Friday • 8.00 am to 1.00 pm Saturdays
Haberfield civil site (C2b)	Civil construction[1]	• 7.00 am to 6.00 pm Monday to Friday • 8.00 am to 1.00 pm Saturdays
Parramatta Road East civil site (C3b)	Civil construction[1]	• 7.00 am to 6.00 pm Monday to Friday • 8.00 am to 1.00 pm Saturdays
	Construction workforce parking	• 24 hours a day, seven days a week
Darley Road civil and tunnel site (C4)	Tunnelling and spoil handling[2]	• 24 hours a day, seven days a week
	Civil construction[1]	• 7.00 am to 6.00 pm Monday to Friday • 8.00 am to 1.00 pm Saturdays
Rozelle civil and tunnel site (C5)	Tunnelling and spoil handling	• 24 hours a day, seven days a week
	Civil construction[1]	• 7.00 am to 6.00 pm Monday to Friday • 8.00 am to 1.00 pm Saturdays
The Crescent civil site (C6)	Civil construction[1]	• 7.00 am to 6.00 pm Monday to Friday • 8.00 am to 1.00 pm Saturdays
Victoria Road civil site (C7)	Civil construction[1]	• 7.00 am to 6.00 pm Monday to Friday • 8.00 am to 1.00 pm Saturdays
Iron Cove Link civil site (C8)	Civil construction[1]	• 7.00 am to 6.00 pm Monday to Friday • 8.00 am to 1.00 pm Saturdays
Pyrmont Bridge Road tunnel site (C9)	Tunnelling and spoil handling	• 24 hours a day, seven days a week
	Civil construction[1]	• 7.00 am to 6.00 pm Monday to Friday • 8.00 am to 1.00 pm Saturdays
Campbell Road civil and tunnel site (C10)	Tunnelling and spoil handling	• 24 hours a day, seven days a week
	Civil construction[1]	• 7.00 am to 6.00 pm Monday to Friday • 8.00 am to 1.00 pm Saturdays

Note

1: Some works outside of standard construction hours may be required.

2: Spoil haulage from the Darley Road civil and tunnel site (C4) would occur between 7.00 am and 6.00 pm Monday to Friday and 8.00 am and 1.00 pm on Saturdays.

Where spoil haulage is carried out outside of the standard daytime construction hours, reasonable and feasible work practices and mitigation measures, consistent with the requirements of the ICNG (DECCW 2009a), would be implemented to manage potential noise impacts, especially late night vehicle movements past sensitive receptors.

Impact duration

The overall effect of a project and the likelihood of adverse community reaction depend on both the level of noise and the duration of the works. While the assessment has been based on realistic worst case noise predictions, noise levels would likely be less than the worst case level for significant periods of time.

For works within an area, noise levels would be greater when works are close to a receiver location and decrease when the work is further away. For works progressing along an alignment, noise levels would typically increase as the works move towards the receiver and decrease at a receiver as works move away over time. This effect must be taken into account when considering the duration of activities and impacts.

Actual impact durations may vary depending on site conditions and finalised methodology and would be considered in the Construction Noise and Vibration Management Plan (CNVMP) developed for the project.

Ground-borne noise

Ground-borne noise impacts at the various sensitive receivers above the proposed tunnelling works have been predicted using a three-dimensional model which uses elevation data for all receivers in the study area, together with the horizontal and vertical information supplied for the underground section of the motorway alignment.

Figure 10-8 presents indicative ground-borne noise levels for roadheaders as measured on other Sydney tunnelling projects. As the figure demonstrates, ground-borne noise levels reduce as the distance between plant and the receiver increases.

The ground-borne noise model calculates the three-dimensional slant distance from the tunnel crown to each sensitive receiver situated above the alignment, where tunnelling works are proposed.

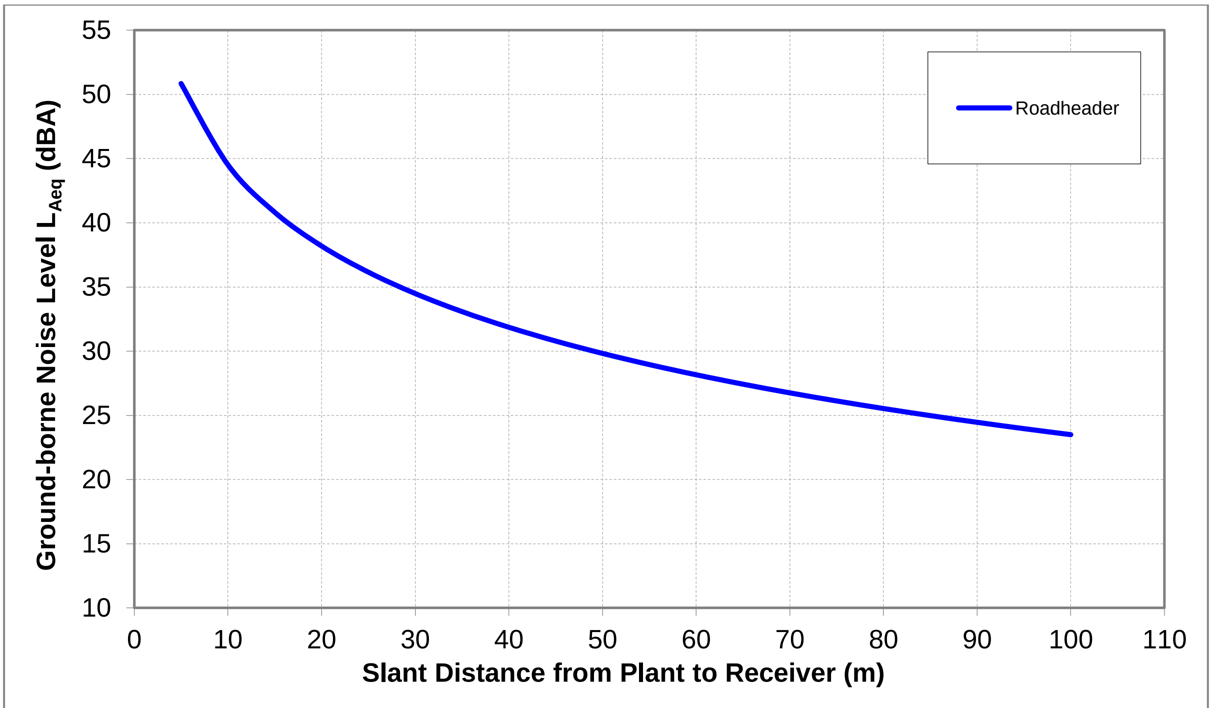


Figure 10-8 Indicative ground-borne noise levels from roadheaders

Source: Australian Acoustical Society Technical Meeting – Tunnelling Noise and Vibration Management (Wilkinson Murray 2003).

Vibration

Propagation of vibration emitted from a source is site specific with the level of vibration potentially experienced at a receiver dependent upon the vibration energy generated by the source, the predominant frequencies of vibration, the localised geotechnical conditions and the interaction of structures and features that can dampen vibration.

While the ground dampening characteristics may vary between the ground types likely to be found in the study area (understood to be shale and sandstone), this is expected to have negligible effect on the vibration predicted at the relatively short distances to the nearest receivers. It should be noted that the source frequency can change with different ground types and local site conditions should be considered further during the detailed design.

The recommended minimum working distances for construction plant in **Table 10-15** are referenced from the CNVG and DIN 4150.

Consistent with BS 7385 and *Assessing Vibration: A Technical Guideline* (DEC 2006a), the recommendations are for the practical management of potential vibration to minimise the likelihood of cosmetic damage to buildings and disturbance or annoyance in humans. The human comfort (response) minimum working distances are conservative, developed with reference to the more stringent objectives for continuous vibration for typical residential building construction.

Table 10-15 Recommended minimum working distances for vibration intensive plant

Plant item	Rating/description	Minimum working distance Cosmetic damage			Human response[1]
		Residential and light commercial[1]	Group 2 (typical)[2]	Group 3 (structurally unsound)[2]	
Vibratory roller	< 50 kN (Typically 1-2t	5 m	7 m	11 m	15 m to 20 m
	< 100 kN (Typically 2-4t)	6 m	8 m	13 m	20 m
	< 200 kN (Typically 4-6t)	12 m	16 m	15 m	40 m
	< 300 kN (Typically 7-13t)	15 m	20 m	31 m	100 m
	> 300 kN (Typically 13-18t)	20 m	26 m	40 m	100 m
	> 300 kN (Typically > 18t)	25 m	33 m	50 m	100 m
Small hydraulic hammer	300 kg – 5 to 12t excavator	2 m	3 m	5 m	7 m
Medium hydraulic hammer	900 kg – 12 to 18t excavator	7 m	10 m	15 m	23 m
Large hydraulic hammer	1600 kg – 18 to 34t excavator	22 m	29 m	44 m	73 m
Vibratory pile driver	Sheet piles	2 m to 20 m	3 m to 26 m[4]	5 m to 40 m[4]	20 m to 100 m[4]
Pile boring	≤ 800 mm	2 m (nominal)	3 m	5 m	4 m
Jackhammer	Hand held	1 m (nominal)	2 m	3 m	2 m
Roadheader[3]	Tunnelling	2 m	3 m	5 m	7 m

Note

1: Criteria referenced from Roads and Maritime CNVG

2: Criteria referenced from DIN 4150

3: Measurement from SLR Database

4: Corresponds to the higher guideline range

10.1.6 Operational noise prediction methodology

Road traffic

Study area

The principles under which the assessment boundary has been defined are as follows:

- A 600 metre boundary width either side of the main project road alignment (as recommended in the RNP)
- A boundary length up to the physical extent of the works. While not required under the NCG, due to the relatively small gap between the Rozelle interchange area and the Iron Cove Link, the length of the boundary areas have been extended in order to include receivers on Victoria Road located between the two assessment areas.

The adjacent collector roads, sub-arterial and arterial roads were modelled to identify the contributions from project and non-project existing roads separately. Roads where design or engineering changes are proposed have generally been considered as project roads. The roads modelled as project roads are listed in **Table 10-16**.

Table 10-16 Project roads included in the operational noise model

Road Name	Section	Comment
Victoria Road	Iron Cove – Between Iron Cove Bridge and Wellington Street	Alignment change and widening
Victoria Road	Between Robert Street and City West Link intersection	Alignment change and widening
City West Link	Between Catherine Street and Anzac Bridge	Alignment change and additional connections to new ramps
The Crescent	Between Johnston Street and City West Link intersection	Alignment change and widening

Roads where no significant design or engineering changes are proposed have been considered as non-project existing roads. Significant design or engineering changes do not include normal tie-in works (eg line marking) where these intersect with a project road. The study boundary and the roads modelled as non-project existing roads are shown on the road classification maps in Annexure D of **Appendix J** (Technical working paper: Noise and vibration).

Modelling

<u>Ground, roads and buildings</u>

The noise model was developed from a combination of a survey of road corridor ground topography, aerial photography and Light Detection and Ranging (LIDAR) information.

The predictions for the No Build scenarios make use of the existing road alignment geometry, with existing noise barriers and features within the road corridor being included in this scenario.

The Build scenarios make use of the proposed design of the project, which includes proposed modifications to the access ramps, widening works of the various roads, new tunnel portals and changes to existing cuttings/embankments. An example screenshot from the Build noise model scenario is provided in **Figure 10-9**.

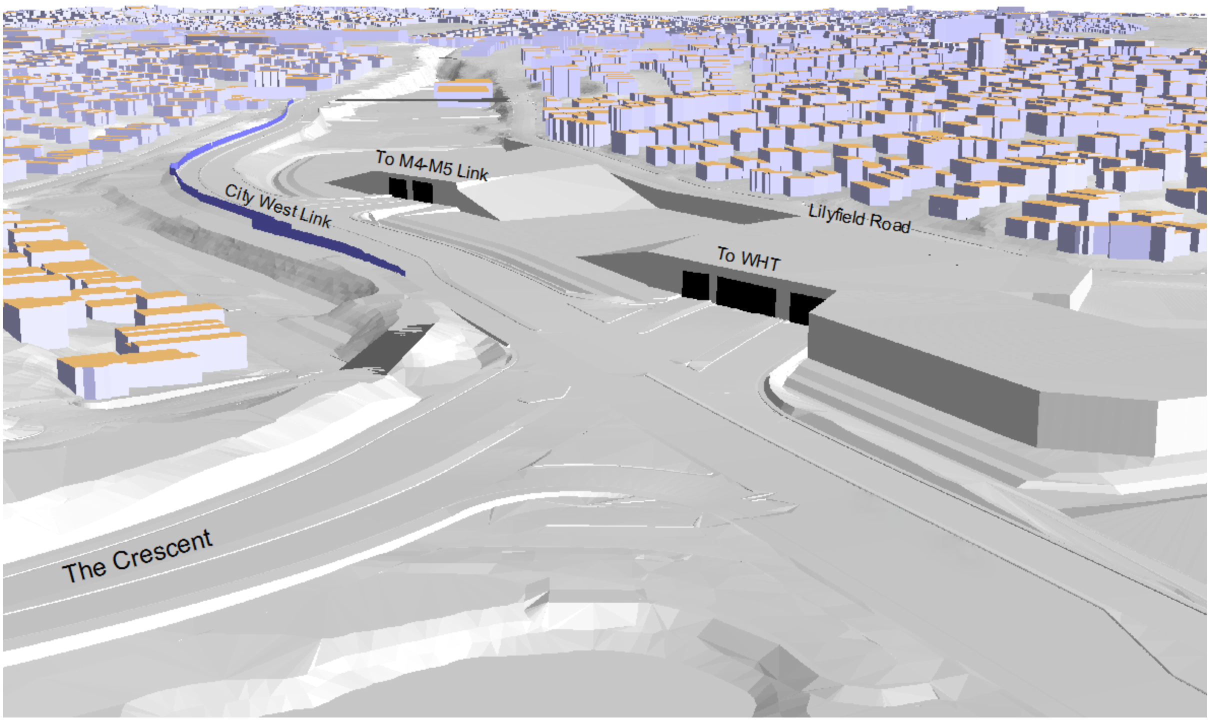


Figure 10-9 Example noise model screenshot. View looking west towards the proposed tunnel portals, with City West Link to the left of the image

Traffic

The traffic data used in this assessment incorporates population and employment projections, and growth in demand. WestConnex has a number of component projects, four of which are approved and either under construction or open to traffic (M4 Widening, M4 East, King Georges Road Interchange Upgrade and New M5) and the M4-M5 Link. Other non-WestConnex projects (proposed future Western Harbour Tunnel and Beaches Link, Sydney Gateway and the F6 Extension) are currently in the early planning stage and not yet approved. Most notable of these projects with regard to WestConnex M4-M5 Link is the construction of future access at the Rozelle interchange for the proposed future Western Harbour Tunnel.

The traffic volume scenarios relating to these key projects are described below and in **Table 10-17**:

- **Do Nothing** (ie without the project or other approved WestConnex stages): This scenario represents the existing road network in the study area in the absence of the project. The traffic data for this scenario does not include any WestConnex component projects or the interfacing projects
- **Do Minimum** (ie without the project): This scenario represents the existing road network in the study area in the absence of the project. The traffic data includes the approved WestConnex component projects
- **Do Something** (ie with the project): This scenario assumes that the project goes ahead and includes the proposed project design. The traffic data includes the M4-M5 Link and the approved WestConnex component projects
- **Do Something Plus** (ie with the project and other projects that interface, overlap or have potentially concurrent impacts): This scenario assumes that the project goes ahead and includes the proposed project design. The traffic data includes the M4-M5 Link and the approved WestConnex component projects, together with other major interfacing projects (the proposed future Western Harbour Tunnel and Beaches Link, proposed future Sydney Gateway and proposed future F6 Extension).

Table 10-17 Additional traffic data scenarios and interfacing projects

Assessment scenario	Traffic data scenario	WCX M4 Widening	WCX M4 East	WCX New M5	WCX M4 M5 Link	King Georges Road Interchange Upgrade	Sydney Gateway	Western Harbour Tunnel[1]	Beaches Link	F6 Extension
2023										
No Build	Do Nothing									
	Do Minimum	✓	✓	✓		✓				
Build	Do Something	✓	✓	✓	✓	✓				
	Do Something Plus	✓	✓	✓	✓	✓	✓	✓		
2033										
No Build	Do Nothing									
	Do Minimum	✓	✓	✓		✓				
Build	Do Something	✓	✓	✓	✓	✓				
	Do Something Plus	✓	✓	✓	✓	✓	✓	✓	✓	✓

Note :

1: The operation of the proposed future Western Harbour Tunnel ramps (as part of the Western Harbour Tunnel and Beaches Link project) at Rozelle are not part of this noise and vibration assessment. Operational impacts would be the subject of future environmental assessment and approval for that project. Construction of the Western Harbour Tunnel ramps are however included and assessed in the construction impacts section of this report.

Due to the ongoing growth within the Sydney road network, there is potential for increases in noise in areas within the M4-M5 Link study area due to other nearby key projects. For this reason, assessment of the cumulative '*Do Something Cumulative'* scenario is considered in addition to the '*Do Something'* scenario. Due to the short-term nature of the '*Do Minimum'* interim scenario, the assessment of project impacts and cumulative impacts uses the '*Do Nothing'* traffic as the No Build baseline for the assessment.

Traffic data for the Build and No Build assessment scenarios for both project opening (2023) and the future design year (2033) references the outputs of the strategic traffic model (WestConnex Road Traffic Model v2.3) used in the operational traffic assessment (refer to **Appendix H** (Technical working paper: Traffic and transport)).

Calculation type

Noise modelling of the study area was carried out using the *Calculation of Road Traffic Noise* (CORTN) algorithms (UK Department of Transport 1988). This modelling allows for traffic volume and mix, type of road surface, vehicle speed, road gradient, reflections off building surfaces, ground absorption and shielding from ground topography and physical noise barriers. The algorithm output of CORTN (designed as an L_{A10} predictor) has been modified to calculate the relevant daytime $L_{Aeq(15\text{-}hour)}$ and night-time $L_{Aeq(9\text{-}hour)}$ road traffic noise emission levels at noise sensitive receivers, as required by the RNP.

The CORTN traffic source line as modelled in SoundPLAN has also been modified to incorporate four effective noise sources (and associated heights) for the centre line of each carriageway, which is important in determining the noise propagation where barriers are present. The four effective noise sources comprise a *'CAR*' source with height of 0.5 metres above pavement and three *'TRUCK*' sources at three separate heights representing the noise emission from truck tyres (0.5 metres), truck engines (1.5 metres) and truck exhausts (3.6 metres).

The SoundPLAN noise models were set up to calculate noise levels at receiver points for all façades and all potentially affected floors of each noise sensitive receiver identified within the study area. All floors of multi-storey receiver buildings have been included in the assessment and evaluated for mitigation against the NMG triggers. The assessment counts each floor and estimates the number of separate dwellings on each floor as a separate receiver. The precise number of individual receivers would be confirmed during detailed design.

Tunnel portals

The assessment utilises the SoundPLAN calculation algorithm for portal noise emissions. This considers traffic flow, length of tunnel and portal opening.

Noise model validation

Noise model validation was undertaken by comparing measured noise levels to predicted noise levels for the existing roads to confirm that noise prediction can be made within the industry accepted modelling tolerance of ± 2 dBA.

The purpose of model validation is to demonstrate that the noise model produced for the existing situation is an accurate representation of the real world within the limitations of the prediction algorithm and to identify errors associated with geospatial data and modelling approach. This is to provide greater confidence in the recommendations and assessment completed for the proposed situation which would be validated post construction.

The noise model validation is summarised in **Table 10-18**. The model over predicts for all locations with the exception of the 198 Victoria Road location. In this case the under predictions are between 1.2 and 1.7 dBA. This site is analogous to the new Iron Cove Link portal locations in Rozelle. Despite this, these results suggest that the noise model predictions are within the normally accepted tolerances at all logger locations with the exceptions as noted. Application of calibration factors to the model is therefore not required.

Table 10-18 Model validation summary

Noise monitoring location		Noise level (dBA L_{Aeq} period)					
		Measured		Predicted		Difference, predicted minus measured	
ID	Address	Daytime	Night-time	Daytime	Night-time	Daytime	Night-time
R.01	Hutcheson Street, Rozelle	64.1	57.6	64.8	58.6	0.7	1.0
R.02	22 Lilyfield Road, Rozelle	57.2	54.0	58.0	54.5	0.8	0.5
R.03	69 Victoria Road, Rozelle	70.5	67.9	71.7	67.8	1.2	-0.1
R.04	27 Victoria Road, Rozelle	71.0	67.3	71.9	67.6	0.9	0.3
R.05	Rozelle Rail Yards – East	70.0	67.2	71.6	68.5	1.6	1.3
R.06	Rozelle Rail Yards – West	62.9	60.0	65.2	62.1	2.3[1]	2.1[1]
R.07	The Crescent – North (24 Chapman Road, Annandale)	65.1	59.4	66.7	61.3	1.6	1.9
C1	28 Warayama Place, Rozelle	72.5	68.5	73.4	68.5	0.59	0.0
C2	198 Victoria Road	73.5	68.9	71.8	67.7	-1.7	-1.2
R.08	279 Johnston Street, Annandale – West	63.2	58.3	64.7	58.6	1.5	0.3
R.09	279 Johnston Street, Annandale – East	60.9	54.9	61.5	56.1	0.6	1.2
R.11[2]	Brenan Street, Rozelle	61.5	-	63.3	-	1.8	-

Noise monitoring location		Noise level (dBA L_{Aeq} period)					
		Measured		Predicted		Difference, predicted minus measured	
ID	Address	Daytime	Night-time	Daytime	Night-time	Daytime	Night-time
					Median	1.1	0.5

Note:

1: Marginal over-prediction outside the normal tolerance (±2 dB) due to localised shielding.

2: Short-term (three-hour daytime) attended monitoring was conducted at this location.

Identifying impacts

The predicted noise levels at all facades of the receiver are compared to the corresponding assessment criteria. An analysis against the NMG mitigation triggers was undertaken to determine the extent of project impacts. The comparison (Build minus No Build) for 2023 would indicate the potential for any noise issues at the commencement of the project, such as community reaction to significant changes in noise levels. The comparison for 2033 would indicate the potential for noise impacts in the longer term once the project is well established and the surrounding road network has stabilised, as well as the change in traffic flows after implementation of the full WestConnex program of works and other interfacing projects (such as the proposed future Western Harbour Tunnel and Beaches Link, proposed future Sydney Gateway and proposed future F6 Extension).

The noise impacts without mitigation have been identified with existing noise barriers in place and the reference dense graded asphalt (DGA) pavement for all new and modified sections of road. The retained noise barriers are located adjacent to the eastbound carriageway on the northern side of Victoria Road (approximately 2.5 metres in height) and adjacent to the westbound carriageway on the southern side of City West Link (approximately three metres in height). A small section of the eastern end of exiting City West Link noise barrier, near to the intersection with The Crescent, would be required to be removed to allow for the new intersection layout. The retained barriers are shown in **Table 10-10**.

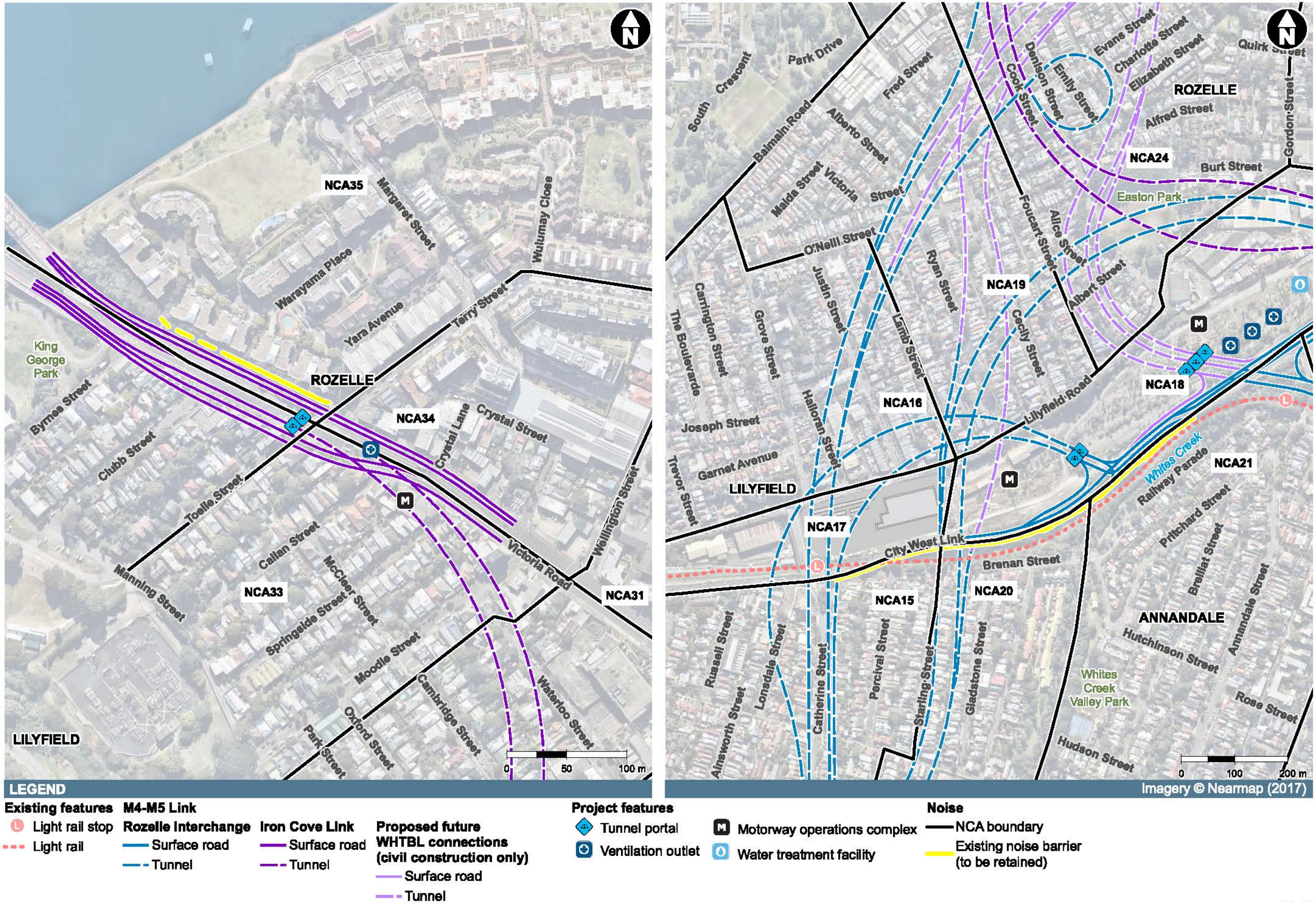


Figure 10-10 Retained existing noise barriers

Predicted noise levels at receivers that are above the NCG controlling criteria do not necessarily qualify for additional noise mitigation. A consideration of reasonableness is used to decide which receivers are eligible for additional noise mitigation measures.

Identifying additional mitigation

Low noise pavement such as porous asphalt may be effective at reducing noise at the source. However, the choice of road pavement surfaces and textures must meet a number of criteria including skid resistance, water shedding, structural integrity and design life as well as potential noise generating characteristics. The road pavement surface's noise performance throughout its design life and the need to maintain that performance by cleaning or replacing the pavement are also important considerations.

The noise assessment considers the use of quieter noise pavement in the form of DGA across the extent of the project. Other pavement surfaces to further reduce road traffic noise at the source would be investigated during detailed design taking into account whole-of-life engineering considerations and the overall social, economic and environmental effects.

In sensitive receiver locations where exceedances of the operational noise criteria are predicted and where four or more eligible properties are found to be closely spaced, new or increased height noise barriers have been considered. Where the number of exceeding receivers is found to be three or less, the specification of noise barriers is not considered to be a reasonable or cost-effective approach and architectural treatment of these receivers would be considered. This approach is consistent with the NMG.

Identifying noise barriers

Noise barriers are typically most efficient when receivers are located at ground floor level. As the height above ground of a receiver increases, the noise reduction effect of the barrier usually is diminished. It is not uncommon for upper floors of multi-storey buildings to see little to no reduction in noise levels from nearby barriers because of their elevation.

The process of determining reasonable barrier heights would therefore generally be less likely to result in noise barriers being considered a reasonable option if upper floors formed part of the analysis. With consideration of this, the assessment and optimisation of noise barriers for the project makes use of noise predictions at ground and first floor only, with architectural treatments to be investigated for higher floors.

The NMG approach identifies the number of receivers (noting that a two storey residence is counted as two receivers) that receive at-residence treatment versus barrier height to establish an initial design height and then conducts a weighted analysis to find the optimal mix of barrier height and at-property treatments. This prioritises at-road mitigation and minimises the use of at-property treatments, as per the intent of the RNP.

In certain situations, the requirements for a barrier cannot always be met due to urban design and amenity considerations. In this case further feasible and reasonable considerations are undertaken with guidance from Roads and Maritime.

Where an existing barrier is relocated as part of the works, the height of the top of the replaced section is maintained at least as high as the top of the original barrier.

Identifying potential at-property treatments

At this stage in the assessment, the identification of at-property treatments is indicative only, as building age, state of repair and heritage status, as well as Roads and Maritime's At-receiver Noise Treatment Guideline must be taken into account when proposing treatment at the detailed design stage.

At-receiver traffic noise mitigation measures may replace or supplement at-road mitigation, only in the following circumstances, subject to a reasonable and feasible assessment:

- Isolated single residences or isolated groups of closely spaced residences as defined in the NMG

- Where the affected community expresses a preference for at-receiver treatment and the cost is less than a combination of a barrier and at-receiver treatment
- Where noise barriers or quieter pavements alone do not achieve the level of noise mitigation required
- Where the only applicable noise criteria are internal (eg places of worship, hospitals or schools and child care facilities where play areas meet external criteria)
- Where other noise mitigation measures have been shown not to be feasible or reasonable.

These treatments are generally limited to acoustic treatment of the building elements (doors, windows, vents, etc) or courtyard fences where they reduce noise to habitable rooms. The installation of courtyard fences close to the dwelling may also provide some mitigation for outdoor living spaces. The overall goal of the architectural treatment is to provide similar acoustic amenity and internal noise levels to those experienced within a receiver where the external noise criteria have been met.

In most instances, assuming brick construction and standard glazing, this goal equates to internal noise levels that are approximately 20 dBA less than the external noise criteria with windows closed. In practice there would be some variation in reduction due to the design of the existing building and other limitations such as building condition. A 20 dBA goal results in internal noise levels that are consistent with other guidelines. These guidelines include the NSW State Environmental Planning Policy (Infrastructure) 2007 and AS 2107. The 20 dBA goal also provides protection against a large increase in internal noise level in accordance with the NCG and RNP relative increase criterion.

Building element treatments are more effective when they are applied to masonry structures than lightly clad timber frame structures. The architectural treatments provided by Roads and Maritime typically include:

- Fresh air ventilation systems that meet the Building Code of Australia requirements with the windows and doors closed
- Upgraded windows and glazing and solid core doors on the exposed façades of the substantial structures (eg masonry or insulated weather board cladding with sealed underfloor). These techniques would be unlikely to produce any noticeable benefit for light frame structures with no acoustic insulation in the walls
- Upgrading window or door seals and appropriately treating sub-floor ventilation
- The sealing of wall vents and underfloor below bearers or eaves.

Alternative at-receiver treatments are the installation of courtyard fences that break the line of sight between the affected façade window and the road where they are feasible and reasonable and are preferred by the owner.

During the installation phase of the acoustic treatments, landowners would be consulted for all receivers identified as eligible for consideration of at-property treatment. This phase also identifies the location of internal habitable areas for each receiver and subsequently the most appropriate form of at-property treatment to be installed.

10.1.7 Operational noise prediction methodology for fixed facilities

Ventilation facilities

Fresh air supply to the tunnels and ventilation exhaust would be managed by the ventilation facilities. These would generally consist of jet fans with baffle-type attenuators located within the ventilation building and ventilation outlets. It is assumed that the ventilation buildings (both intake and outlet buildings) would be constructed such that the breakout noise (ie the noise transmitted externally through the building structure itself) is at least 10 dBA below the noise emanating from the ventilation outlet at the nearest most affected receiver location. The ventilation facilities are assumed to be operational 24 hours a day, seven days a week. The assessment of these facilities assumes that appropriate attenuators are installed.

Tunnel jet fans

The tunnel jet fans are typically located at a distance of at least 100 metres from the tunnel portals. For the purpose of this assessment, calculations assume a conservative distance of 50 metres from the nearest jet fans to the various tunnel portals. Four jet fans have been included in the calculation for each assessment location and are assumed to be operational 24 hours per day, seven days per week.

Substations

At this stage of the assessment, the specifications for the substations are not yet finalised. For the purpose of this assessment, each substation has been assumed to house four 3.15 megavolt-amps (MVA) transformers.

Water treatment plants

At this stage of the assessment, the specifications for the water treatment plants are not yet finalised. For the purpose of this assessment, indicative sound power level data have been used.

Predicted modifying factors

Given the indicative nature of the assessment, it is recommended that all finalised plant items are assessed during detailed design with consideration of the INP modifying factors. Where modifying factors are found to be applicable they should be added to the assessment and compliance with the INP criteria checked at all receivers.

10.1.8 Construction and operational noise mitigation

Construction

The CNVG outlines a number of standard mitigation measures for construction activities likely to result in adverse noise or vibration impact.

Where identified in the impact assessment, particular effort should be directed towards the implementation of all feasible and reasonable noise mitigation and management strategies as per the standard mitigation measures detailed in the ICNG and CNVG noting that, additional site specific measures may also be recommended. Standard mitigation measures that may be considered include:

- Management measures
  - Implementation of any project specific mitigation measures required
  - Implement community consultation or notification
  - Site inductions
  - Behavioural practices
  - Verification
  - Attended vibration measurements
  - Building condition survey
  - Update Environmental Management Plans
- Source controls
  - Construction hours and scheduling
  - Construction respite periods during normal hours and out of hours work
  - Equipment selection
  - Use and siting of plant
  - Plan construction sites and activities to minimise noise and vibration
  - Reduced equipment power

  - Non-tonal and ambient sensitive reversing alarms
  - Minimise disturbance arising from delivery of goods to construction sites.
  - Blasting regime
  - Limiting the use of engine compression brakes
- Path controls
  - Shield stationary noise sources such as pumps, compressors and fans
  - Shield sensitive receivers from noisy activities
- Receptor controls
  - Structural surveys and vibration monitoring.

Operation

In many instances, impacts from construction noise and vibration are unavoidable where works are undertaken close to surrounding receivers. As such, the CNVG includes a list of additional mitigation measures that aim to manage the potential noise and vibration impacts.

The objective of these additional noise mitigation measures is to engage, inform and provide project-specific messages to the community, recognising that advanced warning of potential disruptions can assist in reducing the impact. Additional mitigation measures that may be considered include:

- Notification (letterbox drop or equivalent)
- Specific notifications
- Phone calls
- Individual briefings
- Respite offers
- Respite periods
- Alternative accommodation
- Duration respite
- Verification.

10.1.9 Key assumptions

The key assumptions for each individual component of the noise and vibration assessment are:

- Potential noise barriers – any recommended noise barriers are subject to further considerations during detailed design such as construction limitations, design refinements, overshadowing, urban design, community preference and impacts on local connectivity
- Internal NCG noise criteria have been converted to external noise criteria for the purposes of assessment with external noise level predictions. Where detailed information relating to building construction is not available, the NSW EPA recommends a 10 dBA factor to convert internal to external noise levels on the basis that façades with windows open typically provide approximately 10 dBA attenuation from inside to outside (refer to guidance contained in the ICNG and INP). For non-residential receivers this assumption may be overly conservative as the façade area to window ratios are often larger when compared to residential receivers
- During the installation phase of the acoustic treatments, ownership details would be obtained for all receivers identified as eligible for consideration of at-property treatment and the final number and layout of individual eligible dwellings would be confirmed
- All floors of multi-storey receiver buildings have been included in the assessment and evaluated against the appropriate operational road traffic noise criteria. The assessment counts each floor and estimates the number of separate dwellings (apartments) on each floor, each of which is

counted as a separate receiver; however internal floor plans have not been considered (eg to identify habitable rooms, or to derive an accurate count of individual dwellings within the block)

- Operational ground-borne noise and vibration due to the movement of cars and trucks inside the tunnel is considered to be negligible and would not be expected to cause any noticeable impact at the surface level properties. As such, this noise and vibration source has not been considered further in this report. Ground-borne noise from the construction of the M4-M5 link tunnels has been assessed and is presented in the **section 10.3**.

10.2 Existing environment

This section outlines the noise and vibration receivers in the study area and groups these by noise catchment areas, for the purposes of the assessment. Existing noise levels are also provided for these noise catchment areas.

10.2.1 Noise and vibration sensitive receivers

The sensitivity of receivers to noise and vibration is dependent upon the occupancy type or use of outdoor space/recreational area and the nature of the activities performed. Sensitivity to noise is a subjective response that varies for different individuals and can depend on the existing noise environment.

For the purpose of this assessment, receivers potentially sensitive to noise and vibration have been categorised as:

- Residential dwellings
- Commercial and industrial properties
- Other – Education institutions
- Other – Childcare centres
- Other – Medical (hospital wards or other uses including medical centres)
- Other – Places of worship
- Other – Outdoor open areas (passive and active recreation).

The sensitive receivers within the study area have been identified from site inspections and desktop review and are identified in **Figure 10-11**, **Figure 10-12** and **Figure 10-13**.

Other specific sensitive receivers and items of heritage importance in the study area have been identified in **Chapter 20** (Non-Aboriginal heritage) and **Chapter 21** (Aboriginal heritage).

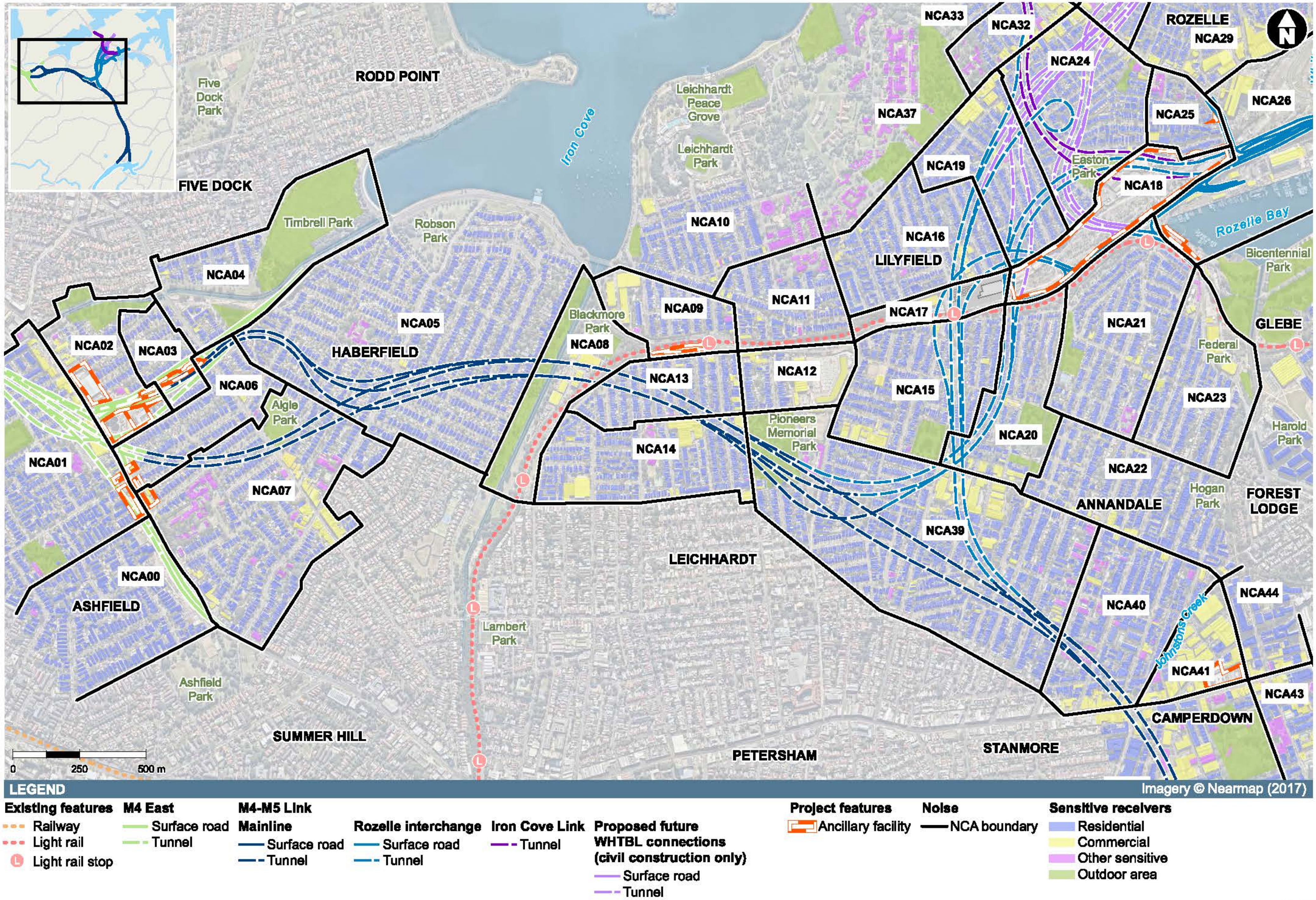


Figure 10-11 Noise sensitive receivers within the study area - (western section)

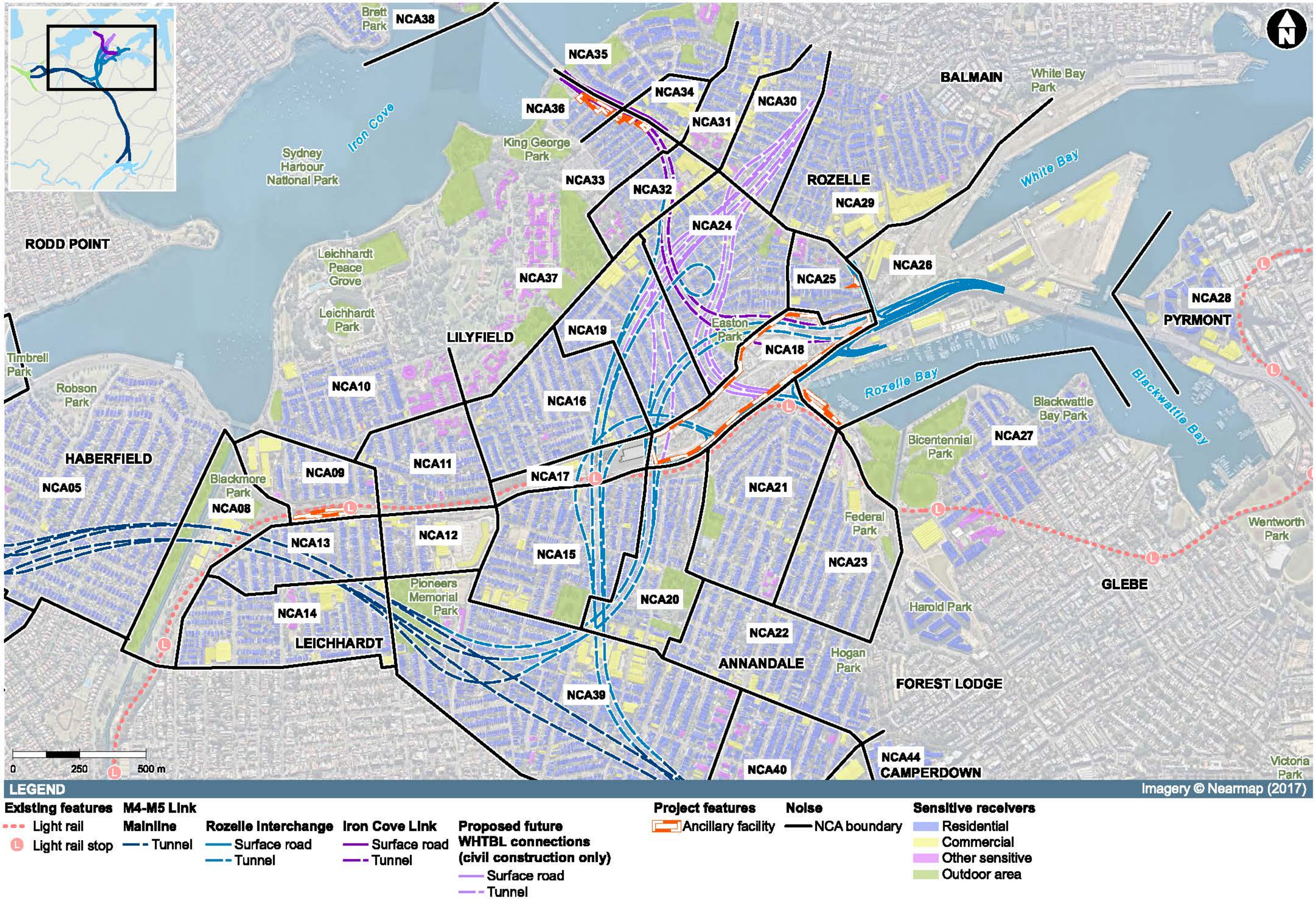


Figure 10-12 Noise sensitive receivers within the study area - (northern section)

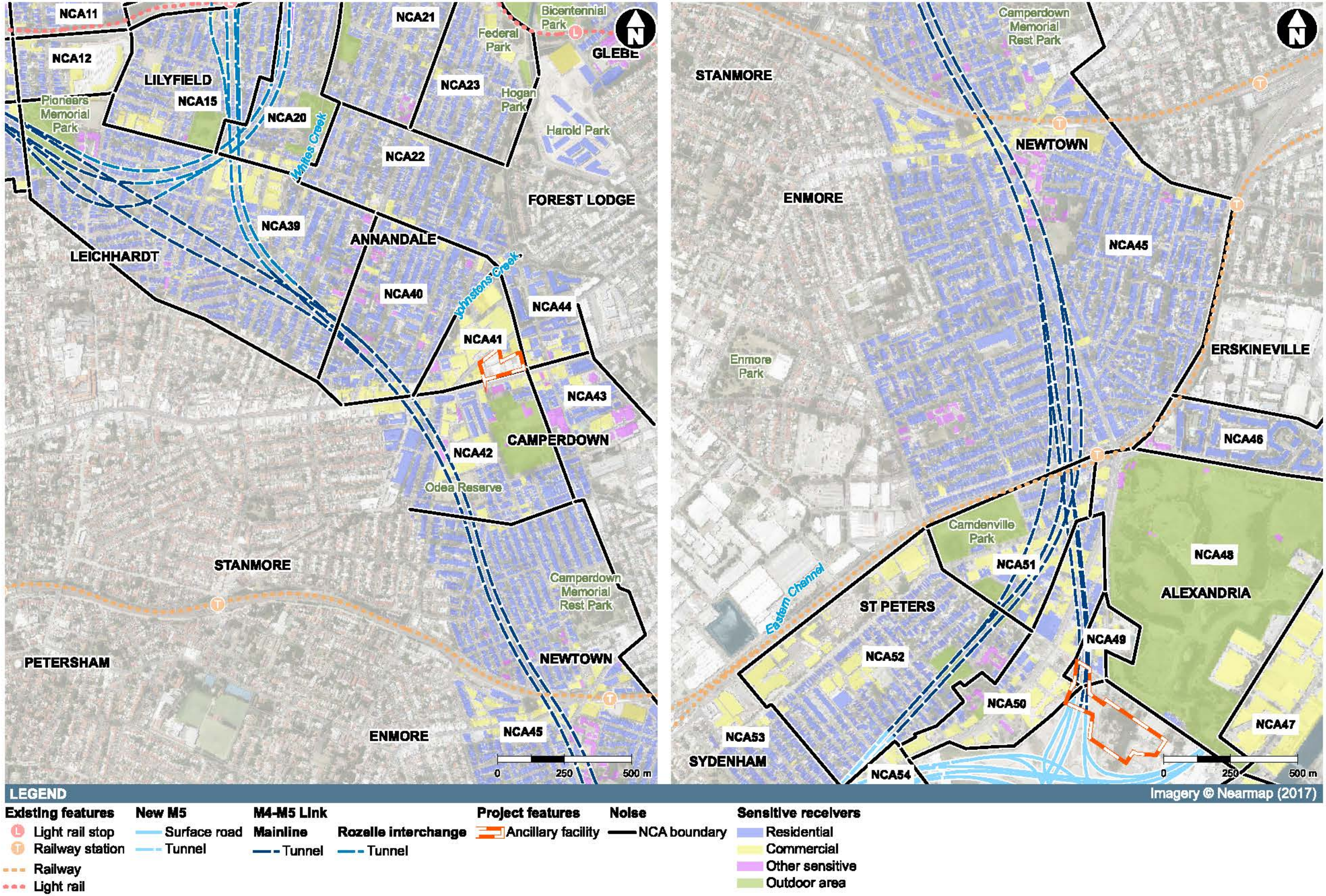


Figure 10-13 Noise sensitive receivers within the study area - (southern section)

10.2.2 Noise catchment areas

As described in **section 10.1**, the study area has been divided into 56 NCAs. These NCAs include the different land uses surrounding the project sites and assists in identifying impacts on groups of receivers likely to be affected by the same works. A description of each NCA is provided in Table 3-1 of **Appendix J** (Technical working paper: Noise and vibration).

The location of the various NCAs are shown in **Figure 10-2** and **Figure 10-3**.

10.2.3 Existing noise levels

The results of the unattended ambient noise surveys undertaken between July and November 2016 are provided in the **Appendix J** (Technical working paper: Noise and vibration).

To establish existing noise levels attended measurements were captured for 15-minute periods at each of the unattended locations. The attended monitoring data are generally consistent with the results of the unattended noise monitoring and show that existing ambient noise levels are dominated by the adjacent major roads (Victoria Road, City West Link and The Crescent).

10.3 Assessment of potential construction impacts

10.3.1 Haberfield

Two options for construction ancillary facilities around Haberfield are described and assessed in this EIS:

- Option A, comprising:
  - Wattle Street civil and tunnel site (C1a)
  - Haberfield civil and tunnel site (C2a)
  - Northcote Street civil site (C3a)
- Option B, comprising:
  - Parramatta Road West civil and tunnel site (C1b)
  - Haberfield civil site (C2b)
  - Parramatta Road East civil site (C3b).

The construction ancillary facilities that comprise these options were grouped in this assessment and are denoted by the suffix *a* (for Option A) or *b* (for Option B) eg C1a Wattle Street civil and tunnel site. The preferred option would be described in the Preferred Infrastructure Report following exhibition of the EIS and discussions with stakeholders and the community.

Haberfield Option A

Description of works

Works in the Haberfield area under Option A would consist of three construction sites:

- **Wattle Street civil and tunnel site (C1a)**

  The existing Wattle Street tunnel site, located on the northern side of Wattle Street would be used for the project to support tunnelling activities launched from the Wattle Street ramps. The on and off ramps for the M4-M4 Link tunnels which are to be constructed during the M4 East project would be used for spoil handling during tunnelling works and would utilise an acoustic roller door to minimise noise

- **Haberfield civil and tunnel site (C2a)**

  The Parramatta Road ventilation facility would be located on the north-eastern corner of the Parramatta Road and Wattle Street intersection. The Parramatta Road ventilation facility would be constructed as part of the M4 East project and fitted out as part of the M4-M5 Link project. Heavy vehicle access to, and egress from the site would be via Parramatta Road, with light vehicles utilising the Northcote Street civil site (C3a) and Wattle Street civil and tunnel site (C1a) for parking

- **Northcote Street civil site (C3a)**

  This site is currently occupied by the Northcote Street tunnel site as part of the M4 East project. At the completion of the M4 East project, Northcote Street would be reopened to traffic and the footpath along Parramatta Road reinstated. The existing tunnel site facilities would be removed and the site used primarily as a car park and laydown area for the duration of the M4-M5 Link project works at Haberfield.

Works schedule

Subject to planning approval, construction activities at Haberfield Option A would be undertaken according to the program shown in **Table 10-19**.

Table 10-19 Indicative construction program and duration – Haberfield Option A

	2019 Q			2020 Q				2021 Q				2022 Q			
	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Wattle Street civil and tunnel site (C1a)															
Initial roadworks and traffic management		■													
Site establishment and utility works		■	■	■	■										
Below ground site set up				■	■										
Tunnelling				■	■	■	■	■	■						
Civil and mechanical fitout									■	■	■				
Testing and commissioning											■	■	■	■	
Site rehabilitation and landscaping														■	■
Haberfield civil and tunnel site (C2a)															
Initial roadworks and traffic management		■													
Site establishment		■	■	■	■										
Below ground site set up			■	■	■										
Temporary ventilation for Wattle Street ramps and mainline (tunnelling support activities)			■	■											
Fitout of ventilation station and substation					■	■	■	■	■	■	■				
Tunnelling				■	■	■	■	■	■						
Civil and mechanical fitout									■	■	■				
Testing and commissioning											■	■	■	■	
Site rehabilitation and landscaping														■	■
Northcote Street civil site (C3a)															
Make good existing construction ancillary facility from previous M4 East Contractor			■	■	■										
Construct car park			■	■											
Construct laydown area			■	■											
Operation of car park and laydown area				■	■	■	■	■	■	■	■	■	■		
Site rehabilitation and landscaping														■	■

Airborne noise

The proposed construction activities, NMLs and sound power levels for the typical operation of construction equipment at the Haberfield Option A sites can be found in **Appendix J** (Technical working paper: Noise and vibration).

A summary of the predicted noise levels (without additional mitigation) in each of the NCAs for the various work activities is also presented in **Appendix J** (Technical working paper: Noise and vibration). These results are split into residential, commercial and other sensitive receivers.

The predicted noise levels presented in **Table 10-21** and **Appendix J** (Technical working paper: Noise and vibration) are representative of the worst case impacts where works are undertaken closest to each NCA. For most construction activities, it is expected that the construction noise levels would frequently be lower than predicted at the most-exposed receiver as the noise levels presented in this report are based on a realistic worst case assessment.

NMLs have been derived for the works at Haberfield based on the measured background noise levels for airborne noise provided in **Appendix J** (Technical working paper: Noise and vibration). These are outlined in **Table 10-20**. The airborne noise NML for commercial receivers in all NCAs is 70 dBA.

Table 10-20 Residential NMLs for Haberfield Option A

NCA	Receiver type	Standard construction (RBL+10 dBA)	Out of hours (RBL+5 dBA)[1]			Sleep disturbance screening (RBL+15 dBA)
		Daytime period	Daytime period	Evening period	Night period	
NCA01	Residential	56	51	51	43	53
NCA02	Residential	68	63	63	57	67
NCA03	Residential	68	63	60	49	59
NCA04	Residential	66	61	58	48	58
NCA05	Residential	61	56	54	47	57
NCA06	Residential	56	51	51	48	58
NCA07	Residential	56	51	51	48	58

Note

1: Out of Hours construction hours includes both evening and night-time construction hours. Evening hours are 6.00 pm to 10.00 pm Monday to Sunday. Night-time hours are 10.00 pm to 7.00 am Monday to Friday and 10.00 pm to 8.00 am Saturday, Sunday and public holidays.

Table 10-21 Predicted airborne noise for Haberfield Option A

Component	Activity	Indicative duration (weeks)	Proposed time of occurrence			Predicted worst case $L_{Aeq15min}$ level in each NCA (dBA)		Sound power level (dBA)	Sound pressure level at 10 m (dBA)
			Day	Evening	Night	At least affected NCA	At worst affected NCA		
Site establishment	Installation of environmental controls	1	Y	N	N	47	74	108	80
	Pavement and infrastructure works	2	Y	Y	Y	55	77	116	88
	Establishment of construction facilities	4	Y	N	N	53	80	114	86
Tunnelling and supporting works	Onsite car parking	132	Y	Y	Y	36	63	97	69
	Workshop, deliveries, maintenance, and storage	132	Y	Y	Y	41	64	103	75
	Northcote Street civil site – on site truck movements	132	Y	Y	Y	<30	47	98	70
	Wattle Street ramps – on site truck movements	132	Y	Y	Y	<30	52	98	70
	Tunnelling support activities	72	Y	Y	Y	<30	46	91	63

Component	Activity	Indicative duration (weeks)	Proposed time of occurrence			Predicted worst case $L_{Aeq15min}$ level in each NCA (dBA)		Sound power level (dBA)	Sound pressure level at 10 m (dBA)
			Day	Evening	Night	At least affected NCA	At worst affected NCA		
Construction	Wattle Street line marking	1	Y	Y	Y	<30	52	109	81
	Ventilation building installation	72	Y	N	N	34	57	102	74
Site rehabilitation and landscaping	Site rehabilitation and landscaping	33	Y	N	N	44	71	105	77

The highest predicted noise levels and greatest impacts are associated with activities that utilise noise intensive plant items, including:

- Diamond/concrete saws
- Excavators with breakers.

Short duration works (up to four weeks) which are required within this study area consist of:

- Installation of environmental controls
- Pavement and infrastructure works
- Establishment of construction facilities.

During standard daytime construction hours, the highest impacts (up to 20 dBA exceedance of NMLs) associated with short term works are generally predicted to be at receivers immediately adjacent to construction sites during the use of noise intensive plant items such as concrete saws.

Works undertaken outside of standard construction hours have the potential for greater noise impacts (greater than 20 dBA exceedance of NMLs) throughout the study area, especially during the most sensitive night-time period. This is due to more stringent NMLs during these periods than during the daytime. Impacts during this period are likely to extend beyond receivers immediately adjacent to the works areas.

Long term construction works (up to 132 weeks) required within this study area consists of:

- Tunnelling activities, including the operation of laydown areas and car parking
- Construction and fitout of the ventilation facility
- Site rehabilitation works.

During standard daytime construction hours, the highest impacts (up to 10 dBA exceedance of NMLs) associated with long term works are generally predicted to be at receivers which are immediately adjacent to the worksites.

During works outside of standard construction hours, the highest impacts (up to 10 dBA exceedance of NMLs) associated with long term works are generally predicted to be at receivers which are immediately adjacent to the construction sites.

Highly noise affected residential receivers

The ICNG considers residential receivers that are subject to predicted noise levels of 75 dBA or greater to be highly noise affected. The number of highly noise affected receivers in the study area has been determined and is summarised in **Table 10-22**. The table shows the number of highly noise affected residential receivers separated by works activity.

Table 10-22 Predicted number of highly noise affected residential receivers by works

Activity	Period		
	Day	Eve	Night
Installation of environmental controls	-	-	-
Pavement and infrastructure works	5	5	5
Establishment of construction facilities	5	-	-
Onsite car parking	-	-	-
Workshop, deliveries, maintenance, and storage	-	-	-
Onsite truck movements – Northcote Street	-	-	-
Onsite truck movements – Wattle Street ramps	-	-	-
Tunnelling support activities	-	-	-
Wattle Street line marking			

Activity	Period		
	Day	Eve	Night
Ventilation building installation	-	-	-
Site rehabilitation and landscaping	-	-	-
Cumulative works scenario	-	-	-

The above table shows that receivers are predicted to be highly noise affected during certain works activities. The highest numbers are apparent during:

- Pavement and infrastructure works, where five receivers are predicted to be highly noise affected
- Establishment of construction facilities, where five receivers are predicted to be highly noise affected.

Both of these works activities require the use of highly noise intrusive equipment such as concrete saws. It is important to note that the installation of environmental controls and establishment of construction facilities are expected to occur for a relatively short period time and that the use of the most noise intrusive equipment (concrete saws) would be expected to be only occurring sporadically throughout the duration of works.

The location of the highly noise affected residential receivers, from all works and in any time period, are shown in **Figure 10-14**.

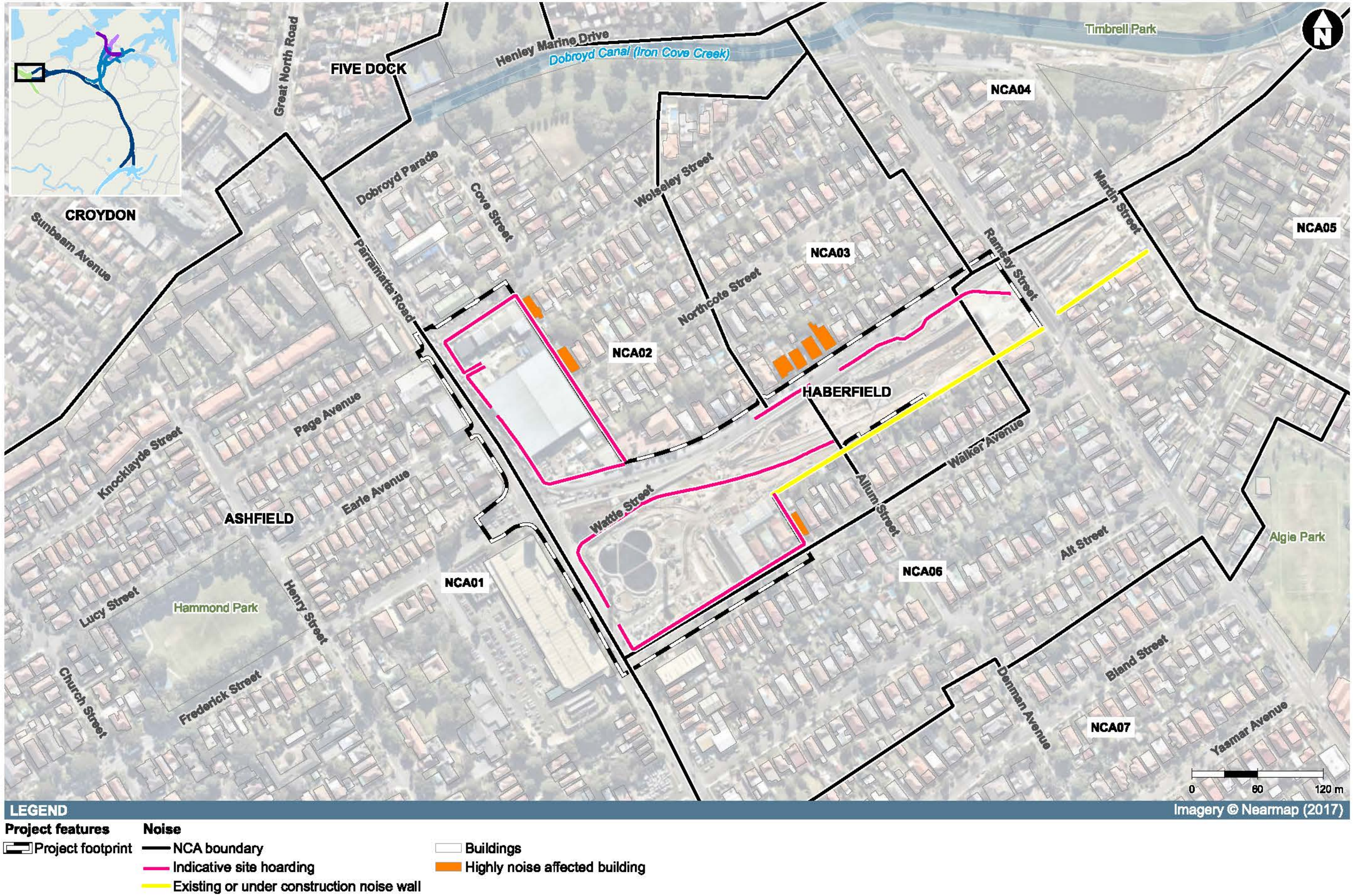


Figure 10-14 Highly noise affected residential receivers – Haberfield (Option A)

The most affected receivers are typically dwellings which surround and have direct line of sight to the various works locations. Worst case noise levels, however, would only be expected to be apparent when high noise generating works are being carried out immediately adjacent to these residential receivers.

Other sensitive receivers

Other sensitive receivers, such as educational facilities, hospitals and childcare centres, which are potentially affected by construction works have been assessed against the various criteria detailed in **section 10.1.3**.

The predicted NML exceedances for other sensitive receivers are summarised in **Table 10-23**. The assessment provides further context to the predicted worst case noise levels presented in **Table 10-21** as it presents the number of and type of receivers predicted to experience exceedances of the NMLs, summarised in bands of 10 dBA.

Table 10-23 Overview of sensitive receiver NML exceedances

Activity	Number of other sensitive receivers exceeding NMLs														
	Education			Medical			Place of Worship			Childcare			Remaining[1]		
	1-10 dBA	11-20 dBA	>20 dBA	1-10 dBA	11-20 dBA	>20 dBA	1-10 dBA	11-20 dBA	>20 dBA	1-10 dBA	11-20 dBA	>20 dBA	1-10 dBA	11-20 dBA	>20 dBA
Installation of environmental controls	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-
Pavement and infrastructure works	-	-	-	-	-	-	1	-	-	4	-	-	-	-	-
Establishment of construction facilities	-	-	-	-	-	-	-	1	-	3	-	-	-	-	-
Onsite car parking	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Workshop, deliveries, maintenance, and storage	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-
Onsite truck movements – Northcote Street	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Onsite truck movements – Wattle Street ramps	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Tunnelling support activities	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Wattle Street line marking	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Ventilation building installation	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Site rehabilitation and landscaping	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-
Cumulative works scenario	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-

Note

1: The ‘Remaining’ category includes public buildings, libraries, café/bars, etc.

The above table shows the following:

- Other sensitive receivers in this precinct are generally predicted to be subject to relatively minor noise impacts. Receivers in the education, medical and remaining categories would not be subject to any NML exceedances
- Only one ‘other sensitive receiver’ in this area would be subject to worst case exceedances of 11 to 20 dBA above NML during the higher noise generating activities. This receiver is the Kingdom Hall of Jehovah’s Witnesses at 12 Wattle Street, Haberfield (located within NCA02).

The recommended ‘standard’ and ‘additional’ noise mitigation as discussed in **section 10.1.8** along with recommended specific site mitigation measures would be implemented to mitigate NML exceedances at other sensitive receivers.

NCA summary

Table 10-24 provides a summary of the key activities within each NCA affected by activities in the Haberfield Option A works area.

Table 10-24 Location summary of construction impacts – Haberfield Option A

NCA	Location
NCA01	**Most affected receivers:** Residential and commercial receivers which are opposite the Northcote Street civil site (C3a) along Parramatta Road, between Page Avenue and Fredrick Street **Worst case construction scenario:** Worksite car parking and deliveries during the night-time period, and pavement and infrastructure work during all works periods **Highest construction noise impacts:** Use of a concrete saw during the night-time period as part of pavement and infrastructure works
NCA02	**Most affected receivers:** Residential receivers which adjoin the Northcote Street civil site (C3a) between Wolseley Street and Wattle Street, and receivers which front Wattle Street between Parramatta Road and Ash Lane **Worst case construction scenario:** Worksite car parking and deliveries during the night-time period, and pavement and infrastructure work during all works periods **Highest construction noise impacts:** Use of a concrete saw during the night-time period as part of pavement and infrastructure works
NCA03	**Most affected receivers:** Residential receivers which front Wattle Street and adjoin the Wattle Street civil and tunnel Site (C1a) and the Haberfield civil and tunnel site (C2a) between Ash Lane and Ramsay Street **Worst case construction scenario:** Worksite car parking and deliveries, truck movements exiting the Wattle Street ramps during the night-time period, and pavement and infrastructure work during all works periods **Highest construction noise impacts:** Use of a concrete saw during the night-time period as part of pavement and infrastructure works
NCA04	**Most affected receivers:** Residential receivers which front Wattle Street between Ramsay Street and Martin Street **Worst case construction scenario:** Worksite car parking and deliveries during the night-time period, and pavement and infrastructure work during all works periods **Highest construction noise impacts:** Use of a concrete saw during the night-time period as part of pavement and infrastructure works
NCA05	**Most affected receivers:** Receivers which front Dobroyd Parade between Martin Street and Waratah Street **Worst case construction scenario:** Pavement and infrastructure work during all out of hours periods. Note that no daytime impacts are predicted within this NCA. Impacts associated with short term works are predicted for outside of standard construction periods only **Highest construction noise impacts:** Use of a concrete saw during the night-time period as part of pavement and infrastructure works
NCA06	**Most affected receivers:** Receivers which adjoin the Haberfield civil and tunnel site (C2a) which are situated along Walker Avenue between Parramatta Road and Allum Street **Worst case construction scenario:** Worksite car parking and deliveries during the night-time period, and by pavement and infrastructure work during all works periods **Highest construction noise impacts:** Use of a concrete saw during the night-time period as part of pavement and infrastructure works

NCA	Location
NCA07	**Most affected receivers:** Receivers which are situated along Bland Street between Denman Avenue and Parramatta Road **Worst case construction scenario:** Minor impacts are predicted during pavement and infrastructure work during all out of hours periods. Note that no daytime impacts are predicted within this NCA. Impacts associated with short term works are predicted for outside of standard construction periods only **Highest construction noise impacts:** Use of a concrete saw during the night-time period as part of pavement and infrastructure works

Cumulative construction impacts

Given the number of work sites associated with the project within the Haberfield study area, it is likely that receivers would, occasionally, be subject to potential cumulative noise impacts from concurrent activities which may occur within the Wattle Street civil and tunnel site (C1a), Haberfield civil and tunnel site (C2a) and the Northcote Street civil site (C3a). This would most likely be apparent during the night period where cumulative impacts are predicted to exceed the NML by up to 10 dBA.

Consecutive construction impacts

The Haberfield study area would likely be subject to potential construction impacts from works associated with other infrastructure projects, including the approved and currently under construction M4 East project. This project, together with the M4-M5 Link, tie in to Wattle Street at Haberfield, where receivers would likely be exposed to extended impacts associated with the consecutive construction of both projects.

The short-term noise intensive works are generally associated with discrete activities which occur over a number of days or weeks in moving locations rather than throughout the entire project at fixed locations. Therefore, the focus of assessing consecutive impacts is to identify works activities which repeat (or are similar to other activities) over extended periods. The longer-term impacts associated with construction ancillary facility activity may continue between separate projects in the area and may appear to be of a similar nature to the community.

The receivers most likely to be affected by consecutive construction impacts are:

- Receivers adjoining the Northcote Street civil site (C3a). This site is currently a tunnel site for the M4 East project, with an acoustic shed constructed across the site
- Receivers adjoining Wattle Street and Walker Avenue which have line of sight to the Wattle Street civil and tunnel site (C1a) and the Haberfield civil and tunnel site (C2a).

In situations where consecutive long term construction noise impacts occur, at-receiver noise mitigation may be considered where feasible and reasonable, once options for at source noise mitigation and management measures have been exhausted. The requirement for this should be evaluated in consultation with Roads and Maritime and the community during detailed design, and should be considered when preparing the site-specific Construction Noise and Vibration Impact Statements (CNVIS) for this area.

Construction road traffic

The assessment indicates that construction traffic is unlikely to result in a noticeable increase in L_{Aeq} noise levels at receivers along the proposed construction traffic routes (Parramatta Road and Wattle Street). It is also important to note that no local roads would be used by heavy vehicles during works.

Management of construction impacts

The assessment of construction impacts identified the following in-situ mitigation measures that should be included for this study area:

- Increased hoarding to height of four metres around the ancillary facilities.

Ground-borne noise and vibration impacts

Works with the potential to cause ground-borne noise impacts in this area, such as excavation of the ventilation facility, ventilation tunnels, Wattle Street dive structures and tunnel stubs, are being undertaken as part of the M4 East project works.

Ground-borne noise from tunnelling works associated with construction of the mainline tunnel alignment and access ramps is summarised in **section 10.3.7**.

As such, airborne noise emissions from the Haberfield Option A construction sites are predicted to be higher than the ground-borne noise levels. For this reason, ground-borne noise is not anticipated to be the controlling factor for these works. Vibration intensive works at the Haberfield Option A site such as demolition of existing buildings, piling works and rock breaking will be undertaken by the M4 East project, and as such, are not considered within this assessment. Vibration from tunnelling works associated with construction of the M4-M5 Link mainline tunnel alignment and connections to the Wattle Street ramps is assessed in **section 10.3.7**.

The following mitigation measures would be considered where feasible and practicable:

- Validation of predicted ground-borne noise levels (note that this may not be required where the ground-borne noise impacts would last less than three weeks at any one sensitive receiver and should be confirmed during detailed design)
- Use of alternative method to de-couple load path/equipment that generates less vibration where feasible and reasonable
- Notification letterbox drops to receivers in the area around the works location, detailing work activities, time periods over which these would occur, impacts and mitigation measures
- Specific notifications provided to receivers where the ground-borne noise levels are predicted to exceed the night-time NMLs, providing additional information when relevant and more specific information than covered in general letterbox drops
- Respite periods may be offered to the affected residents during works where vibration intensive plant levels are predicted to be operated within the safe working distance for human comfort for an extended period of time on any one day.

The specific management strategy for addressing potential impacts associated with ground-borne noise outside of standard daytime construction hours would be documented in the out-of-hours work (OOHW) protocol.

Haberfield/Ashfield Option B

Description of works

The Haberfield Option B works area consists of three construction sites – Parramatta Road West civil and tunnel site (C1b), Haberfield civil site (C2b) and Parramatta Road East civil site (C3b) which all fall within the M4 East footprint.

Key construction activities to be carried out include:

- Demolition of existing buildings and structures (C1b and C3b only)
- Utility works including protection and/or adjustment of existing utilities, removal of redundant utilities and installation of new utilities (C1b and C3b only)
- Establishment of site offices, amenities and temporary infrastructure (all sites)
- Laydown and storage of materials (all sites)
- Delivery of materials, plant and equipment (all sites)
- Construction of an acoustic shed (C1b only)
- Construction of a temporary access tunnel (C1b only)

- Tunnel excavation of the eastbound and westbound mainline tunnels and the Wattle Street entry and exit ramps using roadheaders, as well as stockpiling of excavated material and spoil haulage. (C1b only)
- Mechanical and electrical fitout of a section of the Parramatta Road ventilation facility (that will be built as part of the M4 East project) (C2b only)
- Demobilisation including works to prepare the site for a permissible future use (all sites).

Parramatta Road West civil and tunnel site (C1b)

The Parramatta Road West civil and tunnel site (C1b) would be located west of Parramatta Road between Alt Street and Bland Street at Ashfield. The site is currently occupied by a commercial car dealership and several commercial properties. Residential properties including single dwelling and apartment blocks are located to the immediate west and north. A construction site for the M4 East project is located to the south.

The site would be used for tunnelling support during construction and would include temporary site offices, a workshop and storage facilities, a laydown area, entry and exit points for construction traffic, a temporary substation, temporary ventilation for the tunnels, a temporary water treatment plant and sediment pond, workforce amenities and car parking.

An acoustic shed with a roller door would be established on the site to minimise noise from out-of-hours tunnelling and spoil handling. In addition, temporary noise mitigation measures may include noise barriers and other temporary structures such as site buildings, which would be positioned to minimise effects from noise on surrounding properties.

Construction traffic would enter and exit the site to and from the western (northbound) carriageway of Parramatta Road via new driveways.

Spoil handling on the site would occur 24 hours a day, seven days a week, within an acoustic shed. Excavated spoil from tunnelling would only be stockpiled within the acoustic shed. Heavy vehicle movements associated with the removal of spoil from tunnelling would only occur via access and egress directly to and from Parramatta Road.

Haberfield civil site (C2b)

The Haberfield civil site (C2b) would be used for civil construction where Option B is selected as the preferred construction option at Haberfield. If Option A is selected as the preferred option, the Haberfield civil and tunnel site (C2a) would be used.

The Haberfield civil site would be located at the south-eastern corner of the Parramatta Road and Wattle Street intersection, extending along Parramatta Road between Wattle Street and Walker Avenue. This construction ancillary facility would use land that is currently being used as a construction ancillary facility for the M4 East project.

The Haberfield civil site (C2b) would be used to support civil construction of a substation, and fitout of permanent operational infrastructure including the Parramatta Road ventilation facility (being constructed as part of the M4 East project). The site would include temporary site offices, workshop and storage facilities, laydown areas, ingress and egress for heavy and light vehicles, workforce amenities and car parking.

Heavy vehicles delivering materials and equipment would enter and exit the Haberfield civil site (C2b) via the westbound Wattle Street carriageways. Light vehicles would enter and leave the site via Wattle Street and Walker Avenue.

Parramatta Road East civil site (C3b)

The Parramatta Road East civil site (C3b) would be located east of Parramatta Road at Haberfield between Alt Street and Bland Street. The site is currently occupied by a commercial car dealership. Residential properties are located to the immediate east and north. A construction site for the M4 East project is located to the south.

The Parramatta Road East civil site (C3b) would be used to support tunnelling construction activities that would occur at the Parramatta Road West civil site (C1b) and to provide construction workforce parking. The site would include temporary site offices, ingress and egress for light vehicles, workforce amenities and car parking.

Works schedule

Subject to planning approval, construction activities at Haberfield/Ashfield Option B would be undertaken according to the program shown in **Table 10-25**.

Table 10-25 Indicative construction program and duration – Haberfield/Ashfield Option B

Component	2018 Q				2019 Q				2020 Q				2021 Q				2022 Q			
	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Parramatta Road West civil and tunnel site (C1b)																				
Site establishment and utility works				■	■	■														
Construction of temporary access tunnel						■	■													
Tunnelling								■	■	■	■	■	■							
Civil and mechanical fitout													■	■	■	■	■			
Testing and commissioning																	■	■		
Site rehabilitation																		■		
Haberfield civil site (C2b)																				
Initial roadworks and traffic management							■													
Site establishment and utility works							■	■	■	■										
Fitout of Parramatta Road ventilation facility and substation										■	■	■	■	■	■	■				
Civil and mechanical fitout														■	■	■	■			
Testing and commissioning																■	■	■	■	
Site rehabilitation and landscaping																			■	
Parramatta Road East civil site (C3b)																				
Site establishment and utility works				■	■	■														
Use of car park and site amenities during construction						■	■	■	■	■	■	■	■	■	■	■	■	■	■	
Demobilisation																			■	

Airborne noise

The proposed construction activities, NMLs and sound power levels for the typical operation of construction equipment at the Haberfield Option B sites can be found in **Appendix J** (Technical working paper: Noise and vibration).

A summary of the predicted noise levels (without additional mitigation) in each of the NCAs for the various work activities is also presented in **Appendix J** (Technical working paper: Noise and vibration). These results are split into residential, commercial and other sensitive receivers.

The predicted noise levels presented in **Table 10-27** and **Appendix J** (Technical working paper: Noise and vibration) are representative of the worst case impacts where works are undertaken closest to each NCA. For most construction activities, it is expected that the construction noise levels would frequently be lower than predicted at the most-exposed receiver as the noise levels presented in this report are based on a realistic worst case assessment.

NMLs have been derived for the works at Haberfield based on the measured background noise levels provided in **Appendix J** (Technical working paper: Noise and vibration). These are outlined in **Table 10-26**. The NML for commercial receivers in all NCAs is 70 dBA.

Table 10-26 Residential NMLs for Haberfield/Ashfield Option B

NCA	Receiver type	Standard construction (RBL+10dBA) Daytime period	Out of hours (RBL+5dBA)[1]			Sleep disturbance screening (RBL+15)
			Daytime period	Evening period	Night period	
NCA01	Residential	56	51	51	43	53
NCA02	Residential	68	63	63	57	67
NCA03	Residential	68	63	60	49	59
NCA04	Residential	66	61	58	48	58
NCA05	Residential	61	56	54	47	57
NCA06	Residential	56	51	51	48	58
NCA07	Residential	56	51	51	48	58

Note:

1: Out of hours construction hours includes both evening and night-time construction hours. Evening hours are 6.00 pm to 10.00 pm Monday to Sunday. Night-time hours are 10.00 pm to 7.00 am Monday to Friday and 10.00 pm to 8.00 am Saturday, Sunday and public holidays.

Table 10-27 Predicted airborne noise for Haberfield/Ashfield Option B

Component	Activity	Indicative duration (weeks)	Proposed time of occurrence			Predicted worst case LAeq15min level in each NCA (dBA)		Sound power level (dBA)	Sound pressure level at 10 m (dBA)
			Day	Evening	Night	At least affected NCA	At worst affected NCA		
Site establishment	Demolition of existing buildings	4	Y	N	N	48	86	120	92
	Utility works	2	Y	N	N	45	83	117	89
	Installation of environmental controls	1	Y	N	N	44	74	108	80
	Pavement and infrastructure works	2	Y	Y	Y	54	78	118	90
	Establishment of construction facilities	4	Y	N	N	50	80	114	86
Tunnelling and supporting works	Onsite car parking	168	Y	Y	Y	30	63	97	69
	Workshop, deliveries, maintenance, and storage	168	Y	Y	Y	40	69	103	75
	Spoil handling inside acoustic shed	168	Y	Y	Y	36	70	97	69

Component	Activity	Indicative duration (weeks)	Proposed time of occurrence			Predicted worst case LAeq15min level in each NCA (dBA)		Sound power level (dBA)	Sound pressure level at 10 m (dBA)
			Day	Evening	Night	At least affected NCA	At worst affected NCA		
	Tunnelling support activities	168	Y	Y	Y	<30	42	82	54
Construction	Ventilation building fitout and installation	84	Y	N	N	34	57	102	74
Site rehabilitation and landscaping	Site rehabilitation and landscaping	12	Y	N	N	41	71	105	77

The highest predicted noise levels and greatest impacts are associated with activities which utilise noise intensive plant items, including:

- Diamond/concrete saws
- Excavators with breakers.

Short duration works (up to four weeks) which are required within this study area consist of:

- Demolition of existing structures
- Utility works
- Establishment of construction facilities.

During standard daytime construction hours, the highest impacts (greater than 20 dBA exceedance of NMLs) associated with short term works are generally predicted to be at receivers immediately adjacent to construction sites during the use of noise intensive plant items such as concrete saws and rock breakers.

Works undertaken outside of standard construction hours have the potential for greater noise impacts (greater than 20 dBA exceedance of NMLs) throughout the study area, especially during the most sensitive night-time period. This is due to more stringent NMLs during these periods than during the daytime. Impacts during this period are likely to extend beyond receivers immediately adjacent to the works areas.

Long term construction works (up to 168 weeks) required within this study area consists of:

- Tunnelling activities, including the operation of laydown areas and car parking
- Ventilation building fitout and installation
- Site rehabilitation works.

During works outside of standard construction hours, the highest impacts (up to 20 dBA exceedance of NMLs) associated with long term works are generally predicted to be at receivers which are on Parramatta Road and receivers which adjoin the Parramatta Road West civil and tunnel site (C1b) to the west.

Highly affected noise receivers

The ICNG considers residential receivers that are subject to predicted noise levels of 75 dBA or greater to be Highly Noise Affected. The number of Highly Noise Affected receivers in the study area has been determined and is summarised in **Table 10-28**. The table shows the number of residential receivers separated by works activity.

Table 10-28 Predicted number of highly noise affected residential receivers by works

Activity	Period		
	Day	Eve	Night
Demolition of existing buildings	13	-	-
Utility works	9	-	-
Installation of environmental controls	-	-	-
Pavement and infrastructure works	7	7	7
Establishment of construction facilities	7	-	-
Onsite car parking	-	-	-
Workshop, deliveries, maintenance, and storage	-	-	-
Spoil handling inside acoustic shed	-	-	-
Tunnelling support activities	-	-	-
Ventilation building fit out and installation	-	-	-
Site rehabilitation and landscape	-	-	-
Cumulative	-	-	-

The above table shows that receivers are predicted to be Highly Noise Affected during certain works activities. The highest numbers are apparent during the demolition of existing buildings and utility works, where 13 and nine receivers are predicted to be highly noise affected. These works would be required during standard daytime construction hours. While only seven receivers are predicted to be highly noise affected during pavement and infrastructure works, this activity would be required both during and outside standard daytime construction hours in all time periods.

All activities indicated to result in highly noise affected residential receivers include the use of highly noise intrusive equipment such as diamond/concrete saws and rock breakers. It is important to note that activities that may result in highly noise affected receivers are expected to occur for a relatively short period of time and that the use of the most noise intensive equipment would only sporadically be required at times throughout the duration of works.

The location of the highly noise affected residential receivers, from all works and in any time period, are shown in **Figure 10-15**.

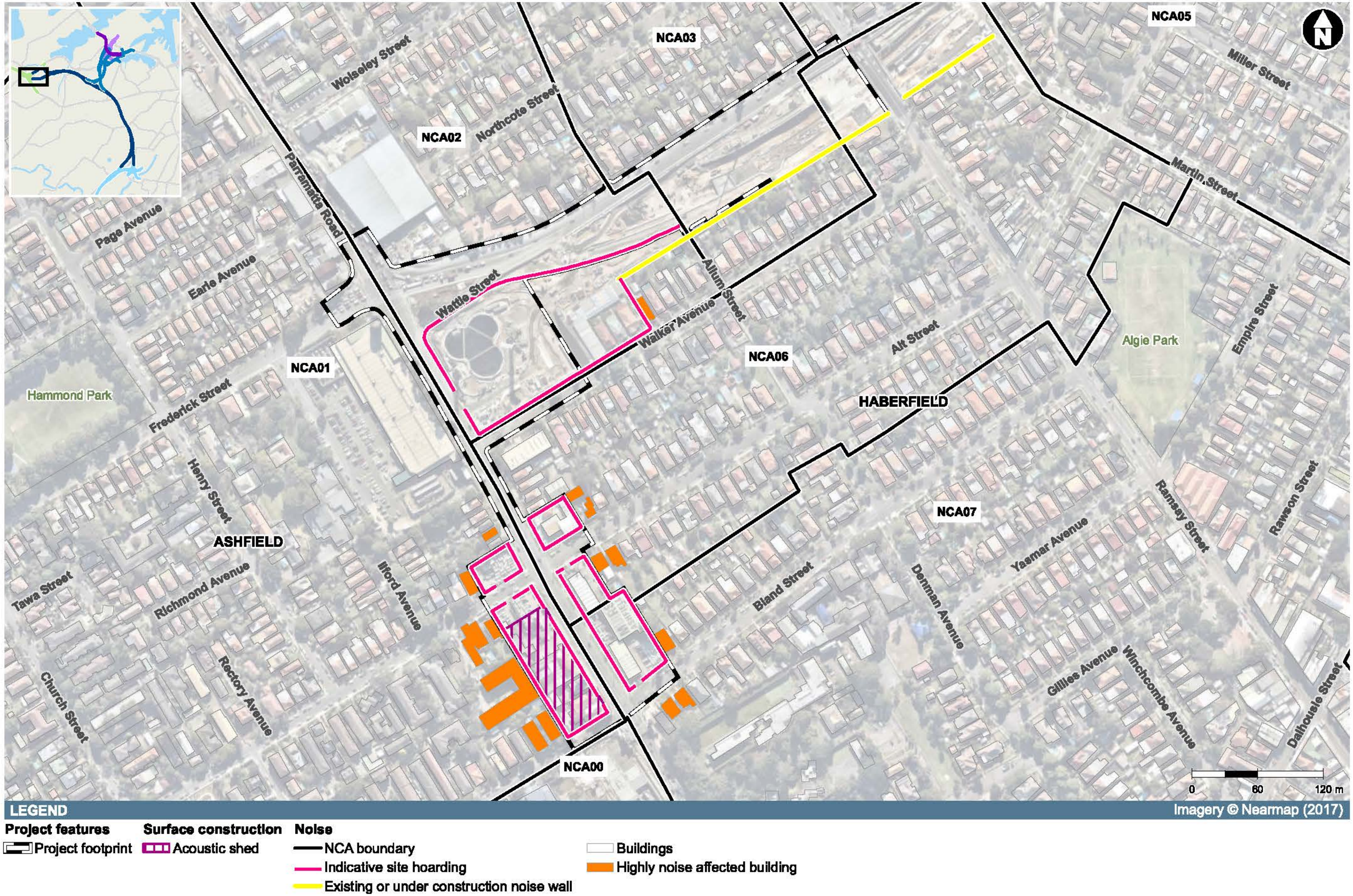


Figure 10-15 Highly noise affected residential receivers - Haberfield and Ashfield (Option B)

The most affected receivers are typically dwellings which surround and have direct line of sight to the various works location. Worst case noise levels, however, would only be expected to be apparent when high noise generating works are being carried out immediately adjacent to these residential receivers.

Other sensitive receivers

Other sensitive receivers, such as educational facilities, hospitals and childcare centres, which are potentially affected by construction works have been assessed against the various criteria detailed in **section 10.1.3**.

The predicted NML exceedances for other sensitive receivers are summarised in **Table 10-29**. The assessment provides further context to the predicted worst case noise levels presented in **Table 10-27** as it presents the number of and type of receivers predicted to experience exceedances of the NMLs, summarised in bands of 10 dBA.

Table 10-29 Overview of sensitive receiver NML exceedances

Activity	Number of other sensitive receivers exceeding NMLS: Education			Medical			Place of Worship			Childcare			Remaining[1]		
	1-10 dBA	11-20 dBA	>20 dBA	1-10 dBA	11-20 dBA	>20 dBA	1-10 dBA	11-20 dBA	>20 dBA	1-10 dBA	11-20 dBA	>20 dBA	1-10 dBA	11-20 dBA	>20 dBA
Demolition of existing buildings	1	1	-	-	-	-	1	-	-	1	1	-	-	-	-
Utility works	2	-	-	-	-	-	-	-	-	1	1	-	-	-	-
Installation of environmental controls	-	-	-	-	-	-	1	-	-	1	-	-	-	-	-
Pavement and infrastructure works	2	-	-	-	-	-	-	1	-	3	-	-	-	-	-
Establishment of construction facilities	2	-	-	-	-	-	-	1	-	2	-	-	-	-	-
Onsite car parking	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Workshop, deliveries, maintenance, and storage	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-
Spoil handling inside acoustic shed	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Tunnelling support activities	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Ventilation building fit out and installation	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Site rehabilitation and landscaping	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-
Cumulative scenario	-	-	-	-	-	-	1	-	-	1	-	-	-	-	-

Note:

1: The ‘Remaining’ category includes public buildings, libraries, café/bars, etc.

The above table shows the following:

- Other sensitive receivers in this precinct are generally predicted be subject to relatively minor noise impacts
- Three ‘other sensitive receivers’ in this area would be subject to worst case exceedances of 11 to 20 dBA above NML during the higher noise generating activities. These receivers are:
  - Child care – The Infants Home at 17 Henry Street, Haberfield (located within NCA01)
  - Place of worship – Kingdom Hall of Jehovah’s Witnesses at 12 Wattle Street, Haberfield (located within NCA02)
  - Educational facility – Juvenile Justice – Yasmar training facility (located within NCA07).

The recommended ‘standard’ and ‘additional’ noise mitigation as discussed in **section 10.1.8** along with recommended specific site mitigation measures would be implemented to mitigate NML exceedances at other sensitive receivers.

NCA summary

Table 10-30 provides a summary of the key activities within each NCA affected by activities in the Haberfield Option B works area.

Table 10-30 Location summary of construction impacts – Haberfield/Ashfield Option B

NCA	Location
NCA00	**Most affected receivers:** Residential receivers which are situated to the south of the Parramatta Road West civil and tunnel site (C1b) on Parramatta Road between Bland Street and Chandos Street **Worst case construction scenario:** Pavement and infrastructure works and spoil handling works within the acoustic shed during all works periods **Highest construction noise impacts:** Use of a rock breaker during the daytime period as part of the demolition works and use of a concrete saw during the night-time period as part of the pavement and infrastructure works
NCA01	**Most affected receivers:** Residential receivers which adjoin the Parramatta Road West civil and tunnel site (C1b) between Bland Street and the Bunnings Warehouse on Parramatta Road **Worst case construction scenario:** Pavement and infrastructure works and spoil handling works within the acoustic shed during all works periods **Highest construction noise impacts:** Use of a rock breaker during the daytime period as part of the demolition works and use of a concrete saw during the night-time period as part of the pavement and infrastructure works. Also, noise impacts from spoil works within the Parramatta Road West civil and tunnel site (C1b) during all periods
NCA02	**Most affected receivers:** Residential receivers which adjoin Wattle Street between Parramatta Road and Ash Lane **Worst case construction scenario:** Pavement and infrastructure works during all works periods associated with the Haberfield civil site (C2b) **Highest construction noise impacts:** Use of a concrete saw during the night-time period as part of pavement and infrastructure works
NCA03	**Most affected receivers:** Residential receivers which front Wattle Street between Ash Lane and Ramsay Street **Worst case construction scenario:** Pavement and infrastructure works during all works periods associated with the Haberfield civil site (C2b) **Highest construction noise impacts:** Use of a concrete saw during the night-time period as part of pavement and infrastructure works
NCA04	**Most affected receivers:** Residential receivers which front Wattle Street between Ramsay Street and Martin Street **Worst case construction scenario:** Pavement and infrastructure works during all works periods associated with the Haberfield civil site (C2b) **Highest construction noise impacts:** Use of a concrete saw during the night-time period as part of pavement and infrastructure works

NCA	Location
NCA05	**Most affected receivers:** Receivers which front Dobroyd Parade between Martin Street and Waratah Street **Worst case construction scenario:** Pavement and infrastructure works during all works periods associated with the Haberfield civil site (C2b) **Highest construction noise impacts:** Use of a concrete saw during the night-time period as part of pavement and infrastructure works
NCA06	**Most affected receivers:** Receivers which adjoin the Haberfield civil site (C2b) on Walker Avenue, between Allum Street and Parramatta Road, and residential receivers located on Alt Street which adjoin the Parramatta Road East civil site (C3b) **Worst case construction scenario:** Demolition works during the daytime period and pavement and infrastructure works during all works periods **Highest construction noise impacts:** Use of a rock breaker during the daytime period as part of the demolition works and use of a concrete saw during the night-time period as part of the pavement and infrastructure works
NCA07	**Most affected receivers:** Residential receivers which are situated to the south of the Parramatta Road East civil site (C3b), between Bland Street and Chandos Street on Parramatta Road **Worst case construction scenario:** Demolition works during the daytime period and Pavement and infrastructure works during all works periods **Highest construction noise impacts:** Use of a rock breaker during the daytime period as part of the demolition works and use of a concrete saw during the night-time period as part of the pavement and infrastructure works

Cumulative construction impacts

Given the number of work sites associated with the project within the Haberfield study area, it is likely that receivers would, occasionally, be subject to potential cumulative noise impacts from construction sites operating concurrently in the same area. This would most likely be apparent during the night period where cumulative impacts are predicted to exceed the NML by greater than 20 dBA within NCA01.

Consecutive construction impacts

The Haberfield study area would likely be subject to potential construction impacts from works associated with other infrastructure projects, including the approved and currently under construction WestConnex M4 East project together with the M4-M5 Link, tie in to Wattle Street and Parramatta Road at Haberfield, where receivers would likely be exposed to extended impacts associated with the consecutive construction of both projects.

The short-term noise intensive works are generally associated with discrete activities which occur over a number of days or weeks in moving locations rather than throughout the entire project at fixed locations. Therefore, the focus of assessing consecutive impacts is to identify works activities which repeat (or are similar to other activities) over extended periods. The longer-term impacts associated with construction ancillary facility activity may continue between separate projects in the area and may appear to be of a similar nature to the community.

The receivers most likely to be affected by consecutive construction impacts are:

- Receivers adjoining the Parramatta Road West civil and tunnel site (C1b), Parramatta Road East civil site (C3b) and Haberfield civil site (C2b), between Walker Avenue and Chandos Street.

In situations where consecutive long term construction noise impacts occur, at-receiver noise mitigation may be considered where feasible and reasonable, once options for at source noise mitigation and management measures have been exhausted. The requirement for this should be evaluated in consultation with Roads and Maritime and the community during detailed design, and should be considered when preparing the site specific CNVIS for this area.

Construction road traffic

The assessment indicates that construction traffic is unlikely to result in a noticeable increase in L_{Aeq} noise levels at receivers along the proposed construction traffic routes.

Management of construction impacts

The assessment of construction impacts identified the following in-situ mitigation measures that should be included for this study area:

- Increased site hoarding to height of four metres around the ancillary facilities
- Upgrading the acoustic shed performance
- Limiting the total internal sound power level to 110 dBA within the acoustic shed.

Ground-borne noise and vibration impacts

Works with the potential to cause ground-borne noise impacts in this area, such as excavation of the ventilation facility, ventilation tunnels, Wattle Street dive structures and tunnel stubs, are being undertaken as part of the M4 East project works.

Ground-borne noise from tunnelling works associated with construction of the mainline tunnel alignment and access ramps is summarised in **section 10.3.7**.

Based on the excavation of the access tunnel at this site, eight residential receivers are predicted to exceed the night-time ground-borne NML for up to approximately 20 days. While most roadheader works would be anticipated to progress at a consistent rate, there may be discreet locations which require a longer duration of tunnelling works due to site conditions.

Up to 22 buildings in this area may be within the minimum vibration working distances should a large rock-breaker be used at the outer extents of the Haberfield/Ashfield Option B works area. For this scenario, around 66 receivers in the vicinity of the site would fall within the nominated minimum working distance for human comfort vibration should a large rock-breaker be used at the outer extents of the works area. No heritage-listed items have been identified as having the potential to be within the minimum safe working distances should a large rock-breaker be used at the outer extents of the project footprint.

The following mitigation measures should be considered where feasible and reasonable:

- Validation of predicted ground-borne noise levels (note that this may not be required where the ground-borne noise impacts would last less than three weeks at any one sensitive receiver and should be confirmed during detailed design)
- Notification letterbox drops to receivers in the area around the works locations, detailing work activities, time periods over which these would occur, impacts and mitigation measures
- Specific notifications provided to receivers where the ground-borne noise levels are predicted to exceed the night-time NML, providing additional information when relevant and more specific information than covered in general letterbox drops.
- Validation of predicted vibration levels at the nearest receiver buildings to the vibration intensive works
- Use of alternative method to de-couple load path/equipment that generates less vibration where feasible and reasonable
- Notification letterbox drops to receivers in the area around the works locations, detailing work activities, time periods over which these would occur, impacts and mitigation measures
- Respite periods may be offered to the affected residents during works where vibration intensive plant levels are predicted to be operated within the safe working distance for human comfort for an extended period of time on any one day.

The specific management strategy for addressing potential impacts associated with ground-borne noise outside of standard daytime construction hours would be documented in the OOHW protocol.

10.3.2 Darley Road

Description of works

Darley Road civil and tunnel site (C4) would be located adjacent to the Leichhardt North light rail stop, between City West Link and Darley Road. The site is a mid-tunnel site at the western end of the project footprint. The site would include:

- Temporary site offices
- Workshop and storage facilities
- Laydown area entry and exit points for haulage of tunnel spoil
- Temporary substation
- Temporary ventilation plant
- Water treatment plant
- Car parking.

It is expected that roadheaders to be launched from this site would initially excavate the construction decline, then the mainline tunnels, traveling in an easterly and westerly direction. An acoustic shed would be established on the site to minimise noise from out-of-hours tunnelling and spoil handling. Heavy vehicle access to and egress from the site would be via Darley Road. Heavy vehicles would turn left to enter City West Link westbound. There would be temporary changes to two intersections to control the flow of heavy vehicles in and out of Darley Road.

Works schedule

Subject to planning approval, construction activities at Darley Road would be undertaken according to the program shown in **Table 10-31**.

Table 10-31 Indicative construction program and duration – Darley Road

Scenario	2018 Q 1	2	3	4	2019 Q 1	2	3	4	2020 Q 1	2	3	4	2021 Q 1	2	3	4	2022 Q 1	2	3	4
Darley Road civil and tunnel site (C4)																				
Site establishment and utility works			■	■	■															
Construction of temporary access tunnel				■	■															
Tunnelling					■	■	■	■	■	■	■	■	■							
Construction of motorway operational infrastructure										■	■	■	■							
Civil and mechanical fitout											■	■	■	■	■					
Testing and commissioning															■	■	■	■	■	
Site rehabilitation and landscaping																		■	■	■

Airborne noise

The proposed construction activities, NMLs and sound power levels for the typical operation of construction equipment at the Darley Road site can be found in **Appendix J** (Technical working paper: Noise and vibration).

A summary of the predicted noise levels (without additional mitigation) in each of the NCAs for the various work activities is also presented in **Appendix J** (Technical working paper: Noise and vibration). These results are split into residential, commercial and other sensitive receivers.

The predicted noise levels presented in this report and **Appendix J** (Technical working paper: Noise and vibration) are representative of the worst case impacts where works are undertaken closest to each NCA. For most construction activities, it is expected that the construction noise levels would frequently be lower than predicted at the most-exposed receiver as the noise levels presented in this report are based on a realistic worst case assessment.

The predicted noise levels presented in **Table 10-33** and **Appendix J** (Technical working paper: Noise and vibration) are representative of the worst case impacts where works are undertaken closest to each NCA. For most construction activities, it is expected that the construction noise levels would frequently be lower than predicted at the most exposed receiver as the noise levels presented in this report are based on a realistic worst case assessment.

NMLs have been derived for the works at Darley Road based on the measured background noise levels provided in **Appendix J** (Technical working paper: Noise and vibration). These are outlined in **Table 10-32**. The NMLs for commercial receivers in all NCAs is 70 dBA.

Table 10-32 Residential NMLs for Darley Road

NCA	Receiver type	Standard construction (RBL+10dBA) Daytime period	Out of hours (RBL+5dBA)[1]			Sleep disturbance screening (RBL+15)
			Daytime period	Evening period	Night period	
NCA05	Residential	61	56	54	47	57
NCA09	Residential	61	56	54	47	57
NCA10	Residential	61	56	54	47	57
NCA11	Residential	61	56	54	47	57
NCA12	Residential	61	56	52	45	55
NCA13	Residential	61	56	52	45	55
NCA14	Residential	61	56	52	45	55

Note:

1: Out of Hours construction hours includes both evening and night-time construction hours. Evening hours are 6.00 pm to 10.00 pm Monday to Sunday. Night-time hours are 10.00 pm to 7.00 am Monday to Friday and 10.00 pm to 8.00 am Saturday, Sunday and public holidays.

Table 10-33 Predicted airborne noise for Darley Road

Component	Activity	Indicative duration (weeks)	Proposed time of occurrence			Predicted worst case LAeq15min level in each NCA (dBA)		Sound power level (dBA)	Sound pressure level at 10 m (dBA)
			Day	Evening	Night	At least affected NCA	At worst affected NCA		
Site establishment	Demolition of existing buildings	4	Y	N	N	53	79	120	92
	Site clearing	2	Y	N	N	47	74	113	85
	Utility works	2	Y	Y	Y	51	78	117	89
	Installation of environmental controls	1	Y	N	N	42	69	108	80
	Pavement and infrastructure works	2	Y	Y	Y	54	91	118	90

Component	Activity	Indicative duration (weeks)	Proposed time of occurrence			Predicted worst case LAeq15min level in each NCA (dBA)		Sound power level (dBA)	Sound pressure level at 10 m (dBA)
			Day	Evening	Night	At least affected NCA	At worst affected NCA		
	Line marking works and road adjustments	2	Y	Y	Y	51	88	115	87
	Construct new signalised intersection	3	Y	Y	Y	43	80	107	79
	Place barriers to new queuing area	1	Y	Y	Y	35	67	101	73
	Establishment of construction facilities	4	Y	N	N	48	75	114	86
Tunnelling and supporting works	Onsite car parking	204	Y	Y	Y	<30	57	97	69
	Workshop, deliveries, maintenance, and storage	204	Y	N	N	37	61	103	75
	Construction of tunnel shaft and declines (outside acoustic shed)	36	Y	N	N	47	74	114	86
	Spoil handling inside acoustic shed	96	Y	Y	Y	40	65	97	69
	On site truck movements	96	Y	N	N	30	60	97	69
	Tunnelling support activities	96	Y	Y	Y	<30	45	82	54
Site rehabilitation and landscaping	Site rehabilitation and landscaping	12	Y	N	N	39	66	105	77

The highest predicted noise levels and greatest impacts are associated with activities which utilise noise intensive plant items, including:

- Diamond/concrete saws
- Road profilers
- Excavators with breakers.

Short duration works (up to four weeks) which are required within this study area consist of:

- Site establishment works
- Traffic management works.

During standard daytime construction hours, the highest impacts (greater than 20 dBA exceedance of NMLs) associated with short term works are generally predicted to be at receivers immediately adjacent to construction sites during the use of noise intensive plant items such as concrete saws, rock breaker and road profilers.

Works undertaken outside of standard construction hours have the potential for greater noise impacts (greater than 20 dBA exceedance of NMLs) throughout the study area, especially during the most sensitive night-time period. This is due to more stringent NMLs during these periods than during the daytime. Impacts during this period are likely to extend beyond receivers immediately adjacent the works areas.

Long term construction works (up to 204 weeks) required within this study area consists of:

- Tunnelling activities, including the operation of laydown areas and car parking
- Construction of declines
- Site rehabilitation works.

During standard daytime construction hours, the highest impacts (up to 20 dBA exceedance of NMLs) associated with long-term works are generally predicted to be at receivers which are immediately adjacent to the construction sites on the southern (opposite) side of Darley Road.

During works outside of standard construction hours, the highest impacts (up to 20 dBA exceedance of NMLs) associated with long term works are generally predicted to be at receivers which are immediately adjacent to the construction sites on the southern (opposite) side of Darley Road.

Highly affected noise receivers

The ICNG considers residential receivers that are subject to predicted noise levels of 75 dBA or greater to be Highly Noise Affected. The number of Highly Noise Affected receivers in the study area has been determined and is summarised in **Table 10-34**. The table shows the number of residential receivers separated by works activity.

Table 10-34 Predicted number of highly noise affected residential receivers by works

Activity	Period		
	Day	Eve	Night
Demolition of existing buildings	7	-	-
Site clearing	-	-	-
Utility works	5	-	-
Installation of environmental controls	-	-	-
Pavement and infrastructure works	36	36	36
Line marking works and road adjustments	22	22	22
Construct new signalised intersection	6	-	-
Place barriers to new queuing area	-	-	-
Establishment of construction facilities	1	-	-

Activity	Period		
	Day	Eve	Night
Onsite car parking	-	-	-
Workshop, deliveries, maintenance, and storage	-	-	-
Construction of tunnel shaft and declines (outside acoustic shed)	-	-	-
Spoil handling inside acoustic shed	-	-	-
Onsite truck movements	-	-	-
Tunnelling support activities	-	-	-
Site rehabilitation and landscape	-	-	-
Cumulative works scenario (day)	-	-	-
Cumulative works scenario (night)	-	-	-

The above table shows that receivers are predicted to be highly noise affected during certain works activities. The highest numbers are apparent during:

- Pavement and infrastructure works, where 36 receivers are predicted to be highly noise affected
- Line marking works and road adjustments, where 22 receivers predicted to be highly noise affected.

Both of these works activities require the use of highly noise intrusive equipment such as concrete saws and road profilers and would be required outside standard daytime construction hours to avoid potential traffic impacts. It is important to note that both activities DAR-05 and DAR-06 along with other activities predicted to have highly noise affected receivers are expected to occur for a relatively short period time and that the use of the most noise intrusive equipment (concrete saws and road profilers) would be expected to be only occurring sporadically throughout the duration of the works.

The location of the highly noise affected residential receivers, from all works and in any time period, are shown in **Figure 10-16**.

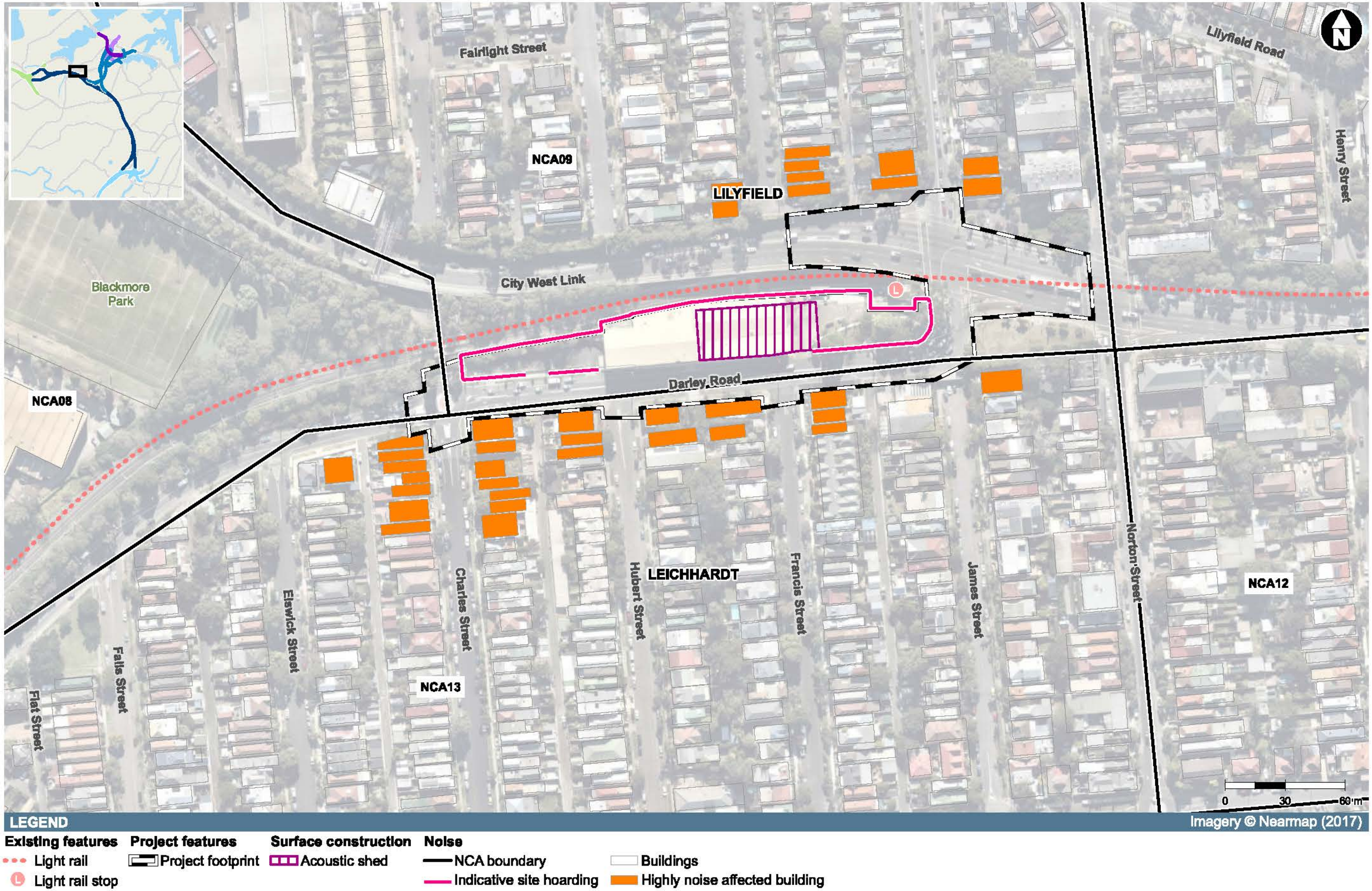


Figure 10-16 Highly noise affected residential receivers - Darley Road

The most affected receivers are typically dwellings which surround and have direct line of sight to the various works locations. Worst case noise levels, however, would only be expected to be apparent when high noise generating works are being carried out immediately adjacent to these residential receivers.

Other sensitive receivers

Other sensitive receivers, such as educational facilities, hospitals and childcare centres, which are potentially affected by construction works have been assessed against the various criteria detailed in **section 10.1.3**.

The predicted NML exceedances for other sensitive receivers are summarised in **Table 10-35**. The assessment provides further context to the predicted worst case noise levels presented in **Table 10-33** as it presents the number and type of receivers predicted to experience exceedances of the NMLs, summarised in bands of 10 dBA.

Table 10-35 Overview of sensitive receiver NML exceedances

Activity	Number of other sensitive receivers exceeding NMLs														
	Education			Medical			Place of Worship			Childcare			Remaining[1]		
	1-10 dBA	11-20 dBA	>20 dBA	1-10 dBA	11-20 dBA	>20 dBA	1-10 dBA	11-20 dBA	>20 dBA	1-10 dBA	11-20 dBA	>20 dBA	1-10 dBA	11-20 dBA	>20 dBA
Demolition of existing buildings	3	-	-	-	-	-	-	-	-	-	2	-	-	-	-
Site clearing	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-
Utility works	1	-	-	-	-	-	-	-	-	-	2	-	-	-	-
Installation of environmental controls	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-
Pavement and infrastructure works	3	-	-	-	-	-	-	-	-	-	2	-	-	-	-
Line marking works and road adjustments	1	-	-	-	-	-	-	-	-	-	2	-	-	-	-
Construct new signalised intersection	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-
Place barriers to new queuing area	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Establishment of construction facilities	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-
Onsite car parking	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Workshop, deliveries, maintenance, and storage	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Construction of tunnel shaft and declines (outside acoustic shed)	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-
Spoil handling inside acoustic shed	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-
On-site truck movements	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Tunnelling support activities	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Site rehabilitation and landscape	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-
Cumulative works (day)	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-
Cumulative works scenario (night)	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-

Note:

1: The ‘Remaining’ category includes public buildings, libraries, café/bars, etc.

The above table shows that:

- Other sensitive receivers in this precinct are generally predicted to be subject to relatively minor noise impacts during the daytime. Receivers in the education, medical and remaining categories would not be subject to any NML exceedances
- Two 'other sensitive receivers' in this area would be subject to worst case exceedances of 11 to 20 dBA above NML during the higher noise generating activities. These receivers are:
  - Child Care – Explore and Develop, 372 Norton Street, Lilyfield (within NCA09)
  - Child Care – Billy Kids learning, 64 Charles Street, Lilyfield (within NCA09).

The recommended 'standard' and 'additional' noise mitigation as discussed in **section 10.1.8** along with recommended specific site mitigation measures would be implemented to mitigate NML exceedances at other sensitive receivers.

NCA summary

Table 10-36 provides a summary of the key activities within each NCA affected by activities in the Darley Road works area.

Table 10-36 Location summary of construction impacts – Darley Road

NCA	Location
NCA05	No impacts above the project NMLs are predicted within this NCA for all works activities
NCA08	No impacts above the project NMLs are predicted within this NCA for all works activities
NCA09	**Most affected receivers:** Residential receivers which front the north side of City West Link between Charles Street and Norton Street **Worst case construction scenario:** Road adjustment works and spoil handling works within the acoustic shed during all works periods **Highest construction noise impacts:** • Use of a rock breaker during the daytime period as part of the demolition works and; • Use of a road profiler during the night-time period as part of the road adjustment works
NCA10	**Most affected receivers:** Residential receivers which front Lilyfield Road and which have line of sight to the works down Francis Street and James Street **Worst case construction scenario:** Minor impacts are predicted only during the night period
NCA11	**Most affected receivers:** Residential receivers which adjoin the north side of City West Link between Norton Street and Henry Street **Worst case construction scenario:** Road adjustment works during the night-time period **Highest construction noise impacts:** Use of a road profiler during the night-time period as part of the road adjustment works
NCA12	**Most affected receivers:** Residential receivers which adjoin the south side of City West Link between Norton Street and Henry Street **Worst case construction scenario:** Road adjustment works during the night-time period **Highest construction noise impacts:** Use of a road profiler during the night-time period as part of the road adjustment works

NCA	Location
NCA13	**Most affected receivers:** Residential receivers which adjoin the Darley Road civil and tunnel site (C4) on Darley Road between Norton Street and Falls Street. The most noise affected receivers are located between Charles Street and Norton Street due to their proximity to the construction site **Worst case construction scenario:** Road adjustments works and spoil handling works within the acoustic shed during all works periods **Highest construction noise impacts:** • Use of a rock breaker during the daytime period as part of the demolition works and • Use of a road profiler during the night-time period as part of the road adjustment works
NCA14	**Most affected receivers:** Residential receivers and the St Columba Primary School located on William Street to the south of the construction site that have line of sight to the construction site down Charles Street, North Street and James Street **Worst case construction scenario:** Minor impacts are predicted only during the night period

Cumulative construction impacts

Given that concurrent activities may occur within Darley Road civil and tunnel site (C4) during any period, it is likely that receivers would, occasionally, be subject to cumulative noise impacts from construction sites operating concurrently in the same area. Cumulative construction noise impacts may be apparent during the daytime period where cumulative impacts are predicted to result in minor NML exceedances of up to 10 dBA.

Construction road traffic

The assessment indicates that construction traffic is unlikely to result in a noticeable increase in L_{Aeq} noise levels at receivers along the proposed construction traffic routes (Darley Road and City West Link). It is also important to note that no local roads would be used by heavy vehicles during works.

Management of construction impacts

The assessment of construction impacts identified the following in-situ mitigation measures that should be included for this study area:

- Increased site hoarding to height of four metres around the ancillary facility
- Upgrading the acoustic shed performance
- Limiting the total internal sound power level to 110 dBA within the acoustic shed.

Ground-borne noise and vibration Impacts

Ground-borne noise from tunnelling works associated with construction of the mainline tunnel alignment and access ramps is summarised in **section 10.3.7**.

Based on the excavation of the access tunnel at this site, 10 residential receivers are predicted to exceed the night-time ground-borne NML for up to approximately 14 days. While most roadheader works are anticipated to progress at a consistent rate, there may be discrete locations which require a longer duration of tunnelling works due to site conditions.

Up to five buildings in this area may be within the minimum vibration working distances should a large rock-breaker be used at the outer extents of the Darley Road works area. Around 74 receivers in the vicinity of the site would fall within the nominated minimum working distance for human comfort vibration should a large rock-breaker be used at the outer extents of the site. One heritage-listed item has been identified as having the potential to be within the minimum safe working distances should a large rock-breaker be used at the outer extents of the project footprint.

The following mitigation measures should be considered where feasible and reasonable:

- Validation of predicted ground-borne noise levels (note that this may not be required where the ground-borne noise impacts would last less than three weeks at any one sensitive receiver and should be confirmed during detailed design)
- Use of alternative method to de-couple load path/equipment that generates less vibration where feasible and reasonable
- Notification letterbox drops to receivers in the area around the works location, detailing work activities, time periods over which these would occur, impacts and mitigation measures
- Specific notifications provided to receivers where the ground-borne noise levels are predicted to exceed the night-time NMLs, providing additional information when relevant and more specific information than covered in general letterbox drops
- Respite periods may be offered to the affected residents during works where vibration intensive plant levels are predicted to be operated within the safe working distance for human comfort for an extended period of time on any one day.

The specific management strategy for addressing potential impacts associated with ground-borne noise outside of standard daytime construction hours would be documented in the OOHW protocol.

10.3.3 Rozelle

Description of works

Rozelle civil and tunnel site (C5)

This site would be mainly used to support:

- Tunnelling of the Rozelle interchange and Iron Cove Link
- Construction of one new intersection on City West Link
- Construction of the cut-and-cover structure and entry and exit ramps that would connect the surface road network with the proposed future Western Harbour Tunnel and Beaches Link
- Modifications to City West Link/The Crescent intersection to enable future use of this intersection by motorists moving between the surface road network and the proposed future Western Harbour Tunnel and Beaches Link
- Upgrade and modification works to the surface road network including along City West Link, The Crescent and Victoria Road
- Construction of the Rozelle motorway operations complex
- Landscaping works, including construction of open space and pedestrian and cyclist facilities.

The site would include temporary site offices, workshops and storage facilities, laydown areas, entry and exit points for construction traffic, a temporary substation, temporary ventilation for the tunnels, temporary water treatment plants and sediment ponds, workforce amenities and car parking.

Roadheaders would be launched from this site to excavate the Rozelle interchange, the Iron Cove Link and the tunnels that would enable connections to the proposed future Western Harbour Tunnel and Beaches Link. Three acoustic sheds would be built on the site to minimise noise from out-of-hours tunnelling and spoil handling.

The Crescent civil site (C6)

The Crescent civil site (C6) would be located between The Crescent and Rozelle Bay on land owned by Roads and Maritime. The site would be used to support the realignment of The Crescent including the construction of the new bridge over Whites Creek, widening and improvement works to Whites Creek, and construction of the drainage outfall and culvert that would direct flows through and from the Rozelle Rail Yards to Rozelle Bay. The site would be cleared and a hardstand and laydown area, site offices, workforce amenities and car parking established.

Victoria Road civil site (C7)

The Victoria Road civil site (C7) would be located on the western side of Victoria Road between Quirk Street and Lilyfield Road on land currently occupied by commercial properties. The existing buildings and other structures on the site would be demolished to facilitate establishment of temporary site offices, a small laydown area, workforce amenities and car parking. A portion of this site would be occupied by operational road infrastructure during operation.

Works schedule

Subject to planning approval, construction activities at Rozelle would be undertaken according to the program shown in **Table 10-37**.

Table 10-37 Indicative construction program and duration – Rozelle

Works	2018 Q				2019 Q				2020 Q				2021 Q				2022 Q				2023 Q			
	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Rozelle civil and tunnel site (C5)																								
Site establishment and utility works				■	■	■	■	■																
Traffic diversions and intersection works						■	■	■																
Construction of cut-and-cover and tunnel portals						■	■	■	■															
Tunnelling									■	■	■	■	■	■	■	■	■	■						
Construction of motorway operational infrastructure									■	■	■	■	■	■	■	■	■	■						
Civil and mechanical fitout													■	■	■	■	■	■	■					
Site rehabilitation and landscaping																			■	■	■			
Demobilisation																						■	■	
Testing and commissioning																			■	■	■	■	■	
The Crescent civil site (C6)																								
Site establishment and utility works					■	■	■																	
Surface road and intersection works					■	■																		
Whites Creek widening and improvement works						■	■	■	■															
Drainage works including construction of the culvert below City West Link and upgrades to the drainage outfall to Rozelle Bay						■	■	■	■	■														
Construction of Whites Creek Bridge and demolition of existing bridge									■	■	■	■	■											
Rehabilitation and landscaping													■	■	■	■								
Victoria Road civil site (C7)																								
Site establishment					■	■	■																	
Support for the operation of the Rozelle civil and tunnel site							■	■	■	■	■	■	■	■	■	■	■	■	■					
Site rehabilitation and landscaping																				■				

Airborne noise

The proposed construction activities, NMLs and sound power levels for the typical operation of construction equipment at the Rozelle site can be found in **Appendix J** (Technical working paper: Noise and vibration).

A summary of the predicted noise levels (without additional mitigation) in each of the NCAs for the various work activities is also presented in **Appendix J** (Technical working paper: Noise and vibration). These results are split into residential, commercial and other sensitive receivers.

The predicted noise levels presented in this report and **Appendix J** (Technical working paper: Noise and vibration) are representative of the worst case impacts where works are undertaken closest to each NCA. For most construction activities, it is expected that the construction noise levels would frequently be lower than predicted at the most-exposed receiver as the noise levels presented in this report are based on a realistic worst case assessment.

The predicted noise levels presented in **Table 10-39** and **Appendix J** (Technical working paper: Noise and vibration) are representative of the worst case impacts where works are undertaken closest to each NCA. For most construction activities, it is expected that the construction noise levels would frequently be lower than predicted at the most-exposed receiver as the noise levels presented in this report are based on a realistic worst case assessment.

NMLs have been derived for the works at Rozelle based on the measured background noise levels provided in **Appendix J** (Technical working paper: Noise and vibration). These are outlined in **Table 10-38**. The NMLs for commercial receivers in all NCAs is 70 dBA.

Table 10-38 Residential NMLs for Rozelle

NCA	Receiver type	Standard construction (RBL+10 dBA) Daytime period	Out of hours (RBL+5 dBA)[1]			Sleep disturbance screening (RBL+15 dBA)
			Daytime period	Evening period	Night period	
NCA15	Residential	54	49	47	40	50
NCA16	Residential	64	59	57	49	59
NCA19	Residential	64	59	57	49	59
NCA20	Residential	54	49	47	40	50
NCA21	Residential	58	53	53	47	57
NCA23	Residential	59	54	50	41	51
NCA24	Residential	64	59	57	49	59
NCA25	Residential	61	56	56	50	60
NCA27	Residential	59	54	54	47	57
NCA28	Residential	55	50	45	40	50
NCA29	Residential	71	66	65	49	59
NCA30	Residential	71	66	65	49	59

Note

1: Out of Hours construction hours includes both evening and night-time construction hours. Evening hours are 6.00 pm to 10.00 pm Monday to Sunday. Night-time hours are 10.00 pm to 7.00 am Monday to Friday and 10.00 pm to 8.00 am Saturday, Sunday and public holidays.

Table 10-39 Predicted airborne noise for Rozelle

Component	Activity	Indicative duration (weeks)	Proposed time of occurrence			Predicted worst case $L_{Aeq15min}$ level in each NCA (dBA)		Sound power level (dBA)	Sound pressure level at 10 m (dBA)
			Day	Evening	Night	At least affected NCA	At worst affected NCA		
Rozelle civil and tunnel site (C5)									
Site establishment	Demolition of existing structures	8	Y	N	N	51	80	120	92
	Site clearing	4	Y	N	N	46	75	113	85
	Installation of environmental controls	4	Y	N	N	41	70	108	80
	Utility works	64	Y	N	N	50	79	117	89
	Establishment of construction facilities	16	Y	N	N	47	76	114	86
	Site drainage	16	Y	N	N	48	74	115	87
Temporary road and intersection modification	Pavement modifications	36	Y	Y	Y	47	68	116	88
	Pavement and infrastructure works	36	Y	Y	Y	44	65	113	85
	Onsite car parking	120	Y	N	N	30	36	71	43
	Workshop, deliveries, maintenance, and storage – laydown areas	120	Y	Y	Y	34	61	104	76
	Tunnel shafts and declines	52	Y	N	N	45	76	114	86
	Onsite truck movements	120	Y	Y	Y	37	52	102	74
	Spoil handling above ground within acoustic shed Rozelle – New M5 via M4-M5 Link	120	Y	Y	Y	36	61	97	69
	Spoil handling above ground within acoustic shed Rozelle – Anzac Bridge to M4 East via M4-M5 Link and City West Link	120	Y	Y	Y	39	54	97	69

Component	Activity	Indicative duration (weeks)	Proposed time of occurrence			Predicted worst case $L_{Aeq15min}$ level in each NCA (dBA)		Sound power level (dBA)	Sound pressure level at 10 m (dBA)
			Day	Evening	Night	At least affected NCA	At worst affected NCA		
	Spoil handling above ground within acoustic shed Rozelle – Western Harbour Tunnel	120	Y	Y	Y	36	61	97	69
	Tunnelling supporting activities	120	Y	Y	Y	31	39	82	54
Civil and mechanical fitout	Ventilation building installation	84	Y	N	N	46	73	115	87
	Ventilation building installation and tunnel – concrete works	84	Y	N	N	37	64	106	78
Site rehabilitation	Site rehabilitation and landscaping	60	Y	N	N	37	66	104	76
The Crescent civil site (C6)									
Site establishment	Site clearing	2	Y	N	N	43	67	113	85
	Installation of environmental controls	2	Y	N	N	38	62	108	80
	Establishment of construction facilities	2	Y	N	N	44	68	114	86
General site operations	Workshop, deliveries, maintenance, and storage – laydown areas	192	Y	Y	Y	34	58	104	76
Victoria Road civil site (C7)									
Site establishment	Demolition of existing structures	4	Y	N	N	42	90	120	92
	Utility works	26	Y	N	N	39	87	117	89
	Site clearing	1	Y	N	N	35	83	113	85
	Installation of environmental controls	1	Y	N	N	30	78	108	80
General construction activities (outside construction ancillary facilities)									
Civil works – CWL, Victoria Road and The Crescent road upgrades including cut-and-	Pilling works	192	Y	N	N	40	78	113	85
	Earthworks and drainage works	192	Y	N	N	45	86	116	88

Component	Activity	Indicative duration (weeks)	Proposed time of occurrence			Predicted worst case $L_{Aeq15min}$ level in each NCA (dBA)		Sound power level (dBA)	Sound pressure level at 10 m (dBA)
			Day	Evening	Night	At least affected NCA	At worst affected NCA		
cover/dive structures and approach roads	Bridge works	192	Y	Y	Y	39	66	111	83
	Concrete works	192	Y	Y	Y	34	76	106	78
	Road works and utility works	192	Y	Y	Y	44	83	113	85

The highest noise levels and greatest impacts are associated with activities that utilise noise intensive plant items, including:

- Diamond/concrete saws
- Excavators with breaker.

Short duration works (up to four weeks) which are required within this study area consist of:

- Demolition of existing structures
- Site clearing
- Installation of environmental controls
- Establishment of construction facilities and site remediation.

During standard daytime construction hours, the highest impacts (greater than 20 dBA exceedance of NMLs) associated with short term works are generally predicted to be at receivers immediately adjacent to construction sites during the use of noise intensive plant items such as concrete saws.

Works undertaken outside of standard construction hours have the potential for greater noise impacts (greater than 20 dBA exceedance of NMLs) throughout the study area, especially during the most sensitive night-time period. This is due to more stringent NMLs during these periods than during the daytime. Impacts during this period are likely to extend beyond receivers immediately adjacent to the construction sites.

Long term construction works (up to 192 weeks) required within this study area consists of:

- Utility works
- Establishment of construction facilities and drainage works
- Temporary road and intersection modifications
- Tunnelling activities, including spoil handling and supporting activities
- Civil and mechanical works including earthworks, road works, and ventilation facility works
- General operations associated with construction ancillary facilities.

During standard daytime construction hours, the highest impacts (greater than 20 dBA exceedance of NMLs) associated with long term works are generally predicted to be at receivers which are immediately adjacent to the construction sites during the operation of high noise construction plant such as graders and dozers.

During works outside of standard construction hours, the highest impacts (greater than 20 dBA exceedance of NMLs) associated with long term works are generally predicted to be at receivers which are immediately adjacent to the construction sites. The highest NML exceedances predicted for long-term works outside of standard construction hours are representative of the operation of high noise construction plant such as graders and dozers in close proximity to sensitive receivers.

While construction works at long term construction sites would be undertaken over a relatively longer percentage of the overall project duration, the noisy construction plant responsible for the worst case construction noise impacts would not be in continuous operation, nor would the works be undertaken in the same area for the full duration of the construction project. During periods where the noisy construction plant is either not in operation, or is not located immediately adjacent a sensitive receiver, the construction noise levels are anticipated to be significantly lower than the worst case predictions.

Highly noise affected residential receivers

The ICNG considers residential receivers that are subject to predicted noise levels of 75 dBA or greater to be highly noise affected. The number of highly noise affected receivers in the study area has been determined and is summarised in **Table 10-40**. The table shows the number of residential receivers separated by works activity.

Table 10-40 Predicted number of highly noise affected residential receivers by works

Activity	Period		
	Day	Eve	Night
Rozelle civil and tunnel site (C5)			
Demolition of existing structures	20	-	-
Site clearing	1	-	-
Installation of environmental controls	-	-	-
Utility works	29	-	-
Establishment of construction facilities	3	-	-
Site drainage	-	-	-
Pavement modifications	-	-	-
Pavement and infrastructure works	-	-	-
General worksite and car parking	-	-	-
Workshop, deliveries, laydown areas	-	-	-
Tunnel shafts and declines	3	-	-
Onsite truck movements	-	-	-
Spoil handling above ground within acoustic shed Rozelle – New M5 to CWL	-	-	-
Spoil handling above ground within acoustic shed Rozelle AB to M4 to M5 Link	-	-	-
Spoil handling above ground within acoustic shed Rozelle Western Harbour Tunnel	-	-	-
Tunnelling supporting activities	-	-	-
Ventilation building installation	-	-	-
Ventilation building installation and tunnel – concrete works	-	-	-
Site rehabilitation and landscaping	-	-	-
The Crescent civil site (C6)			
Site clearing	-	-	-
Installation of environmental controls	-	-	-
Establishment of construction facilities	-	-	-
Workshop, deliveries, maintenance and storage laydown area	-	-	-
Victoria Road civil site (C7)			
Demolition of existing structures	20	-	-
Utility works	13		
Site clearing	6	-	-
Installation of environmental controls	5	-	-
General construction activities			
Piling and general	1	-	-
Earthworks, drainage and general utility works	24	-	-
Bridge works	-	-	-
Concrete works	1	1	1

Activity	Period		
	Day	Eve	Night
Road works and utility works	11	11	11
Rozelle cumulative assessment			
Cumulative assessment	-	-	-

The above table shows that receivers are predicted to be highly noise affected during certain works activities. The highest numbers are apparent during:

- Demolition of existing structures, where 40 receivers are predicted to be highly noise affected
- Utility works, where 29 receivers predicted to be highly noise affected
- Earthworks general and drainage, where 24 receivers are predicted to be highly noise affected.

Eleven highly noise affected receivers are predicted due road works and utility works, which would be required both during and outside standard daytime construction hours to avoid potential traffic impacts.

The locations of the highly noise affected residential receivers, from all works and in any time period, are shown in red in **Figure 10-17**.

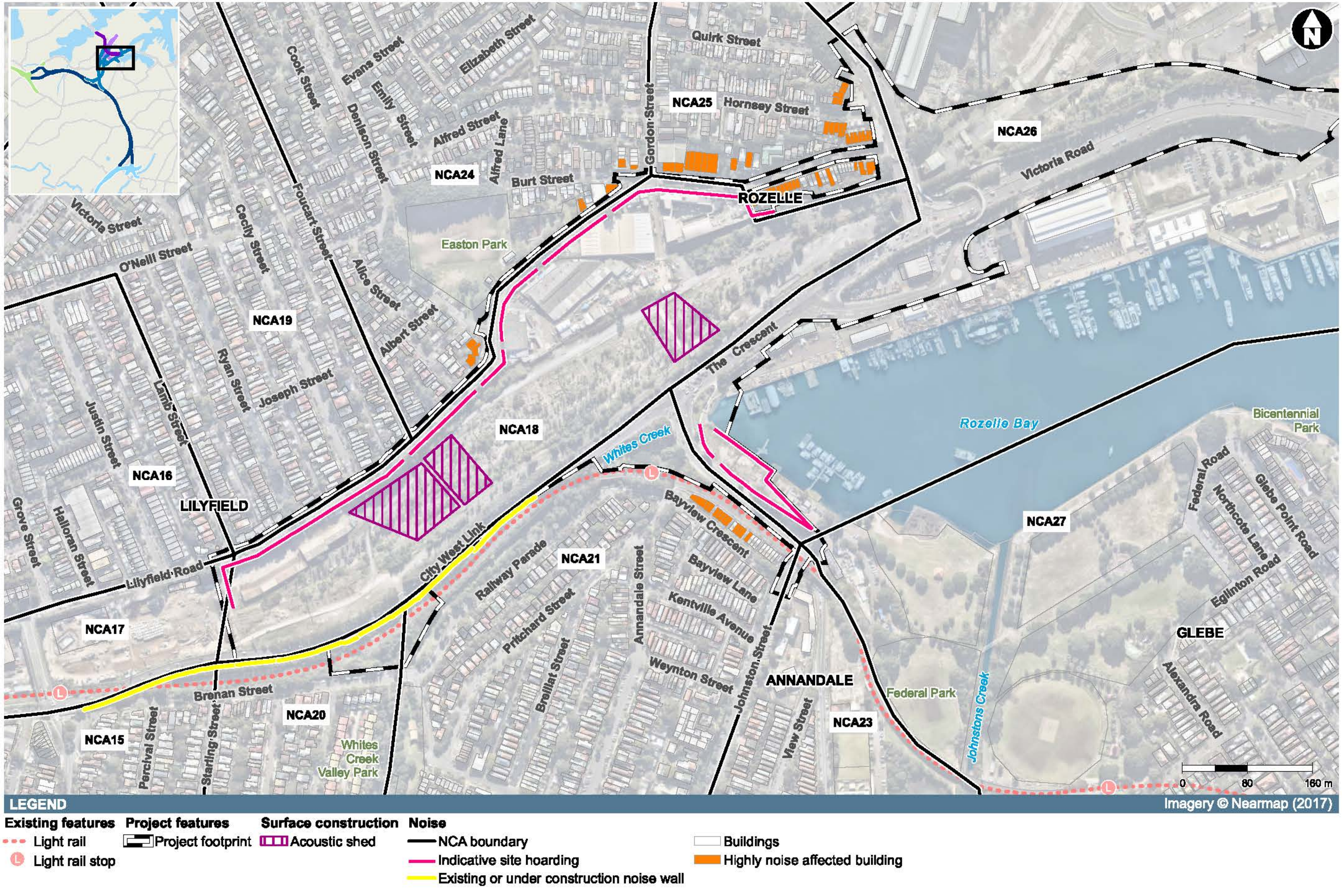


Figure 10-17 Highly noise affected residential receivers - Rozelle

The most affected receivers are typically dwellings which surround and have direct line of sight to the various works locations. Worst case noise impacts, however, would only occur when high noise generating works are being carried out immediately adjacent to these residential receivers.

Other sensitive receivers

Other sensitive receivers, such as educational facilities, hospitals and childcare centres, which are potentially affected by construction works have been assessed against the various criteria detailed in **section 10.1.3**.

The predicted NML exceedances for other sensitive receivers are summarised in **Table 10-41**. The assessment provides further context to the predicted worst case levels presented in Table 10-39 as it presents the number of receivers predicted to experience exceedances of the NMLs, summarised in bands of 10 dBA, and separated by receiver type.

Table 10-41 Overview of sensitive receiver NML exceedances

Activity	Number of other sensitive receivers exceeding NMLs														
	Education			Medical			Place of Worship			Childcare			Remaining[1]		
	1-10 dBA	11-20 dBA	>20 dBA	1-10 dBA	11-20 dBA	>20 dBA	1-10 dBA	11-20 dBA	>20 dBA	1-10 dBA	11-20 dBA	>20 dBA	1-10 dBA	11-20 dBA	>20 dBA
Rozelle civil and tunnel site (C5)															
Demolition of existing structures	1	-	-	-	-	-	1	-	-	2	-	-	1	-	-
Site clearing	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-
Installation of environmental controls	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Utility works	1	-	-	-	-	-	1	-	-	1	-	-	1	-	-
Establishment of construction facilities	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-
Site drainage	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-
Pavement modifications	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Pavement and infrastructure works	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
On site car parking	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Workshop, deliveries, laydown areas	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Tunnel shafts and declines	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Onsite truck movements	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Spoil handling above ground within acoustic shed Rozelle – New M5 via M4-M5 Link	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Spoil handling above ground within acoustic shed Rozelle – Anzac Bridge to M4 East via M4-M5 Link and City West Link	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Spoil handling above ground within acoustic shed Rozelle – Western Harbour Tunnel	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Tunnelling supporting activities	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Ventilation building installation	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Ventilation building installation and	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Activity	Number of other sensitive receivers exceeding NMLs														
	Education			Medical			Place of Worship			Childcare			Remaining[1]		
	1-10 dBA	11-20 dBA	>20 dBA	1-10 dBA	11-20 dBA	>20 dBA	1-10 dBA	11-20 dBA	>20 dBA	1-10 dBA	11-20 dBA	>20 dBA	1-10 dBA	11-20 dBA	>20 dBA
tunnel – concrete works															
Site rehabilitation and landscaping	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
The Crescent civil site (C6)															
Site clearing	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Installation of environmental controls	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Establishment of construction facilities	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Workshop, deliveries, maintenance and storage laydown area	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Victoria Road civil site (C7)															
Demolition of existing structures	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-
Utility works	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-
Site clearing	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-
Installation of environmental controls	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-
General construction activities															
Piling works	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-
Earthworks and drainage works	-	-	-	-	-	-	1	-	-	-	1	-	-	-	-
Bridge works	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-
Concrete works	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-
Road works and utility works	-	-	-	-	-	-	1	-	-	-	-	1	-	-	-
Rozelle cumulative assessment															
Cumulative assessment	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Note:

1: The ‘Remaining’ category includes public buildings, libraries, cafés/bars, etc.

The above table shows that:

- Other sensitive receivers in this precinct are generally predicted be subject to relatively minor noise impacts during the daytime. Receivers in the education, medical and remaining categories would not be subject to any NML exceedances
- One ‘other sensitive receiver’ in this area would be subject to worst case exceedances of 11 to 20 dBA above NML during the higher noise generating activities. This receiver is a childcare centre at 5 Quirk Street, Rozelle (located within NCA25). This same receiver would also be subject to worst case exceedances of >20 dBA above NML during the higher noise generating activities.

The recommended ‘standard’ and ‘additional’ noise mitigation as discussed in **section 10.1.8** along with recommended specific site mitigation measures would be implemented to mitigate NML exceedances at other sensitive receivers.

NCA summary

Table 10-42 provides a summary of the key activities within each NCA affected by activities in the Darley Road works area.

Table 10-42 Location summary of construction impacts – Rozelle

NCA	Location
NCA15	**Most affected receivers:** residential receivers located to the south of City West Link between Starling Street and Russell Street **Worst case construction scenario:** Roadworks and utility works and site establishment works within the Rozelle civil and tunnel site (C5) during all works periods **Highest construction noise impacts:** Use of a number of noise intensive items of plant during the night-time period as part of road works
NCA16	**Most affected receivers:** Residential receivers which situated to the north of Lilyfield Road between Grove Street and Lamb Street **Worst case construction scenario:** Roadworks and utility works and site establishment works within the Rozelle civil and tunnel site (C5) during all works periods **Highest construction noise impacts:** Use of a number of noise intensive items of plant during the night-time period as part of road works
NCA17	All receivers within this NCA are predicted to comply with the construction NMLs for all construction scenarios during all works periods
NCA18	All receivers within this NCA are predicted to comply with the construction NMLs for all construction scenarios during all works periods
NCA19	**Most affected receivers:** Residential receivers which are situated to the north of Lilyfield Road between Lamb Street and Foucart Street **Worst case construction scenario:** Roadworks and utility works, site establishment works and spoil handling activities within the Rozelle civil and tunnel site (C5) during out of hours works periods **Highest construction noise impacts:** Use of a number of noise intensive items of plant during the night-time period as part of road works
NCA20	**Most affected receivers:** Residential receivers which are situated near Brenan Street between Starling Street and Railway Parade **Worst case construction scenario:** Roadworks and utility works, and activities within the Rozelle civil and tunnel site (C5) during out of hours works periods **Highest construction noise impacts:** Use of a number of noise intensive items of plant during the night-time period as part of road works
NCA21	**Most affected receivers:** Residential receivers which are situated near Railway Parade and Bayview Crescent **Worst case construction scenario:** Roadworks and utility works and activities within the Rozelle civil and tunnel site (C5) and The Crescent civil site (6) during all works periods **Highest construction noise impacts:** Use of a number of noise intensive items of plant during the night-time period as part of road works
NCA22	All receivers within this NCA are predicted to comply with the construction NMLs for all construction scenarios during all works periods
NCA23	**Most affected receivers:** Residential receivers and an educational facility which are situated near The Crescent and Johnston Street intersection **Worst case construction scenario:** Roadworks and utility works and activities within The Crescent civil site (6) during all works periods. **Highest construction noise impacts:** Use of a number of noise intensive items of plant during the night-time period as part of road works

NCA	Location
NCA24	**Most affected receivers:** Residential receivers which are situated to the north of Lilyfield Road between Foucart Street and Gordon Street **Worst case construction scenario:** Roadworks and utility works, site establishment works and spoil handling activities within the Rozelle civil and tunnel site (C5) during all works periods **Highest construction noise impacts:** Use of a concrete saw during the night-time period as part of pavement and infrastructure works
NCA25	**Most affected receivers:** Residential receivers which are situated near Lilyfield Road between Gordon Street and Victoria Road **Worst case construction scenario:** Roadworks and utility works, site establishment works and spoil handling activities within the Rozelle civil and tunnel site (C5) and the Victoria Road civil site (C7) during all works periods. **Highest construction noise impacts:** • Use of a rock breaker during the daytime period as part of the demolition works and • Use of a number of noise intensive items of plant during the night-time period as part of road works
NCA26	**Most affected receivers:** Commercial receivers situated along James Craig Drive **Worst case construction scenario:** Roadworks and utility works during the daytime period **Highest construction noise impacts:** Use of a number of noise intensive items of plant during the night-time period as part of road works
NCA27	**Most affected receivers:** Residential receivers which front Rozelle Bay between Alexandra Road and Glebe Point Road **Worst case construction scenario:** Roadworks and utility works during all work periods **Highest construction noise impacts:** Use of a number of noise intensive items of plant during the night-time period as part of road works
NCA28	**Most affected receivers:** Residential receivers which front Rozelle Bay and Anzac Bridge **Worst case construction scenario:** Roadworks and utility works during all work periods **Highest construction noise impacts:** Use of a number of noise intensive items of plant during the night-time period as part of road works
NCA29	**Most affected receivers:** Residential receivers which are situated near Victoria Road between Robert Street and Evans Street **Worst case construction scenario:** Roadworks and utility works and site establishment works located at the Victoria Road civil site (C7) during all works periods **Highest construction noise impacts:** • Use of a rock breaker during the daytime period as part of the demolition works and • Use of a number of noise intensive items of plant during the night-time period as part of road works

NCA	Location
NCA30	**Most affected receivers:** Residential receivers which are situated near Victoria Road between Darling Street and Evans Street **Worst case construction scenario:** Roadworks and utility works and site establishment works located at the Victoria Road civil site (C7) during all works periods **Highest construction noise impacts:** • Use of a rock breaker during the daytime period as part of the demolition works and • Use of a number of noise intensive items of plant during the night-time period as part of road works

Cumulative construction impacts

Given that several tunnelling works activities may operate simultaneously during any period, it is likely that receivers would, occasionally, be subject to cumulative noise impacts from works activities operating concurrently in the same area (associated with both M4-M5 Link and the proposed future Western Harbour Tunnel). Cumulative construction noise impacts may be apparent during out of hour's works periods where cumulative impacts are predicted to result in NML exceedances of up to 20 dBA during the night-time period.

Consecutive construction impacts

The Rozelle study area would likely be subject to construction impacts from works associated with other infrastructure projects, including the approved and currently under construction CBD and South East Light Rail (CSELR) Rozelle maintenance depot. This combination of these projects may result in receivers being exposed to extended construction noise impacts, which may occur consecutively.

The short-term noise intensive works are generally associated with discrete activities which occur over a number of days or weeks in moving locations rather than throughout the entire project at fixed locations. Therefore, the focus of assessing consecutive impacts is to identify works activities which repeat (or are similar to other activities) over extended periods. The longer-term impacts associated with construction ancillary facility activity may continue between separate projects in the area and may appear to be of a similar nature to the community.

The receivers most likely to be affected by consecutive construction impacts are:

- Receivers adjoining Lilyfield Road between Justin Street and Ryan Street (NCA16 and NCA19)
- Receivers adjoining Brenan Street between Starling Street and White Street (NCA15).

In situations where consecutive long term construction noise impacts occur, at-receiver noise mitigation may be considered where feasible and reasonable, once options for at source noise mitigation and management measures have been exhausted. The requirement for this should be evaluated in consultation with Roads and Maritime and the community during detailed design, and should be considered when preparing the site specific CNVIS for this area.

Construction road traffic

The assessment indicates that construction traffic is unlikely to result in a noticeable increase in L_{Aeq} noise levels at receivers along the proposed construction traffic routes (City West Link, Victoria Road and The Crescent).

Management of construction impacts

The assessment of construction impacts identified the following in-situ mitigation measures that should be included for this study area:

- Increasing site hoarding to height of four metres along the boundary with Lilyfield Road and on the eastern side of The Crescent at Annandale
- Upgrading the acoustic shed performance.

Ground-borne noise and vibration impacts

Ground-borne noise from tunnelling works associated with construction of the mainline tunnel alignment and access ramps is summarised in **section 10.3.7**.

Based on the excavation of the ventilation tunnels at this site, 63 residential receivers are predicted to exceed the night-time ground-borne NML for up to a maximum of approximately 16 days for each roadheader. While most roadheader works would be anticipated to progress at a consistent rate, there may be discreet locations which require a longer duration of tunnelling works due to site conditions.

In the Rozelle area, there are several ventilation tunnels, mainline tunnels and access ramps which may be under construction simultaneously and/or consecutively. During simultaneous construction, ground-borne noise levels would be dominated by the closest roadheader to the receiver, however, where multiple roadheaders are operating at a similar distance from the receiver this may result in ground-borne noise impacts marginally higher than the predicted noise levels. Consecutive construction with roadheaders would not increase the level of ground-borne noise but may increase the duration of impacts at any one receiver. Detailed scheduling of roadheader works would be determined during detailed design.

Up to 124 buildings in this area may be within the minimum vibration working distances should a large rock-breaker be used at the outer extents of the project footprint. Around 345 receivers in the vicinity of this works location would fall within the nominated minimum working distance for human comfort vibration should a large rock-breaker be used at the outer extents of the works location. Nineteen heritage-listed items have been identified as having the potential to be within the minimum safe working distances should a large rock-breaker be used at the outer extents of the project footprint.

The following mitigation measures would be considered and implemented where feasible and reasonable:

- Validation of predicted ground-borne noise levels (note that this may not be required where the ground-borne noise impacts would last less than three weeks at any one sensitive receiver and would be confirmed during detailed design)
- Notification letterbox drops to receivers in the area around the works locations, detailing work activities, time periods over which these would occur, impacts and mitigation measures
- Specific notifications provided to receivers where the ground-borne noise levels are predicted to exceed the night-time NML, providing additional information when relevant and more specific information than covered in general letterbox drops
- Validation of predicted vibration levels at the nearest receiver buildings to the vibration intensive works
- Use of alternative method to de-couple load path/equipment that generates less vibration where feasible and reasonable
- Notification letterbox drops to receivers in the area around the works locations, detailing work activities, time periods over which these would occur, impacts and mitigation measures
- Respite periods may be offered to affected residents during works where vibration intensive plant levels are predicted to be operated within the safe working distance for human comfort for an extended period of time on any one day.

The specific management strategy for addressing potential impacts associated with ground-borne noise outside of standard daytime construction hours would be documented in the OOHW protocol.

10.3.4 Iron Cove

Description of works

The Iron Cove Link civil site (C8) would be located on Victoria Road, east of Iron Cove Bridge, between Byrnes Street and Springside Street. The site would support the construction of the Iron Cove Link tunnel connection and would include the following elements:

- Temporary site offices

- Workshop and storage facilities
- Laydown area
- Temporary and permanent substations
- Water treatment plant (temporary)
- Car parking
- Construction of twin tunnel declines
- Construction of ventilation facilities (supply and exhaust)
- Demolition of acquisition properties along Victoria Road.

Heavy vehicle access to the site would be directly onto Victoria Road. Heavy vehicles would turn left after exiting the site and head west over Iron Cove Bridge. All tunnel spoil from the Iron Cove Link would be loaded via the Rozelle civil and tunnel site. Construction activities would change the configuration of streets which currently access Victoria Road between Byrnes Street and Springside Street.

Works schedule

Subject to planning approval, construction activities at the Iron Cove Link civil site would be undertaken according to the program shown in **Table 10-31**.

Table 10-43 Indicative construction program and duration – Iron Cove Link

Activity	2018 Q				2019 Q				2020 Q				2021 Q				2022 Q				2023 Q			
	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Site establishment and utility works				■	■	■	■	■	■	■	■	■												
Traffic diversions and intersection works						■	■	■																
Construction of cut-and-cover and tunnel portals									■	■	■	■	■	■	■	■	■	■	■	■				
Construction of motorway operational infrastructure									■	■	■	■	■	■	■	■	■	■	■	■				
Site rehabilitation and landscaping																			■	■	■			
Testing and commissioning																			■	■	■	■	■	

Airborne noise

The proposed construction activities, NMLs and sound power levels for the typical operation of construction equipment at the Darley Road site can be found in **Appendix J** (Technical working paper: Noise and vibration).

A summary of the predicted noise levels (without additional mitigation) in each of the NCAs for the various work activities is also presented in **Appendix J** (Technical working paper: Noise and vibration). These results are split into residential, commercial and other sensitive receivers.

The predicted noise levels presented in this report and **Appendix J** (Technical working paper: Noise and vibration) are representative of the worst case impacts where works are undertaken closest to each NCA. For most construction activities, it is expected that the construction noise levels would frequently be lower than predicted at the most-exposed receiver as the noise levels presented in this report are based on a realistic worst case assessment.

The predicted noise levels presented in **Table 10-45** and **Appendix J** (Technical working paper: Noise and vibration) are representative of the worst case impacts where works are undertaken closest to each NCA. For most construction activities, it is expected that the construction noise levels would frequently be lower than predicted at the most-exposed receiver as the noise levels presented in this report are based on a realistic worst case assessment.

Noise management levels (NML) have been derived for the works at Haberfield based on the measured background noise levels provided in **Appendix J** (Technical working paper: Noise and vibration). These are outlined in **Table 10-44**. The NMLs for commercial receivers in all NCAs is 70 dBA.

Table 10-44 Residential NMLs for Iron Cove

NCA	Receiver type	Standard construction (RBL+10 dBA)	Out of hours (RBL+5 dBA)[1]			Sleep disturbance screening (RBL+15 dBA)
		Daytime period	Daytime period	Evening period	Night period	
NCA30	Residential	71	66	65	49	59
NCA31	Residential	73	68	63	48	58
NCA32	Residential	73	68	63	48	58
NCA33	Residential	54	49	45	36	46
NCA34	Residential	75	70	65	51	61
NCA35	Residential	75	70	65	51	61
NCA36	Residential	54	49	45	36	46
NCA38	Residential	55	50	45	40	50

Note

1: Out of hours construction hours includes both evening and night-time construction hours. Evening hours are 6.00 pm to 10.00 pm Monday to Sunday. Night-time hours are 10.00 pm to 7.00 am Monday to Friday and 10.00 pm to 8.00 am Saturday, Sunday and public holidays.

Table 10-45 Predicted airborne noise for Iron Cove

Component	Activity	Indicative duration (weeks)	Proposed time of occurrence			Predicted worst case $L_{Aeq15min}$ level in each NCA (dBA)		Sound power level (dBA)	Sound pressure level at 10 m (dBA)
			Day	Evening	Night	At least affected NCA	At worst affected NCA		
Site establishment	Demolition of existing buildings	24	Y	N	N	56	91	122	94
	Site clearing	1	Y	N	N	47	82	113	85
	Installation of environmental controls	1	Y	N	N	42	77	108	80
	Utility works	104	Y	Y	Y	51	86	117	89
	Pavement and infrastructure works	2	Y	Y	Y	50	85	116	88
	Establishment of construction	1	Y	N	N	48	83	114	86
General site operations	Onsite car parking	144	Y	N	N	30	66	97	69
	Workshop, deliveries, maintenance, and storage	144	Y	N	N	38	73	104	76
	Supporting infrastructure	144	Y	Y	Y	<30	52	82	54
Construction	Pilling	84	Y	N	N	46	75	113	85
	Earthworks general and drainage	84	Y	N	N	49	84	116	88
	Concrete works	84	Y	Y	Y	48	80	111	83
	Roadworks	104	Y	Y	Y	50	82	113	85
	Ventilation facilities and substation	144	Y	N	N	37	71	107	79
Site rehabilitation and landscaping	Site rehabilitation and landscaping	12	Y	N	N	38	73	104	76

The highest noise levels and greatest impacts are associated with activities that utilise noise intensive plant items, including:

- Diamond/concrete saws
- Excavators with breaker.

Short duration works (up to two weeks) which are required within this study area consist of:

- Site clearing
- Installation of environmental controls
- Pavement and infrastructure works
- Establishment of construction facilities.

During standard daytime construction hours, the highest impacts (greater than 20 dBA exceedance of NMLs) associated with short term works are generally predicted to be at receivers immediately adjacent to construction sites during the use of noise intensive plant items such as concrete saws.

Works undertaken outside of standard construction hours have the potential for greater noise impacts (greater than 20 dBA exceedance of NMLs) throughout the study area, especially during the most sensitive night-time period. This is due to more stringent NMLs during these periods than during the daytime. Impacts during this period are likely to extend beyond receivers immediately adjacent the works areas.

Long term construction works (up to 144 weeks) required within this study area consist of:

- Demolition of existing buildings
- Utility works
- General construction ancillary facility operations including car parking, deliveries, and supporting works
- Civil works including earthworks, bridge works, and road works
- Site rehabilitation.

During standard daytime construction hours, the highest impacts (greater than 20 dBA exceedance of NMLs) associated with long term works are generally predicted to be at receivers which are immediately adjacent to the construction sites during the operation of high noise construction plant such as concrete saws, rock breakers, and dozers.

During works outside of standard construction hours, the highest impacts (greater than 20 dBA exceedance of NMLs) associated with long term works are generally predicted to be at receivers which are immediately adjacent to the construction sites. The highest NML exceedances predicted for long-term works outside of standard construction hours are representative of the operation of high noise construction plant such as concrete saws in close proximity to sensitive receivers.

While construction works at long term construction sites would be undertaken over a relatively longer percentage of the overall project duration, the noisy construction plant responsible for the worst case construction noise impacts would not be in continuous operation, nor would the works be undertaken in the same area for the full duration of the construction project. During periods where the noisy construction plant is either not in operation, or is not located immediately adjacent a sensitive receiver, the construction noise levels are anticipated to be significantly lower than the worst case predictions. **Table 10-48** provides a summary of the general locations of impacts associated works.

Highly noise affected residential receivers

The ICNG considers residential receivers that are subject to predicted noise levels of 75 dBA or greater to be highly noise affected. The number of highly noise affected receivers in the study area has been determined and is summarised in **Table 10-46**. The table shows the number of residential receivers separated by works activity.

Table 10-46 Predicted number of highly noise affected residential receivers by works

Activity	Period		
	Day	Eve	Night
Demolition of existing buildings	53	-	-
Site Clearing	8	-	-
Installation of environmental controls	2	-	-
Utility works	17	17	17
Pavement and infrastructure works	14	14	14
Establishment of construction facilities	10	-	-
On site car parking	-	-	-
Worksite delivers maintenance and storage	-	-	-
Supporting infrastructure	-	-	-
Pilling	4	-	-
Earthworks general and drainage	22	-	-
Concrete works	8	8	8
Roadworks	22	22	22
Ventilation facility and substation	-	-	-
Site rehabilitation	-	-	-
Cumulative works scenario	-	-	-

The location of the highly noise affected residential receivers, from all works and in any time period, are shown in red in **Figure 10-18**.

LEGEND

Project features

Project footprint

Noise

NCA boundary

Indicative site hoarding

Existing or under construction noise wall

Buildings

Highly noise affected building

Figure 10-18 Highly noise affected residential receivers - Iron Cove

The most affected receivers are typically dwellings which have direct line of sight to the various works locations. Highly noise affected residential receivers are predicted outside standard daytime construction hours associated with utility works, pavement and infrastructure works and roadworks. These activities would be required outside standard daytime construction hours to avoid potential traffic impacts. Worst case noise levels, however, would only be expected to be apparent when high noise generating works are being carried out immediately adjacent to these residential receivers. These activities would not be expected to occur continuously over the entire durations indicated.

Other sensitive receivers

Other sensitive receivers, such as educational facilities, hospitals and childcare centres, which are potentially affected by construction works have been assessed against the various criteria detailed in **section 10.1.3**.

The predicted NML exceedances for other sensitive receivers are summarised in **Table 10-47**. The assessment provides further context to the predicted worst case noise levels presented in as it presents the number of and type of receivers predicted to experience exceedances of the NMLs, summarised in bands of 10 dBA.

Table 10-47 Overview of sensitive receiver NML exceedances

Activity	Number of other sensitive receivers exceeding NMLs														
	Education			Medical			Place of Worship			Childcare			Outdoor Recreational		
	1-10 dBA	11-20 dBA	>20 dBA	1-10 dBA	11-20 dBA	>20 dBA	1-10 dBA	11-20 dBA	>20 dBA	1-10 dBA	11-20 dBA	>20 dBA	1-10 dBA	11-20 dBA	>20 dBA
Demolition of existing buildings	2	-	-	-	-	-	1	-	-	5	-	-	1	1	-
Site clearing	-	-	-	-	-	-	-	-	-	1	-	-	1	-	-
Installation of environmental controls	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-
Utility works	1	-	-	-	-	-	-	-	-	2	-	-	-	1	-
Pavement and infrastructure works	1	-	-	-	-	-	-	-	-	2	-	-	-	1	-
Establishment of construction facilities	1	-	-	-	-	-	-	-	-	1	-	-	-	1	-
On site car parking	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Worksite delivers maintenance and storage	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Supporting infrastructure	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Pilling	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Earthworks general and drainage	1	-	-	-	-	-	-	-	-	2	-	-	1	1	-
Concrete works	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-
Roadworks	-	1	-	-	-	-	1	-	-	-	-	-	-	2	-
Ventilation station and substation	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Site rehabilitation	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-
Cumulative works scenario	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

The above table shows the following:

- Other sensitive receivers are generally predicted to be subject to relatively minor noise impacts during the daytime with no exceedances of greater than 20 dBA

- One educational facility in this area would be subject to worst case exceedances of 11 to 20 dBA above NML during the higher noise generating activities. This receiver is Rozelle Public School, located at 663 Darling Street, Rozelle (within NCA31).

The recommended ‘standard’ and ‘additional’ noise mitigation as discussed in **section 10.1.8**, along with recommended specific site mitigation measures would be implemented to mitigate NML exceedances at other sensitive receivers.

NCA summary

Table 10-48 provides a summary of the key activities within each NCA affected by activities in the Darley Road works area.

Table 10-48 Location summary of construction impacts – Iron Cove

NCA	Location
NCA30	**Most affected receivers:** Residential receivers which front Victoria Road and Darling Street **Worst case construction scenario:** Receivers within this NCA are generally predicted to comply with the construction NMLs for all construction scenarios during all works periods with the exception of minor exceedances during roadworks, utility works, and pavement and infrastructure works activities **Highest construction noise impacts:** Use of a number of noise intensive items of plant during the night-time period
NCA31	**Most affected receivers:** Residential, commercial and educational receivers fronting front Victoria Road, Darling Street, and Merton Street **Worst case construction scenario:** Roadworks, utility works and pavement and infrastructure works during all works periods **Highest construction noise impacts:** Use of a number of noise intensive items of plant during the night-time period
NCA32	**Most affected receivers:** Residential and commercial receivers that front Victoria Road and Waterloo Street **Worst case construction scenario:** Roadworks, utility works and pavement and infrastructure works during all works periods **Highest construction noise impacts:** Use of a number of noise intensive items of plant during the night-time period
NCA33	**Most affected receivers:** Residential receivers closest to Victoria Road **Worst case construction scenario:** Demolition of existing buildings during the daytime, roadworks, utility works and pavement and infrastructure works during out of hour’s works periods **Highest construction noise impacts:** Use of a number of noise intensive items of plant during the night-time period
NCA34	**Most affected receivers:** Commercial receivers fronting Victoria Road and residential receivers on Terry Street and Wellington Street **Worst case construction scenario:** • For commercial receivers: demolition of existing buildings and earthworks during the daytime • For residential receivers: roadworks, utility works and pavement and infrastructure works during out of hours works periods **Highest construction noise impacts:** Use of a number of noise intensive items of plant during the night-time period

NCA	Location
NCA35	**Most affected receivers:** Residential receivers fronting front Victoria Road and the construction site **Worst case construction scenario:** roadworks, utility works and pavement and infrastructure works during out of hour's works periods **Highest construction noise impacts:** Use of a number of noise intensive items of plant during the night-time period
NCA36	**Most affected receivers:** Residential receivers at the eastern end of Byrnes Street, Clubb Street, and Toelle Street that are closest to the construction site **Worst case construction scenario:** • Demolition of existing buildings during the daytime • Utility works and pavement and infrastructure works during out of hours works periods **Highest construction noise impacts:** Use of a number of noise intensive items of plant during the night-time period
NCA38	**Most affected receivers:** residential receivers fronting the Parramatta River with line of sight to the construction site **Worst case construction scenario:** utility works and pavement and infrastructure works during out of hour's works periods **Highest construction noise impacts:** Use of a number of noise intensive items of plant during the night-time period

Cumulative construction impacts

Given that several construction ancillary facility related activities may operate simultaneously during any period, it is likely that receivers would, occasionally, be subject to cumulative noise impacts from works activities operating concurrently in the same area. Cumulative construction noise impacts may be apparent during the standard daytime works period where cumulative impacts are predicted to result in NML exceedances of up to 20 dBA.

Construction road traffic

The assessment indicates that construction traffic is unlikely to result in a noticeable increase in L_{Aeq} noise levels at receivers along the proposed construction traffic routes (Victoria Road). It is also important to note that no local roads would be used by heavy vehicles during works.

Management of construction impacts

The assessment of construction impacts identified the following in-situ mitigation measures that should be included for this study area:

- Increased site hoarding to height of four metres around all construction sites.

Site hoarding along the property boundaries may not be able to be installed until after the demolition of the acquired buildings has been completed.

Ground-borne noise and vibration impacts

Ground-borne noise from tunnelling works associated with construction of the mainline tunnel alignment and access ramps is summarised in **section 10.3.7**.

The nature of the construction works at the Iron Cove site (surface works with minimal screening effects) means that ground-borne noise impacts are expected to be negligible. This is because the airborne noise emissions in most circumstances are much higher than the ground-borne noise levels. As such ground-borne noise is not anticipated to be the controlling factor for these works.

Up to 45 buildings in this area may be within the minimum cosmetic damage vibration working distances should a large rock-breaker be used at the outer extents of the project footprint. Under this scenario, around 107 receivers in the vicinity of the works location would fall within the nominated minimum working distance for human comfort vibration. No heritage-listed items have been identified that would be within the minimum safe working distances should a large rock-breaker be used at the outer extents of the project footprint.

The following mitigation measures should be considered where feasible and reasonable:

- Validation of predicted vibration levels at the nearest receiver buildings to the vibration intensive works
- Use of alternative methods to de-couple load path/equipment that generates less vibration where feasible and reasonable
- Notification letterbox drops to receivers in the area around the works locations, detailing work activities, time periods over which these would occur, impacts and mitigation measures
- Respite periods may be offered to affected residents during works where vibration intensive plant levels are predicted to be operated within the safe working distance for human comfort for an extended period of time on any one day.

The specific management strategy for addressing potential impacts associated with ground-borne noise outside of standard daytime construction hours would be documented in the OOHW protocol.

10.3.5 Pyrmont Bridge Road

Description of works

The Pyrmont Bridge Road tunnel site (C9) would be located at the intersection of Pyrmont Bridge Road and Parramatta Road, between Gordon Street and Mallet Street. The site currently comprises commercial properties. The construction site would not include the brewery on the west side of the site or the residential and commercial properties northeast of Bignell Lane. Access to the properties from Bignell Lane would be retained, which would be converted to a cul-de-sac for the duration of the works.

The Pyrmont Bridge Road tunnel site would be the main mid-tunnel construction site along the eastern section of the mainline tunnel alignment. The site would include:

- Workshop and storage facilities
- Laydown area
- Entry and exit point for haulage of tunnel spoil
- Temporary substation
- Temporary ventilation plant
- Temporary water treatment plant
- Car parking.

Roadheaders would be launched from this site and would initially excavate the construction decline and then the mainline tunnels traveling in a northerly and southerly direction. An acoustic shed would be established on the site to minimise noise from out-of-hours tunnelling and spoil handling.

Heavy vehicle access to the site would be via Parramatta Road. Heavy vehicles would turn left to enter the site from the eastbound carriageway of Parramatta Road and a site access road would be constructed to take trucks directly into the acoustic shed. Heavy vehicle egress from the site would be via Pyrmont Bridge Road.

Works schedule

Subject to planning approval, construction activities at the Pyrmont Bridge Road site would be undertaken according to the program shown in **Table 10-51**.

Table 10-49 Indicative construction program and duration – Pyrmont Bridge Road

Activity	2018 Q				2019 Q				2020 Q				2021 Q				2022 Q			
	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Initial road works and traffic management			■																	
Site establishment and utility works			■	■	■															
Construction of temporary access tunnel				■	■	■														
Tunnelling						■	■	■	■	■	■	■	■							
Civil and mechanical fitout												■	■	■	■					
Testing and commissioning																■	■	■	■	
Site rehabilitation																			■	■

Airborne noise

The proposed construction activities, NMLs and sound power levels for the typical operation of construction equipment at the Pyrmont Bridge Road site can be found in **Appendix J** (Technical working paper: Noise and vibration).

A summary of the predicted noise levels (without additional mitigation) in each of the NCAs for the various work activities is also presented in **Appendix J** (Technical working paper: Noise and vibration). These results are split into residential, commercial and other sensitive receivers.

The predicted noise levels presented in this report and **Appendix J** (Technical working paper: Noise and vibration) are representative of the worst case impacts where works are undertaken closest to each NCA. For most construction activities, it is expected that the construction noise levels would frequently be lower than predicted at the most-exposed receiver as the noise levels presented in this report are based on a realistic worst case assessment.

The predicted noise levels presented in **Table 10-51** and **Appendix J** (Technical working paper: Noise and vibration) are representative of the worst case impacts where works are undertaken closest to each NCA. For most construction activities, it is expected that the construction noise levels would frequently be lower than predicted at the most-exposed receiver as the noise levels presented in this report are based on a realistic worst case assessment.

Noise management levels (NML) have been derived for the works at Haberfield based on the measured background noise levels provided in **Appendix J** (Technical working paper: Noise and vibration). These are outlined in **Table 10-52**. The NMLs for commercial receivers in all NCAs is 70 dBA.

Table 10-50 Residential NMLs for Pyrmont Bridge Road

NCA	Receiver type	Standard construction (RBL+10 dBA) Daytime period	Out of hours (RBL+5 dBA)[1]			Sleep disturbance screening (RBL+15 dBA)
			Daytime period	Evening period	Night period	
NCA40	Residential	61	56	54	46	56
NCA41	Residential	61	56	54	46	56
NCA42	Residential	61	56	54	46	56
NCA43	Residential	61	56	54	46	56
NCA44	Residential	61	56	54	46	56

Note:

1: Out of hours construction hours includes both evening and night-time construction hours. Evening hours are 6.00 pm to 10.00 pm Monday to Sunday. Night-time hours are 10.00 pm to 7.00 am Monday to Friday and 10.00 pm to 8.00 am Saturday, Sunday and public holidays.

Table 10-51 Predicted airborne noise for Pyrmont Bridge Road

Component	Activity	Indicative duration (weeks)	Proposed time of occurrence			Predicted worst case $L_{Aeq15min}$ level in each NCA (dBA)		Sound power level (dBA)	Sound pressure level at 10 m (dBA)
			Day	Evening	Night	At least affected NCA	At worst affected NCA		
Site establishment	Demolition of existing buildings	8	Y	N	N	62	84	120	92
	Site clearing	1	Y	N	N	55	77	113	85
	Utility works	1	Y	N	N	56	78	117	89
	Installation of environmental controls	1	Y	N	N	50	72	108	80
	Pavement and infrastructure works	2	Y	Y	Y	54	82	118	90
	Establishment of construction facilities	6	Y	N	N	56	78	114	86
Tunnelling and supporting works	Onsite car parking	180	Y	Y	Y	34	49	97	69
	Workshop, deliveries, maintenance, and storage	180	Y	Y	Y	45	60	103	75

Component	Activity	Indicative duration (weeks)	Proposed time of occurrence			Predicted worst case $L_{Aeq15min}$ level in each NCA (dBA)		Sound power level (dBA)	Sound pressure level at 10 m (dBA)
			Day	Evening	Night	At least affected NCA	At worst affected NCA		
	Construction of tunnel shaft and declines (outside acoustic shed)	48	Y	N	N	54	72	114	86
	Spoil handling inside acoustic shed	72	Y	Y	Y	47	64	97	69
	Onsite truck movements	72	Y	Y	Y	35	51	94	66
	Tunnelling support activities	72	Y	Y	Y	<30	40	82	54
Site rehabilitation and landscaping	Site rehabilitation and landscaping	12	Y	N	N	47	69	105	77

The highest noise levels and greatest impacts are associated with activities that utilise noise intensive plant items, including:

- Diamond/concrete saws
- Excavators with breakers.

Short duration works (up to two weeks) which are required within this study area consist of:

- Site clearing
- Utility works
- Installation of environmental controls
- Pavement and infrastructure works.

During standard daytime construction hours, the highest impacts (greater than 20 dBA exceedance of NMLs) associated with short term works are generally predicted to be at receivers immediately adjacent to the construction site during the use of noise intensive plant items such as rock breakers.

Works undertaken outside of standard construction hours have the potential for greater impacts (greater than 20 dBA exceedance of NMLs) throughout the study area, especially during the most sensitive night-time period. This is due to more stringent NMLs during these periods than during the daytime. Impacts during this period are likely to extend beyond receivers immediately adjacent the works areas.

Long term construction works (up to 180 weeks) which are required within this study area consist of:

- Demolition of existing buildings
- Establishment of construction facilities
- Tunnelling activities, including the operation of laydown areas and car parking.
- Construction of access tunnel
- Site rehabilitation works.

During standard daytime construction hours, the highest impacts (greater than 20 dBA exceedance of NMLs) associated with long term works are generally predicted to be at receivers which are immediately adjacent to the construction site.

During works outside of standard construction hours, the highest impacts (up to 20 dBA exceedance of NMLs) associated with long term works are also generally predicted to be at receivers which are immediately adjacent to the construction site.

Highly noise affected residential receivers

The ICNG considers residential receivers that are subject to predicted noise levels of 75 dBA or greater to be highly noise affected. The number of highly noise affected receivers in the study area has been determined and is summarised in **Table 10-52**. The table shows the number of residential receivers separated by works activity.

Table 10-52 Predicted number of highly noise affected residential receivers by works – Pyrmont Bridge Road

Activity	Period		
	Day	Eve	Night
Demolition of existing buildings	6	-	-
Site clearing	1	-	-
Utility works	2	-	-
Installation of environmental controls	-	-	-
Pavement and infrastructure works	4	4	4
Establishment of construction facilities	2	-	-

Activity	Period		
	Day	Eve	Night
Onsite car parking	-	-	-
Workshop, deliveries, maintenance, and storage	-	-	-
Construction of tunnel shaft and declines (outside acoustic shed)	-	-	-
Spoil handling inside acoustic shed	-	-	-
On site truck movements	-	-	-
Tunnelling support activities	-	-	-
Site rehabilitation and Landscape	-	-	-
Cumulative	-	-	-

The location of the highly noise affected residential receivers, from all works and in any time period, are shown in **Figure 10-19**.

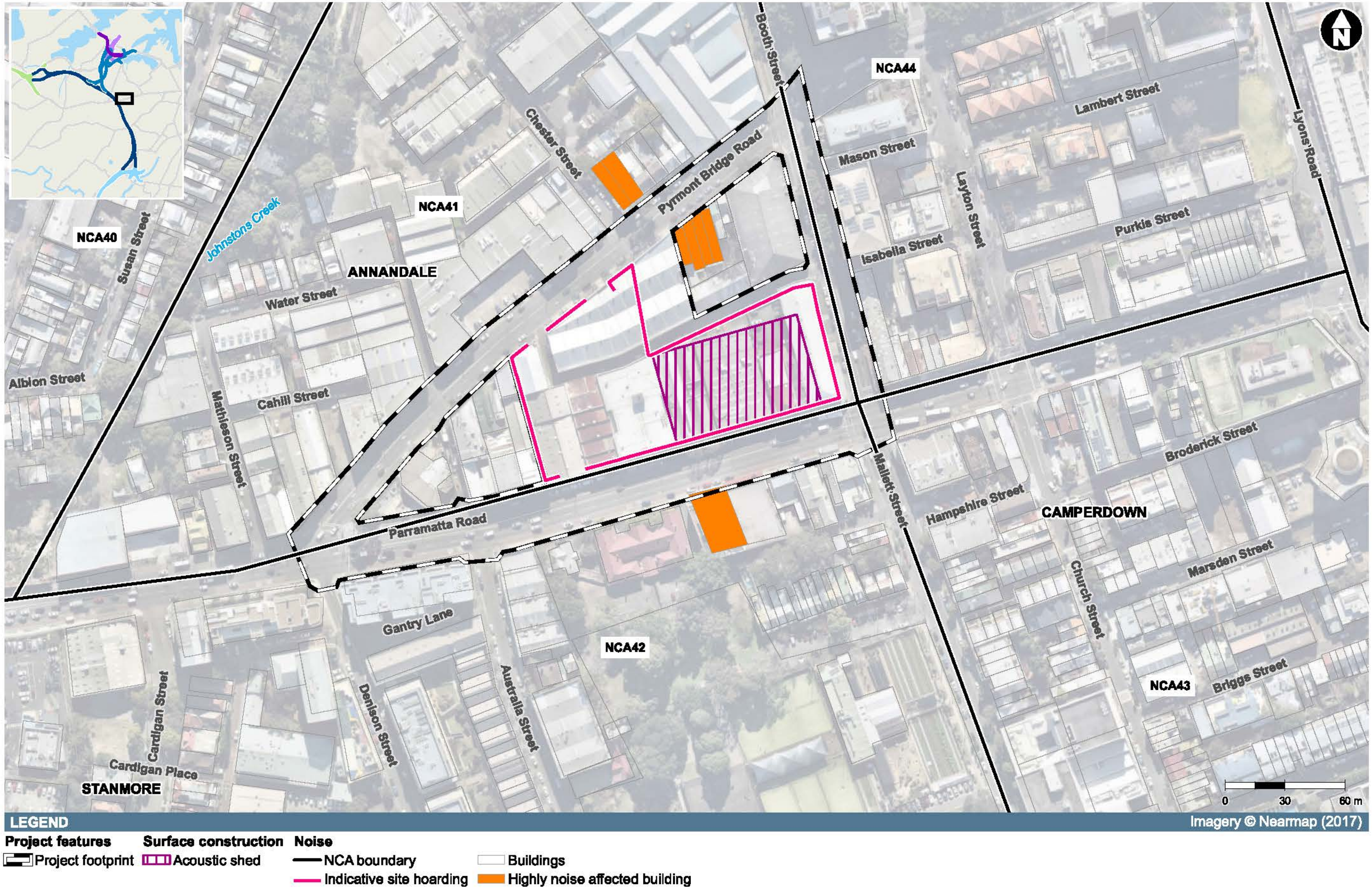


Figure 10-19 Highly noise affected residential receivers - Pyrmont Bridge Road

The most impacted receivers are typically dwellings which surround and have direct line of sight to the various works locations. Worst case noise levels, however, would only be expected to be apparent when high noise generating works are being carried out immediately adjacent to these residential receivers.

Other sensitive receivers

Other sensitive receivers, such as educational facilities, hospitals and childcare centres, which are potentially affected by construction works have been assessed against the various criteria detailed in **section 10.1.3**.

The predicted NML exceedances for other sensitive receivers are summarised in **Table 10-53**. The assessment provides further context to the predicted worst case noise levels presented in **Table 10-51** as it presents the number of and type of receivers predicted to experience exceedances of the NMLs, summarised in bands of 10 dBA.

Table 10-53 Overview of sensitive receiver NML exceedances – Pyrmont Bridge Road

Activity	Number of other sensitive receivers exceeding NMLs														
	Education			Medical			Place of Worship			Childcare			Remaining		
	1-10 dBA	11-20 dBA	>20 dBA	1-10 dBA	11-20 dBA	>20 dBA	1-10 dBA	11-20 dBA	>20 dBA	1-10 dBA	11-20 dBA	>20 dBA	1-10 dBA	11-20 dBA	>20 dBA
Demolition of existing buildings	1	-	1	4	-	-	1	-	-	3	-	-	3	-	-
Site clearing	-	1	-	-	-	-	-	-	-	-	-	-	1	-	-
Utility works	-	1	-	-	-	-	-	-	-	-	-	-	1	-	-
Installation of environmental controls	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Pavement and infrastructure works	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-
Establishment of construction facilities	-	1	-	-	-	-	-	-	-	-	-	-	1	-	-
Onsite car parking	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Workshop, deliveries, maintenance, and storage	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Construction of tunnel shaft and declines (outside acoustic shed)	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-
Spoil handling inside acoustic shed	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-
On site truck movements	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Tunnelling support activities	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Site rehabilitation and Landscape	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cumulative	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Note:

1: The 'Remaining' category includes public buildings, libraries, café/bars, etc.

The above table shows the following:

- Other sensitive receivers in this precinct are generally predicted be subject to relatively minor noise impacts during the daytime

- One ‘other sensitive receiver’ in this area would be subject to worst case exceedances of 11 to 20 dBA above NML during the higher noise generating activities. This receiver is Bridge Road School located at 127 Parramatta Road, Camperdown (within NCA42). This same receiver would also be subject to worst case exceedances of >20 dBA above NML during the higher noise generating activities.

The recommended ‘standard’ and ‘additional’ noise mitigation as discussed in **section 10.1.8,** along with recommended specific site mitigation measures would be implemented to mitigate NML exceedances at other sensitive receivers.

NCA summary

Table 10-54 provides a summary of the key activities within each NCA affected by activities in the Pyrmont Bridge Road works area.

Table 10-54 Location summary of construction impacts – Pyrmont Bridge Road

NCA	Location
NCA40	**Most affected receivers:** Residential receivers which are situated on Susan Street and Nelson Street between Parramatta Road and Chester Street **Worst case construction scenario:** Pavement and infrastructure works during all works periods **Highest construction noise impacts:** Use of a concrete saw during the night-time period as part of pavement and infrastructure works
NCA41	**Most affected receivers:** Residential receivers which front Pyrmont Bridge Road and adjoin the Pyrmont Bridge Road tunnel site (C9) between Parramatta Road and Booth Street **Worst case construction scenario:** Demolition of existing structures, construction site car parking and deliveries and pavement and infrastructure work during all works periods **Highest construction noise impacts:** • Use of a rock breaker during the daytime period as part of the demolition works • Use of a concrete saw during the night-time period as part of the pavement and infrastructure works
NCA42	**Most affected receivers:** Residential receivers and an educational facility which front the southern side of Parramatta Road between Bridge Road and Mallet Street. **Worst case construction scenario:** Demolition of existing structures, construction site car parking, construction ancillary facility deliveries, and pavement and infrastructure works during all periods. **Highest construction noise impacts:** • Use of a rock breaker during the daytime period as part of the demolition works • Use of a concrete saw during the night-time period as part of the pavement and infrastructure works
NCA43	**Most affected receivers:** Residential receivers which front the southern side of Parramatta Road between Mallet Street and Missenden Road **Worst case construction scenario:** Demolition of existing structures, construction site car parking and deliveries and pavement and infrastructure works during all periods **Highest construction noise impacts:** • Use of a rock breaker during the daytime period as part of the demolition works • Use of a concrete saw during the night-time period as part of the pavement and infrastructure works

NCA	Location
NCA44	**Most affected receivers:** Residential receivers which front the eastern side of Mallett Street between Parramatta Road and Alexandra Drive **Worst case construction scenario:** demolition of existing structures, construction site car parking, construction ancillary facility deliveries, and pavement and infrastructure works during all periods **Highest construction noise impacts:** • Use of a rock breaker during the daytime period as part of the demolition works • Use of a concrete saw during the night-time period as part of the pavement and infrastructure works

Cumulative construction impacts

Given that several tunnelling works activities may operate simultaneously during any period, it is likely that receivers would, occasionally, be subject to cumulative noise impacts from works activities operating concurrently in the same area. Cumulative construction noise impacts may be apparent during the standard daytime works periods where cumulative impacts are predicted to result in minor NML exceedances of up to 20 dBA during the night period.

Construction road traffic

The assessment indicates that construction traffic is unlikely to result in a noticeable increase in L_{Aeq} noise levels at receivers along the proposed construction traffic routes (Parramatta Road and Pyrmont Bridge Road). It is also important to note that no local roads would be used by heavy vehicles during works.

Management of construction impacts

The assessment of construction impacts identified the following in-situ mitigation measures that should be included for this study area:

- Increasing site hoarding to four metres in select areas
- Upgrading the acoustic shed performance.

Ground-borne noise and vibration impacts

Ground-borne noise from tunnelling works associated with construction of the mainline tunnel alignment and access ramps is summarised in **section 10.3.7**.

Based on the excavation of the access tunnel at this site, three residential receivers and two other sensitive receivers are predicted to exceed the night-time ground-borne NML for up to approximately 16 days. While most roadheader works are anticipated to progress at a consistent rate, there may be discreet locations which require a longer duration of tunnelling works due to site conditions.

Up to 33 buildings in this area may be within the minimum vibration working distances should a large rock-breaker be used at the outer extents of the project footprint. For this scenario, around 73 receivers in the vicinity of the site would fall within the nominated minimum working distance for human comfort vibration. Five heritage listed items have been identified as having the potential to be within the minimum safe working distances should a large rock-breaker be used at the outer extents of the project footprint. The following mitigation measures should be considered where feasible and reasonable:

- Validation of predicted ground-borne noise levels (note that this may not be required where the ground-borne noise impacts would last less than three weeks at any one sensitive receiver and should be confirmed during detailed design)
- Notification letterbox drops to receivers in the area around the works locations, detailing work activities, time periods over which these would occur, impacts and mitigation measures

- Specific notifications provided to receivers where the ground-borne noise levels are predicted to exceed the night-time NML, providing additional information when relevant and more specific information than covered in general letterbox drops
- Validation of predicted vibration levels at the nearest receiver buildings to the vibration intensive works
- Use of alternative method to de-couple load path / equipment that generates less vibration where feasible and reasonable
- Notification letterbox drops to receivers in the area around the works locations, detailing work activities, time periods over which these would occur, impacts and mitigation measures
- Respite periods may be offered to affected residents during works where vibration intensive plant levels are predicted to be operated within the safe working distance for human comfort for an extended period of time on any one day.

The specific management strategy for addressing potential impacts associated with ground-borne noise outside of standard daytime construction hours would be documented in the OOHW protocol.

10.3.6 St Peters

Description of works

The Campbell Road civil and tunnel site (C10) would be located on the southern side of Albert Street and Campbell Lane at St Peters. The site is currently being used as a construction ancillary facility for the New M5 project.

The Campbell Road civil and tunnel site would be the main tunnel site at the southern end of the project footprint. The site would include:

- Temporary site offices
- Workshop and storage facilities
- Laydown area
- Entry and exit points for haulage of tunnel spoil
- Temporary substation, ventilation and water treatment plant
- Sedimentation pond
- Workforce amenities and car parking.

Roadheaders would be launched from this site and would excavate the tunnels and ramps travelling in a northern direction. An acoustic shed would be established on the site to minimise noise from out-of-hours tunnelling and spoil handling. In addition, temporary noise mitigation measures would include noise barriers and other temporary structures such as site buildings, which would be provided to minimise noise impacts on the surrounding properties.

Access to and egress from the site for all vehicles would be via Campbell Street at Albert Street. There would be permanent changes to the intersection on Campbell Street at Albert Street to allow heavy vehicles to turn right into the site.

Works schedule

Subject to planning approval, construction activities at Campbell Road would be undertaken according to the program shown in **Table 10-55**.

Table 10-55 Indicative construction program and duration – Campbell Road

Works	2018 Q				2019 Q				2020 Q				2021 Q				2022 Q			
	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Campbell Road civil and tunnel site (C10)																				
Initial road works and traffic management				■																
Site establishment and utility works				■	■	■														
Tunnelling						■	■	■	■	■	■	■	■							
Civil and mechanical fitout													■	■	■	■				
Construction of motorway operational infrastructure												■	■	■	■	■	■			
Testing and commissioning																■	■	■	■	■
Site demobilisation and rehabilitation																			■	■

Airborne noise

The proposed construction activities, NMLs and sound power levels for the typical operation of construction equipment at the St Peters site can be found in **Appendix J** (Technical working paper: Noise and vibration).

A summary of the predicted noise levels (without additional mitigation) in each of the NCAs for the various work activities is also presented in **Appendix J** (Technical working paper: Noise and vibration). These results are split into residential, commercial and other sensitive receivers.

The predicted noise levels presented in this report and **Appendix J** (Technical working paper: Noise and vibration) are representative of the worst case impacts where works are undertaken closest to each NCA. For most construction activities, it is expected that the construction noise levels would frequently be lower than predicted at the most-exposed receiver as the noise levels presented in this report are based on a realistic worst case assessment.

The predicted noise levels presented in **Table 10-57** and **Appendix J** (Technical working paper: Noise and vibration) are representative of the worst case impacts where works are undertaken closest to each NCA. For most construction activities, it is expected that the construction noise levels would frequently be lower than predicted at the most-exposed receiver as the noise levels presented in this report are based on a realistic worst case assessment.

Noise management levels (NML) have been derived for the works at Haberfield based on the measured background noise levels provided in **Appendix J** (Technical working paper: Noise and vibration). These are outlined in **Table 10-58**. The NMLs for commercial receivers in all NCAs is 70 dBA.

Table 10-56 Residential NMLs for St Peters

NCA	Receiver type	Standard construction (RBL+10 dBA) Daytime period	Out of hours (RBL+5 dBA)[1]			Sleep disturbance screening (RBL+15 dBA)
			Daytime period	Evening period	Night period	
NCA47	Residential	67	62	56	45	55
NCA48	Residential	67	62	56	45	55
NCA49	Residential	64	59	50	45	55
NCA50	Residential	62	57	55	49	59
NCA51	Residential	60	55	51	44	54
NCA52	Residential	60	55	51	44	54
NCA54	Residential	68	63	61	54	64
NCA55	Residential	68	63	61	47	57

Note:

1: Out of hours construction hours includes both evening and night-time construction hours. Evening hours are 6.00 pm to 10.00 pm Monday to Sunday. Night-time hours are 10.00 pm to 7.00 am Monday to Friday and 10.00 pm to 8.00 am Saturday, Sunday and public holidays.

Table 10-57 Predicted airborne noise for St Peters

Component	Activity	Indicative duration (weeks)	Proposed time of occurrence			Predicted worst case LAeq15min level in each NCA (dBA)		Sound power level (dBA)	Sound pressure level at 10 m (dBA)
			Day	Evening	Night	At least affected NCA	At worst affected NCA		
Site establishment	Installation of environmental controls	2	Y	N	N	38	57	108	80
	Pavement and infrastructure works	2	Y	N	N	45	64	113	85
	Establishment of construction facilities	24	Y	N	N	44	63	114	86
General site operations	On site car parking	4	Y	Y	Y	<30	42	97	69
	Workshop, deliveries, maintenance, and storage	4	Y	Y	Y	32	48	103	75

Component	Activity	Indicative duration (weeks)	Proposed time of occurrence			Predicted worst case LAeq15min level in each NCA (dBA)		Sound power level (dBA)	Sound pressure level at 10 m (dBA)
			Day	Evening	Night	At least affected NCA	At worst affected NCA		
	Spoil handling above ground within acoustic shed	72	Y	Y	Y	33	54	97	69
	On site truck movements	72	Y	Y	Y	31	35	97	69
	Tunnelling support activities	72	Y	Y	Y	<30	37	82	54
Construction	Ventilation building installation	72	Y	N	N	35	59	107	79
	Lane configuration changes (ramp)	8	Y	N	N	37	60	113	85
	Construction of tunnel cut-and-cover (outside acoustic shed)	8	Y	N	N	42	70	114	86
Site rehabilitation and landscaping	Site rehabilitation and landscaping	12	Y	N	N	35	54	105	77

During standard daytime construction hours, the proposed construction works at the St Peters construction site are predicted to comply with the applicable NMLs in all NCAs.

The highest noise levels and greatest impacts are associated with activities that are performed during the more sensitive out of hours periods, especially during the most sensitive night-time period. This is due to more stringent NMLs during these periods than during the daytime.

During works outside of standard construction hours, the highest impacts are generally predicted to be at receivers which are closest to tunnelling and supporting works. NML exceedances of less than 10 dBA are predicted at the potentially most affected receivers during the evening and night-time periods.

Highly noise affected residential receivers

The ICNG considers residential receivers that are subject to predicted noise levels of 75 dBA or greater to be highly noise affected. No residential receivers are predicted to be classified as highly noise affected within this study area.

Other sensitive receivers

Other sensitive receivers, such as educational facilities, hospitals and childcare centres, which are potentially affected by construction works have been assessed against the various criteria detailed in **section 10.1.3**.

The predicted NML exceedances for other sensitive receivers are summarised in **Table 10-58**. The assessment provides further context to the predicted worst case noise levels presented in **Table 10-57** as it presents the number of and type of receivers predicted to experience exceedances of the NMLs, summarised in bands of 10 dBA.

Table 10-58 Overview of sensitive receiver NML exceedances in precinct

Activity	Number of other sensitive receivers exceeding NMLs														
	Education			Medical			Place of Worship			Childcare			Outdoor Recreational		
	1-10 dBA	11-20 dBA	>20 dBA	1-10 dBA	11-20 dBA	>20 dBA	1-10 dBA	11-20 dBA	>20 dBA	1-10 dBA	11-20 dBA	>20 dBA	1-10 dBA	11-20 dBA	>20 dBA
Installation of environmental controls	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Pavement and infrastructure works	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-
Establishment of construction facilities	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-
On site car parking	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Workshop, deliveries, maintenance, and storage	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Spoil handling above ground within acoustic shed	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Onsite truck movements	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Tunnelling support	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Ventilation building installation	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Lane configuration changes (ramp)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Construction of tunnel cut- and-cover (outside acoustic shed)	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-
Site rehabilitation and	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Activity	Number of other sensitive receivers exceeding NMLs														
	Education			Medical			Place of Worship			Childcare			Outdoor Recreational		
	1-10 dBA	11-20 dBA	>20 dBA	1-10 dBA	11-20 dBA	>20 dBA	1-10 dBA	11-20 dBA	>20 dBA	1-10 dBA	11-20 dBA	>20 dBA	1-10 dBA	11-20 dBA	>20 dBA
Landscape															
Cumulative	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

The above table shows that only one outdoor recreational receiver (Sydney Park) is predicted to experience a minor exceedance of the NML (less than 10 dB).

NCA summary

Table 10-59 Location summary of construction impacts

NCA	Location
NCA48	**Most affected receivers:** Residential receivers situated on the southern side of Campbell Street between Woodley Street and Harber Street. **Worst case construction scenario:** Construction site deliveries and tunnelling operations inside the acoustic shed during the night-time period.
NCA49	**Most affected receivers:** Residential receivers situated on the northern side of Campbell Street between Crown Street and Barwon Park Road. **Worst case construction scenario:** construction site deliveries and tunnelling operations inside the acoustic shed during the night-time period.
NCA50	No impacts above the project NMLs are predicted within this NCA for all works activities.
NCA51	No impacts above the project NMLs are predicted within this NCA for all works activities.
NCA52	No impacts above the project NMLs are predicted within this NCA for all works activities.
NCA54	No impacts above the project NMLs are predicted within this NCA for all works activities.
NCA55	No impacts above the project NMLs are predicted within this NCA for all works activities.

Ground-borne noise and vibration impacts

Airborne noise emissions from the St Peters site are predicted to be higher than the ground-borne noise levels. For this reason, ground-borne noise is not anticipated to be the controlling factor for these works. No vibration intensive works are proposed from the St Peters site as part of the M4-M5 Link project

Consecutive construction impacts

When evaluating the extent of noise impacts within the Campbell Road civil and tunnel site (C10), it is noted that this area would likely be subject to potential construction impacts from works associated with other infrastructure projects, including the approved and currently under construction New M5 project. This project, together with the M4-M5 Link, tie in to the St Peters interchange at St Peters, where receivers would likely be exposed to extended impacts associated with the construction of these infrastructure projects.

The indicative construction programme for the New M5 and M4-M5 link are shown in **Table 10-60**.

Table 10-60 Indicative construction program – New M5 and M4-M5 link

Project	2016 Q				2017 Q				2018 Q				2019 Q				2020 Q				2021 Q				2022 Q			
	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
New M5		■	■	■	■	■	■	■	■	■	■	■	■	■	■													
M4-M5 Link											■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■		

Excluding short-term works such as pavement and utility works, receivers located within NCA48 and, NCA49, which front Campbell Road, are predicted to experience up to 10 dBA exceedances of the project NMLs (in the night-time period) during construction of the M4-M5 link project. While the magnitude of the predicted exceedance is relatively low, these impacts are predicted at receivers which would likely have been exposed to significant noise impacts from the New M5 project.

In situations where consecutive long-term construction noise impacts occur, at-receiver noise mitigation may be considered where feasible and reasonable, if options for at source noise mitigation and management measures have been exhausted. The requirement for this should be evaluated in consultation with Roads and Maritime and the community during detailed design, and should be appropriately considered when preparing the CNVMP.

Construction road traffic

The assessment indicates that construction traffic is unlikely to result in a noticeable increase in L_{Aeq} noise levels at receivers along the proposed construction traffic routes (Campbell Road). It is also important to note that no local roads would be used by heavy vehicles during works.

With regard to potential night-time maximum noise events, construction traffic on the major roads are unlikely to significantly increase the number of maximum noise events due to the relatively high existing traffic volumes on these roads.

Ground-borne noise and vibration impacts

Ground-borne noise from tunnelling works associated with construction of the mainline tunnel alignment and access ramps is summarised in **section 10.3.7**.

Vibration intensive sub-surface works associated with construction of the Campbell Road civil and tunnel site (C10) that have the potential to cause ground-borne noise impacts in this area, such as excavation of the ventilation facility and ventilation tunnels, are being undertaken as part of the New M5 project works and are not relevant to this assessment.

No sub-surface vibration intensive works are proposed as part of construction of the Campbell Road civil and tunnel site (C10) as part of the M4-M5 Link project. As such, airborne noise emissions from the Campbell Road civil and tunnel site (C10) are predicted to be higher than the ground-borne noise levels. For this reason, ground-borne noise is not anticipated to be the controlling factor for these works.

10.3.7 Mainline tunnel alignment

Ground-borne noise

Figure 10-20 shows the approximate tunnel depths (from ground elevation to the tunnel crown) for the project alignment and illustrates that the tunnel depth varies from a few metres below ground in the vicinity of the tunnel portals, to up to around 65 metres below ground at the deepest points.

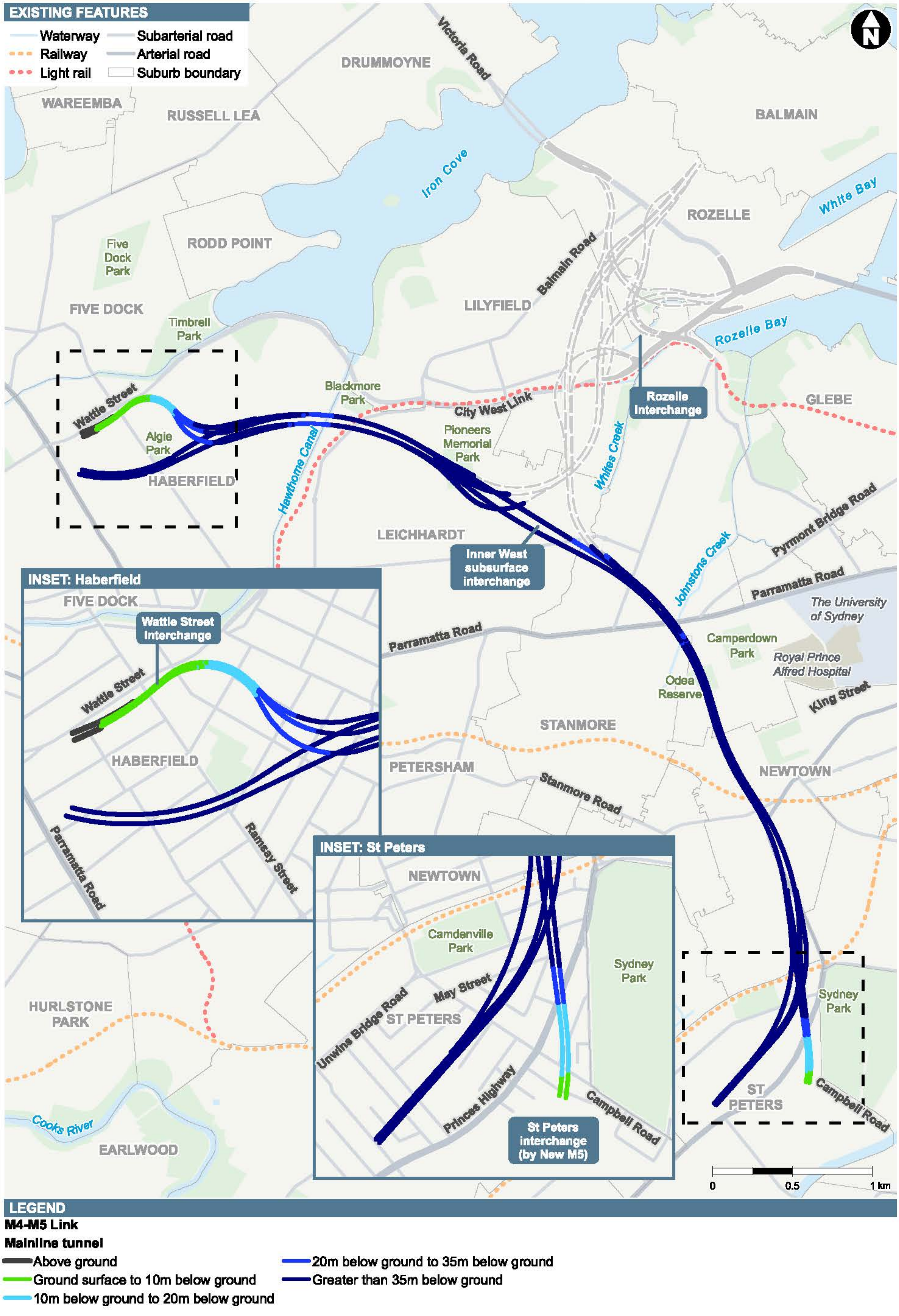


Figure 10-20 Approximate tunnel depths below the ground surface

The ground-borne noise assessment is based on the worst case predicted L_{Aeq} internal ground-borne noise level when the tunnelling works are at their closest point below each receiver.

Given the progression rate of the roadheader works (about 20 to 25 metres per week), it is anticipated that the worst case ground-borne noise impacts along the majority of the alignment would only be apparent for a relatively short period of time (ie several days for each roadheader) while the tunnelling works are directly beneath a particular sensitive receiver. As the works progress and move away, a particular receiver's exposure to ground-borne noise would notably reduce. This concept is illustrated in **Figure 10-21**.

The figure indicates that the night-time NML of 35 dBA $L_{Aeq(15minute)}$ is likely to be exceeded at a particular location as each roadheader passes for the following approximate durations:

- 10 days where a slant distance of about 20 metres from the tunnels is apparent
- 11 days where a slant distance of about 15 metres from the tunnels is apparent
- 13 days where a slant distance of about 10 metres from the tunnels is apparent.

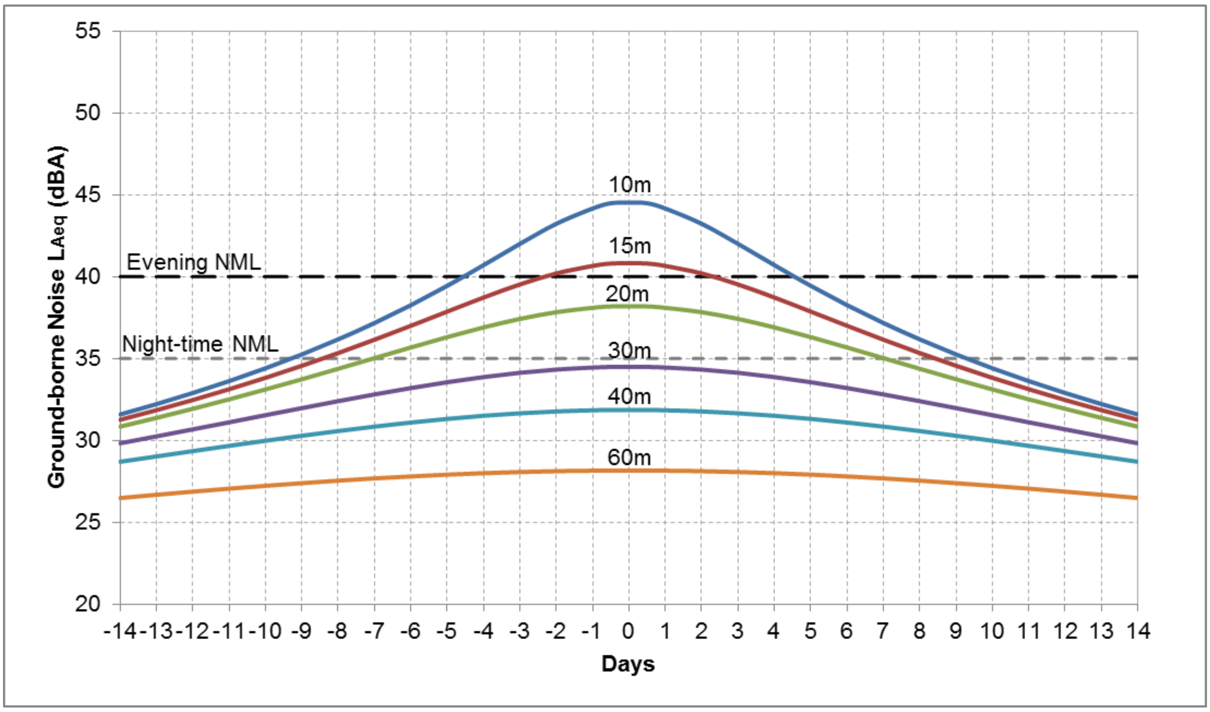


Figure 10-21 Ground-borne noise levels at slant distances from roadheader (progress = 20 m/week)

No surface works associated with the mainline tunnel alignment would occur outside of the areas discussed above and therefore the impacts at receivers for the construction of the mainline tunnel alignment would be limited to ground-borne noise and vibration.

At residential locations greater than a distance of 30 metres from the nearest tunnel (ie taking into account the tunnel depth and the horizontal offset distance), exceedances of the ground-borne NML of 35 dBA $L_{Aeq(15minute)}$ during night-time periods are unlikely.

Based on a progression rate of approximately 20 to 25 metres per week for the excavation using roadheaders, potential ground-borne noise impacts are predicted at the following locations:

- In Haberfield (near Wattle Street, north of Martin Street), where the tunnel ramps climb to meet with the Wattle Street tunnel stubs, 46 receivers are predicted to experience noise levels above the criteria for about 19 days for each roadheader. Ground-borne noise levels of up to approximately 44 dBA $L_{Aeq(15minute)}$ are predicted when tunnelling equipment is located at the shortest distance to the receiver
- In the vicinity of the Rozelle interchange (primarily to the north of Lilyfield Road and around Catherine Street), where the tunnel ramps climb to meet City West Link, 225 receivers are

predicted to experience noise levels above the criteria for about 19 days for each roadheader. Ground-borne noise levels of up to approximately 45 dBA $L_{Aeq(15minute)}$ are predicted when tunnelling equipment is located at the shortest distance to the receiver. Due to the number of tunnels being constructed in this area (consecutive construction works) the duration of impacts may extend at these locations

- In the vicinity of the Iron Cove Link tunnel portals (south of Victoria Road between Toelle Street and Cambridge Street), where the tunnel ramps climb to meet Victoria Road, 29 receivers are predicted to experience noise levels above the criteria for about 17 days for each roadheader. Ground-borne noise levels of up to approximately 42 dBA $L_{Aeq(15minute)}$ are predicted when tunnelling equipment is located at the shortest distance to the receiver
- At Annandale (between Moore, Catherine, Reserve and Annandale streets) where the tunnels veer north towards the Rozelle interchange, 48 receivers are predicted to experience noise levels above the criteria for up to around 12 days for each roadheader. Ground-borne noise levels of up to about 44 dBA $L_{Aeq(15minute)}$ are predicted when tunnelling equipment is located at the shortest distance to the receiver
- In the vicinity of the St Peters interchange (west of Sydney Park), where the tunnel ramps climb to meet the St Peters tunnel stubs, 39 receivers are predicted to experience noise levels above the criteria for about 19 days for each roadheader. Ground-borne noise levels of up to approximately 44 dBA $L_{Aeq(15minute)}$ are predicted when tunnelling equipment is located at the shortest distance to the receiver.

While most roadheader works would be anticipated to progress at a consistent rate, there may be discrete locations which require a longer duration of tunnelling works due to site conditions.

The following mitigation measures would be considered where feasible and reasonable:

- Validation of predicted ground-borne noise levels (note that this may not be required where the ground-borne noise impacts would last less than three weeks at any one sensitive receiver and would be confirmed during detailed design)
- Notification letterbox drops to receivers in the area around the works locations, detailing work activities, time periods over which these would occur, impacts and mitigation measures
- Specific notifications provided to receivers where the ground-borne noise levels are predicted to exceed the night-time NML, providing additional information when relevant and more specific information than covered in general letterbox drops.

At receivers predicted to exceed the night-time NMLs by more than 10 dBA, the following mitigation measures would be considered in addition to those outlined above:

- Individual briefings to inform the residents about the impacts of the works and mitigation measures that would be implemented. Where the resident cannot be met with individually then an alternative form of engagement would be used
- Respite periods may be offered to affected residents during works where noise levels are predicted to exceed the NML by 10 dBA or more
- Alternative accommodation options may be offered to affected residents for the periods where noise levels are predicted to exceed the NML by 10 dBA or more.

Vibration

No sensitive receivers are located within the minimum working distances for roadheaders during tunnelling works for the mainline tunnel alignment. As such, vibration impacts associated with tunnelling works are expected to be negligible.

Sydney Water Pressure Tunnel

The M4-M5 Link mainline tunnels are expected to pass with clearances of 12 metres and 11 metres from the Sydney Water Pressure Tunnel and the Sydney Water City Tunnel, respectively. The Pressure tunnel, completed in 1935, carries drinking water from Potts Hill Reservoir to Waterloo and is a historically critical link in the water supply of Sydney. The City Tunnel, completed in 1961 is largely a duplicate of the Pressure Tunnel and connects the same locations.

Based on available project information, assessment according to DIN 4150 and a safe vibration threshold for the tunnels of 25 millimetres per second, the safe working distance is less than the anticipated offsets. As such, adverse impact from the effects of direct vibration is deemed unlikely.

Royal Prince Alfred Hospital

The Royal Prince Alfred (RPA) Hospital is located either side of Missenden Road in Camperdown, in NCA43. The hospital houses a variety of equipment that may be sensitive to vibration from tunnelling activities. The nearest RPA building to the tunnel alignment is the Camperdown Child and Family Clinical Services building which is 450 metres to the east of the nearest point tunnelling works. The next closest building is 600 metres from the works.

The proposed mainline tunnel alignment passes to the west of RPA. The nearest RPA building to the tunnel alignment is the Camperdown Child and Family Clinical Services building. This is located approximately 450 metres to the east of the nearest point tunnelling works for the project. The next closest RPA buildings are approximately 600 metres to the east of the nearest point of tunnelling works.

It is anticipated that the hospital would be consulted during detail design to establish appropriate design vibration levels taking into account any sensitive equipment that may be located within the hospital.

Rock breaking and blasting

Blasting and rock-breaking may be used to excavate benches, cross passages and other voids within the tunnel sections of the project. There is potential for ground-borne noise and vibration impacts from these activities where receivers are situated above the tunnel.

The use of excavators with breakers within the tunnels has the potential to generate ground-borne noise at the surface. The potential for ground-borne noise due to rock-breaking within the tunnels increases with decreasing distance to the surface. Such excavation methods, however, may only be required at certain locations within the tunnels, limiting the locations that might be subject to associated ground-borne noise and the number of potentially affected receivers. Also, there is scope to schedule rock-breaking within the tunnels to avoid impacts in the more sensitive evening and night-time periods. The potential for impacts associated with rock-breaking within the tunnel would be considered further during the development of the detailed design and detailed construction methodologies. Appropriate measures to reduce the potential for ground-borne noise impacts due to rock-breaking within the tunnels would be included in the project CNVMP.

As any blasting required for the project would be conducted within the mainline tunnel, airborne noise and airblast overpressure impacts would be negligible at sensitive receivers in or near the project footprint.

While the proposed blasting may generate audible ground-borne noise at receivers above tunnelling works, assessment of impulsive blasting, typically conducted as a single event, against the ICNG $L_{Aeq(15minute)}$ criteria is not appropriate.

At a location with a typical 30 metre depth of cover, the predicted level of vibration at the surface for a maximum instantaneous charge of 10 kilograms is 12 millimetres per second. This is below the transient vibration guide value for the prevention of cosmetic building damage of 26 millimetres per second. However, where the subject building is a heritage listed item, and is considered to be structurally unsound, a transient vibration guide value for the prevention of cosmetic building damage would be four millimetres per second.

The corresponding guide value for human comfort is a maximum of 10 millimetres per second. Compliance with a ground vibration level of 10 millimetres per second is predicted to be achieved by using a maximum instantaneous charge of approximately 7.0 kilograms.

Blasting recommendations

Blasting has the potential to significantly reduce noise and vibration impacts if managed appropriately by the contractor. Blasting is proposed as an excavation technique because the potential vibration and ground-borne noise impacts from blasting are of a much shorter duration for nearby sensitive receivers compared to the vibration impacts associated with mechanical excavation methods such as rock-breakers.

If blasting is proposed, noise and vibration impact predictions for blasting operations would be undertaken in the detailed design phase when more information is available on the blasting scope and methods. Blasting specific noise and vibration mitigation methods would be incorporated into the CNVMP where required.

Blasting would be restricted to standard daytime hours only (except where approved by the relevant authority). Site investigations would be conducted prior to production blasting to define suitable blast sizes to comply with project blasting noise and vibration criteria. Dilapidation studies of nearby receiver buildings may be required where potential for exceedances of the blasting criteria are identified.

10.3.8 Utility works

Construction works associated with utility relocation, diversions and connections would likely be required at most ancillary facility and construction sites. Utility works would also be required along various streets in the vicinity of construction sites and ancillary facility locations. Where the utilities are within the road reserve, the work may be required outside standard daytime construction hours.

The Utilities Management Strategy (refer to **Appendix F**) prepared for the project provides details about known utilities adjustments that would be required to facilitate the project. Other utility works would be identified during development of the detail design and construction methodology. The types of equipment required to carry out the utility works would likely include typical ground excavation items such as excavators, vacuum trucks, boring and directional drilling machines, concrete saws and rock-breakers.

An assessment of the potential noise levels from the likely plant items associated with utility works is provided in **Table 10-61**. Noise levels have been predicted at various offset distances to give an indication of the possible impacts with line of sight.

Table 10-61 Potential noise levels from utility works

Equipment	Predicted noise level at distance ($L_{Aeq(15\text{-minute})}$ dBA)			
	15 m	30 m	50 m	70 m
Vacuum truck	84	78	74	71
Directional drilling	76	70	66	63
Concrete saw[1]	85	79	75	72
Excavator	77	71	67	64
Excavator (breaker)[1]	86	80	76	73
Hand tools (unpowered)	62	56	52	49

Note 1: Assumed to be working for 7.5 minutes in worst case 15-minute period.

Table 10-61 shows that relatively high noise impacts are likely where noise intensive plant items are required near to adjacent receivers. On typical streets surrounding the construction sites, residential receivers are situated around 15 metres from the road. In this situation, noise levels as high as 86 dBA are possible when noise intensive plant items are in use.

Utilities are often within or immediately adjacent to trafficable parts of the road network. As such, lane occupancies are often required to facilitate utility works. To maintain the operational integrity of the surrounding road network, utility works in busy road corridors must often be carried out outside standard day time construction hours when traffic volumes are low. Night-time NMLs in the vicinity of most worksites are in the region of 40 to 50 dBA. As such, exceedances of greater than 30 dBA above NML are likely where noise intensive plant items are in use during the night-time.

Specific management measures for potential noise and vibration impacts due to utility works would be determined when further information regarding the extent and locations of the works is known. Potential noise impacts would be managed by adopting standard management measures which would be outlined in a CNVMP. The potential noise impacts associated with utility works would be identified when the extent and locations of the works have been confirmed. Appropriate mitigation measures would be selected from the CNVG and implemented.

10.4 Assessment of operational road traffic impacts

This assessment compares noise levels predicted due to the project in 2023 (modelled as the year 'at opening') and 2033 (modelled as 10 years after opening) with those predicted without the project. Impacts associated with the project only are accounted for by assessing the *'Do Something'* traffic scenario. Cumulative impacts are accounted for by assessing an additional scenario (the *'Do Something Plus'* traffic scenario) which uses road traffic inputs for the full WestConnex scheme in addition to key infrastructure/development proposals in the Greater Sydney area (including the proposed future Western Harbour Tunnel and Beaches Link, Sydney Gateway and F6 Extension projects).

Under the *'Do Something'* scenario, even without additional noise mitigation (ie over and above road design and traffic management), the project is predicted to reduce the overall number of sensitive receivers with an exceedance of the relevant noise goals. This is mainly due to areas where the project reduces traffic, such as sections of Victoria Road in Rozelle, where surface traffic would be significantly reduced.

The change in road traffic noise exposure is generally anticipated to be less than 2 dBA in areas such as The Crescent and parts of Johnston Street where traffic volume is forecast to increase. This change in road traffic noise exposure is considered by the NSW EPA to be barely perceptible. In Iron Cove to the south of Victoria Road where substantial buildings would be removed to accommodate the proposed road widening, exposure to road traffic noise is anticipated to increase by over 5 dBA at the immediately adjacent receivers and would require consideration of mitigation measures to mitigate operational noise impact. If the Haberfield Option B construction sites are selected, consideration of additional noise mitigation at six residential receivers including multi-storey buildings would be required due to reduced screening benefit with the removal of intervening shielding.

Operational road traffic impacts have been predicted where surface works associated with the project are required. This corresponds to noise catchments NCA15 to NCA37. All floors of multi-storey receiver buildings are included in the assessment and evaluated against the applicable noise criteria. The assessment counts each floor in a multi-storey dwelling as a separate receiver; for example, a two-storey residential building would count as two receivers.

10.4.1 Operational noise predictions without mitigation

The approach taken in this assessment is to assess noise impacts from the project by considering the 'Do Nothing' scenario to represent the No Build (ie 'without project') impacts and the 'Do Something' scenario to represent the Build (ie 'with project') impacts.

Noise predictions throughout the study area indicate that receivers adjacent to the project footprint are subject to existing road traffic noise impacts and in many cases already exceed the NCG controlling criterion, as shown in the No Build scenarios in **Table 10-62**, which summarises the predicted change in noise levels (Build minus No Build) across the study area.

Table 10-62 Receivers exceeding the NCG controlling criteria without mitigation

NCA	Receiver type	Floor	2023 No build		2023 Build		2033 No build		2033 Build	
			Day	Night	Day	Night	Day	Night	Day	Night
NCA15	All	All	76	76	72	70	77	76	70	70
NCA16	All	All	149	134	133	118	152	138	137	124
NCA17	All	All	0	0	0	0	0	0	0	0
NCA18	All	All	2	2	0	0	2	2	0	0
NCA19	All	All	262	227	195	184	266	233	201	187
NCA20	All	All	28	23	15	7	28	28	15	10

NCA	Receiver type	Floor	2023 No build		2023 Build		2033 No build		2033 Build	
			Day	Night	Day	Night	Day	Night	Day	Night
NCA21	All	All	270	222	242	208	333	246	250	226
NCA22	All	All	130	129	130	130	130	130	130	130
NCA23	All	All	133	125	145	134	140	131	153	149
NCA24	All	All	487	453	472	440	492	467	479	447
NCA25	All	All	286	268	293	281	290	274	293	290
NCA26	All	All	0	0	0	0	0	0	0	0
NCA27	All	All	32	45	71	200	41	85	71	222
NCA28	All	All	0	0	0	0	0	0	0	0
NCA29	All	All	224	220	211	207	228	222	211	209
NCA30	All	All	190	180	169	159	195	180	170	160
NCA31	All	All	201	173	200	172	201	173	201	172
NCA32	All	All	92	72	89	70	92	73	89	72
NCA33	All	All	54	45	61	52	56	52	63	57
NCA34	All	All	106	103	95	90	108	104	96	92
NCA35	All	All	317	301	316	298	319	304	316	301
NCA36	All	All	54	52	40	39	54	54	39	39
NCA37	All	All	66	0	66	0	69	0	65	0
NCA38	All	All	0	0	0	0	0	0	0	0
NCA39	All	All	41	40	41	41	41	41	41	41
NCA40	All	All	63	53	64	54	63	54	64	55
All	**All**	**All**	**3263**	**2943**	**3120**	**2954**	**3377**	**3067**	**3154**	**3053**

Note:

Predicted noise levels at receivers which are above the NCG controlling criteria do not necessarily qualify for additional noise mitigation. As per the discussion in **section 10.1.6**, further criteria are used to determine which of those receivers are eligible for additional noise mitigation measures.

The information presented in **Table 10-62** and **Figure 10-22** indicates that:

- The project is predicted to result in an overall decrease in the number of receivers with an exceedance of the NCG criteria across the study area as a whole during both the daytime and night-time periods, in both 2023 and 2033. This is mainly due to forecast reductions in traffic volumes on some parts of the road network as a result of the project (ie moving vehicles from surface roads to the tunnels)
- The project is predicted to result in a reduction in noise levels for approximately 65 per cent of the receivers within the study area
- A minor (less than 2 dBA) increase in noise levels is predicted at just over 34 per cent of the receivers. This magnitude of noise increase is noted in the RNP as being unlikely to be perceptible by the average person
- Less than one per cent of the receivers are predicted to experience an increase of more than 2 dBA due to the project
- Marginal increases (1-2 dBA) are seen on The Crescent and parts of Johnston Street, and also on some of the adjacent roads, such as Gordon Street, associated with increased volume due to redistribution of traffic

- Of the total number of receivers over the daytime NCG criteria in the No Build (ie without the project), between five and seven per cent are predicted to experience a reduction to below the criteria with the project
- Significant reductions in noise (up to around -4 dBA) are identified along sections of Victoria Road in Rozelle, where the project is forecast to significantly reduce traffic numbers
- Large increases in noise (up to around +15 dBA) are identified in NCA33 and NCA36 (on Victoria Road near Iron Cove Bridge in the vicinity of the proposed tunnel portals) and NCA25 (near the new Victoria Road bridge), where the project results in traffic lanes being moved closer to receivers, in combination with removing existing screening due to property acquisitions. These predicted increases are generally limited to the receivers that would have partial or direct line of sight to Victoria Road once the acquired buildings are demolished. This location would be assessed further during development of the detailed design to identify appropriate noise mitigation measures to address these large predicted increases. The measures that would be considered would include low road noise pavement, noise barriers, at-property treatments and beneficial changes to the project design.

The requirement for the project to provide additional noise mitigation is largely due to the existing high noise levels. That is, the project contributes only a relatively minor change in noise levels but when considered cumulatively the identified exceedances qualify receivers for additional noise mitigation.

Figure 10-22 Predicted change in noise levels (Build minus No Build) without mitigation for 2033 (day time scenario at ground floor level)

10.4.2 Receivers considered for additional noise mitigation

A total of 431 receivers (200 individual buildings) are predicted to have exceedances of the operational road traffic noise criteria for the project and are therefore eligible for consideration of additional noise mitigation. The 431 exceedances fall into the following categories:

- The predicted Build noise level exceeds the NCG controlling criterion, and the noise level increase due to the project is greater than 2 dBA. A total of 29 receivers are triggered on this criterion alone
- The predicted Build noise level is 5 dBA or more above the criteria (exceeds the cumulative limit) and the receiver is significantly influenced by project road noise, regardless of the incremental impact of the project. A total of 155 receivers are triggered on this criterion alone
- Where the noise level contribution from the road project is acute (daytime $L_{Aeq(15hour)}$ 65 dBA or higher, or night-time $L_{Aeq(9hour)}$ 60 dBA or higher) then it qualifies for consideration of noise mitigation, even if noise levels are dominated by another road. While some receivers are predicted to experience noise levels above acute levels, no receivers are triggered on this criterion alone
- 247 receivers are triggered due to a mix of the above criteria.

The NCAs with the most triggered receivers are NCA25, NCA33, NCA35 and NCA36. These catchments are at Iron Cove and adjacent to Victoria Road.

Forty-eight other sensitive receivers (27 individual buildings) are predicted to have exceedances of the operational road traffic noise criteria for the project and are therefore eligible for consideration of additional noise mitigation. The other sensitive receivers that are eligible for consideration of additional mitigation are primarily located in NCA25, NCA27, NCA31 and NCA37.

Sixty-four per cent of the identified receivers are on the first two floors, with 15 per cent of the triggers being on level three, nine per cent being on level four, four per cent on level five, and eight per cent for all floors including and above level six.

Additional noise mitigation

The operational assessment has identified the potential noise benefits associated with the use of low noise pavement, noise barrier and at-property treatment. However, due to engineering uncertainties as well as unresolved urban design challenges, a provisional noise mitigation option in the form of at-property treatment has been recommended. A preferred noise mitigation option (low noise pavement, noise barrier, architectural treatments, a combination or other) would be determined during detailed design taking into account whole-of-life engineering considerations and the overall social, economic and environmental effects. The preference would be given to selecting noise mitigation measures that reduce outdoor noise levels and the number of at-property treatment.

In sensitive receiver locations where exceedances of the operational noise criteria are predicted, new or increased height noise barriers have been considered where four or more eligible properties are found to be closely spaced. Where the number of exceeding receivers is found to be three or less, the specification of noise barriers is not considered to be a reasonable or cost-effective approach and at-property treatments of these receivers should be considered by Roads and Maritime in conjunction with the construction contractor during the detailed design stage. This approach is consistent with the NMG. At present only one location (Iron Cove north) is recommended for an additional noise barrier.

10.4.3 Maximum noise levels

Indicative increases in maximum noise levels have been predicted in the noise model using a source height corresponding to the approximate height of a truck exhaust.

The noise predictions indicate that maximum noise levels may increase at residential receivers in the following locations:

- NCA33 and NCA36 – receivers south of Victoria Road adjacent to the Iron Cove Link tunnel portals. In this location, demolition of acquired buildings results in residences having line of sight to the widened Victoria Road where they were previously screened by existing buildings.

Indicatively, typical increases of between 5 dBA and 10 dBA are predicted. Some receivers in this catchment would be eligible for consideration of at-property treatments as part of the project

- NCA24 – receivers west of Victoria Road at Rozelle. In this location, demolition of acquired buildings results in some residences having line of sight to Victoria Road where they were previously screened by existing buildings. Indicatively, typical increases of between 2 dBA and 10 dBA are predicted. A small number of receivers experience a higher increase due to the removal of adjacent buildings. Some receivers in this catchment would be eligible for consideration of at-property treatments as part of the project.

The change in maximum operational noise levels at receivers in other catchment areas is predicted to be negligible.

While it is noted that existing bus operations mean that the character of noise would not be expected to change, service frequency and final stop location may influence noise levels from bus operations and should be considered further during detailed design.

10.4.4 Operational assessment at Haberfield/Ashfield Option B

Property acquisitions of existing commercial buildings (for demolition) may be required at Haberfield if Option B is selected, since this option would result in residential receivers that were previously screened from Parramatta Road being subject to reduce screening benefit.

Receivers that have been identified as being eligible for consideration of additional noise mitigation are presented in **Figure 10-23**.

Figure 10-23 Noise affected receivers around the construction ancillary facility sites at Haberfield and Ashfield (Option B)

The removal of intervening shielding requires the consideration of additional noise mitigation at six residential receivers. The potential impacts should be further investigated during detailed design to confirm mitigation options should this option be selected.

10.4.5 Operational impacts at either end of the project footprint

While no major permanent road infrastructure is proposed at either ends of the project as part of the M4-M5 Link, the future (2033 Build) traffic volumes (including other major Sydney road projects) may influence noise levels at adjacent receivers in these areas. Both ends of the M4-M5 Link interface with other stages of WestConnex; the M4 East project at Haberfield and the New M5 project at St Peters, both of which will significantly alter the road design in the respective areas.

As part of the EIS reports prepared for both the M4 East and the New M5 projects, noise and vibration assessments were prepared to assess operational traffic noise on:

- The surface road network at Haberfield including Parramatta Road, Frederick Street/Wattle Street/Dobroyd Parade and Ramsay Street
- The surface road network at St Peters including Campbell Road, the Princes Highway, Euston Road.

Both of these interfacing WestConnex projects (the M4 East and New M5 projects) are considered within the WestConnex program and as such considered a future forecast traffic scenario which included the M4-M5 Link (and other major Sydney road projects) as part of their EIS assessment of potential cumulative impacts. The cumulative scenario assessed for each of these interfacing project identified receivers which were subject to a perceptible increase in noise level of more than 2 dBA and exceeds noise criterion or where noise level remain 5 dBA above the noise criterion. Appropriate mitigation measures recommended to address these impacts can include the treatment of road surfaces, noise barriers and/or architectural treatments where feasible and reasonable.

Conditions of Approval

The conditions of approval for both of the interfacing WestConnex projects require the Proponent of each to undertake an Operational Noise and Vibration Review (ONVR) to confirm the operational noise predictions, impacts on receivers and the suitability of proposed mitigation measures. This review would be based on the final detailed design of each project and updated traffic modelling forecasts for the future traffic scenario as required by NSW EPA Road Noise Policy.

Reference is made to the following Instrument of Approval for each project:

- M4 East: SSI 6307 dated 11 February 2016
- New M5: SSI 6788 dated 20 April 2016.

Potential changes – M4-M5 Link

For the M4-M5 Link, differences in the forecast traffic volumes on the surface road network at Haberfield and St Peters may occur as the result of a combination of factors including:

- Updated version of traffic model (WestConnex Road Traffic Model version 2.3)
- Updated land use, employment forecasts and future projects that form part of the cumulative operational scenario
- Changes in design of M4-M5 Link project.

The changes in forecast traffic volumes between the interfacing WestConnex projects and the M4-M5 Link and in turn differences in the operational noise assessments would be captured in a progressive manner by:

- The ONVRs being undertaken as part of the conditions of approval for the M4 East project which is due to open in 2019 and the New M5 project which is due to open in 2020
- The ONVR that will be undertaken as part of the conditions of approval for the M4-M5 Link project (should that project be approved). The project is due to open in a staged manner in 2022 and 2023

Mitigation for cumulative impacts

Consistent with the requirements of the NMG, the future forecast traffic volumes are required to be considered in the assessment of the final design for each project and are therefore expected to be addressed in the respective ONVR for each interfacing project. This would be addressed through the following process:

- The Proponents of the M4 East and New M5 projects are required to review the suitability of the operational noise mitigation measures (refer to Condition E33 for the M4 East project and Condition E37 for the New M5 project)
- Under these conditions, the Proponent must implement the identified noise and vibration control measures of the final design and make the ONVR publicly available
- The Proponents for the M4 East and New M5 projects are also required to undertake operational noise and vibration monitoring to compare the actual noise and vibration performance of the State significant infrastructure against the noise performance predicted in the ONVR (refer to Condition E34 for the M4 East project and Condition E38 for the New M5 project)
- The Proponents for these projects must implement further feasible and reasonable mitigation measures (where required) as identified in the Operational Noise and Vibration Compliance Report in consultation with affected property owners (refer to Condition E35 for the M4 East project and Condition E39 for the New M5 project).

The Operational Noise and Vibration Compliance Report for each project is expected to include assessment of the final design with calibration of the noise model taking into account considerations such as traffic numbers and land use change (if applicable). It is therefore anticipated that any changes in design as well as forecast traffic in the as-built noise model would be used to evaluate the adequacy of noise mitigation measures during preparation of the Operational Noise and Vibration Compliance Report for each project (M4 East and the New M5).

10.4.6 Minor changes to project design

As with any large infrastructure project, minor design refinements are investigated as the project progresses through the design stages. Minor design changes can include reconfiguration of lane markings, provision of additional turning lanes, and alteration and relocation of kerbs.

The M4-M5 Link project is currently evaluating potential minor design changes in a number of locations:

- Wattle Street/Parramatta Road/Frederick Street turning lane configurations
- Additional right turn lane on The Crescent at the intersection with Johnston Street
- Minor lane configuration changes at the St Peters interchange ramps.

As these design changes are not expected to change the volume of traffic and would be within the road reserve, the change to operational road traffic noise levels at adjacent receivers would be expected to be negligible.

Notwithstanding, the potential impacts of all design refinements associated with the project would be evaluated during detailed design when operational noise mitigation is reviewed prior to the project being constructed.

10.4.7 Fixed facilities operational noise impacts

Noise assessment

Noise impacts from the operation of the fixed facilities associated with the project have been predicted for the NCAs nearest to the facilities. These predicted noise levels are summarised in **Table 10-63**.

Table 10-63 Predicted noise levels – fixed facilities

Area	NCAs	Noise level (dBA L_{Aeq})		
		Criteria	Predicted	Exceedance
Haberfield	NCA01	43	33	-
	NCA02	45	36	-
	NCA03	45	35	-
	NCA06	45	39	-
Darley Road	NCA09	45	41	-
	NCA13	45	45	-
Rozelle	NCA15	40	28	-
	NCA16	45	35	-
	NCA19	45	39	-
	NCA20	40	34	-
	NCA21	45	39	-
	NCA24	45	34	-
	NCA25	45	33	-
	NCA27	45	24	-
Iron Cove	NCA33	45	57	12
	NCA34	45	40	-
	NCA35	45	42	-
	NCA36	45	39	-
St Peters	NCA46	45	20	-
	NCA48	45	30	-
	NCA49	45	41	-
	NCA50	45	34	-
	NCA51	44	28	-

The above results assume the presence of existing noise barriers in the Rozelle and Iron Cove areas, and the noise barriers that are being constructed in the Haberfield area as part of the M4 East project.

The results indicate that the assessed fixed facilities are predicted to comply with the relevant criteria during the more stringent night-time period in all NCAs in the Haberfield, Darley Road, Rozelle and St Peters areas.

The selected mechanical equipment for each facility, and in particular Iron Cove Link, would be reviewed and assessed against the relevant operational noise criteria at the detailed design stage of the project. Specific plant would be selected and designed to achieve compliance with the relevant criteria. The cumulative noise emissions from all fixed facility noise sources should be considered when determining the appropriate mitigation options.

Modifying factors

The indicative source levels have not been found to trigger the requirement to correct the predicted noise level due to low frequency or tonal components. Notwithstanding, tonal and/or low frequency noise is often observed from fans and the predictions would be revisited during detailed design based on the actual specifications of the final selection of equipment. Based on the assessment presented in this report, receivers in NCA09, NCA13, NCA34, NCA35 and NCA49 have been identified as most likely to exceed the criteria specified in **Table 10-63** should application of a +5 dBA correction be triggered (see **section 10.1.7**).

Mitigation

The equipment and sound power levels modelled are indicative only and may be subject to change during the detailed design phase of the project. It is envisaged that the mechanical plant noise sources associated with the fixed facilities would be controllable by common engineering methods that may consist of:

- Judicious location selection
- Noise barriers
- Silencers
- Acoustically lined ductwork
- Acoustic louvres.

The selected mechanical equipment for each facility, and in particular at Iron Cove, would be reviewed and assessed against the relevant operational noise criteria at the detailed design stage of the project. Specific plant would be selected and designed to achieve compliance with the relevant criteria. The cumulative noise emissions from all fixed facility noise sources would be considered when determining the appropriate mitigation options.

10.5 Environmental management measures

Mitigation and management measures for potential ambient noise and vibration impacts during construction and operation are shown in **Table 10-64**. Most of these measures are routinely employed as 'standard practice' on projects of this scale.

Table 10-64 Noise and vibration management measures to be implemented during construction and operation

Impact	No.	Environmental management measure	Timing
Construction			
Construction noise and vibration impacts	NV1	A suitably qualified and experienced acoustics advisor, who is independent of the design and construction personnel, will be engaged for the duration of construction of the project. The acoustics advisor will be responsible for: • Reviewing management plans related to noise and vibration and endorsing that they address all relevant conditions of approval and requirements of all applicable guidelines • Providing advice to the Proponent, the construction contractor(s) and the Secretary regarding the management of potential noise and vibration impacts associated with the project and compliance with relevant conditions of approval.	Construction

Impact	No.	Environmental management measure	Timing
	NV2	A Construction Noise and Vibration Management Plan will be prepared for the project. The plan will: • Identify relevant performance criteria in relation to noise and vibration • Identify noise and vibration sensitive receivers and features in the vicinity of the project • Include standard and additional mitigation measures from CNVG and details about when each will be applied • Describe the process(es) that will be adopted for carrying out location and activity specific noise and vibration impact assessments to assist with the selection of appropriate mitigation measures • Include protocols that will be adopted to manage works required outside standard construction hours in accordance with relevant guidelines • Detail monitoring that will be carried out to confirm project performance in relation to noise and vibration performance criteria. The CNVMP will be implemented for the duration of construction of the project.	Construction
	NV3	Detailed noise assessments will be carried out for all ancillary facilities required for construction of the project. The assessment will consider the proposed site layouts and noise generating activities that will occur at the facilities and assess predicted noise levels against the relevant noise management levels determined in accordance with the requirements of the ICNG. The assessments will be used to determine the appropriate heights and configurations of noise barriers, and other appropriate noise management measures, consistent with the requirements of the ICNG and the CNVG. Noise barriers, as confirmed through the noise assessments, will be installed as early as possible during site establishment and as a minimum prior to the commencement of excavation associated with tunnel access.	Construction
	NV4	Location and activity specific noise and vibration impact assessments will be carried out prior to (as a minimum) activities: • With the potential to result in noise levels above 75 dBA at any receiver • Required outside standard construction hours likely to result in noise levels in greater than the relevant noise management levels • With the potential to exceed relevant performance criteria for vibration. The assessments will clarify predicted impacts at relevant receivers in the vicinity of the activities to assist with the selection of appropriate management measures, consistent with the requirements of ICNG and CNVG, that will be implemented during the works.	Construction

Impact	No.	Environmental management measure	Timing
Out-of-hours noise impacts	NV5	An out-of-hours works protocol will be developed for the construction of the project. The protocol will include: • Details of works required outside standard construction hours, including justification of why the activities are required outside standard construction hours • Measures that will be implemented to manage potential impacts associated with works outside standard construction hours • Location and activity specific noise and vibration impact assessment process(es) that will be followed to identify potentially affected receivers, clarify potential impacts and select appropriate management measures • Details of the approval process (internal and external) for works proposed outside standard construction hours. The protocol will be prepared in consultation with DP&E and the NSW EPA, endorsed by the acoustic advisor for the project and implemented during construction of the project.	Construction
Additional noise and vibration activity impacts	NV6	Monitoring will be carried out at the commencement of new noise and vibration intensive activities and works in new locations to confirm that actual noise and vibration levels are consistent with noise and vibration impact predictions and that the management measures that have been implemented are appropriate.	Construction
Acoustic sheds	NV7	Acoustic sheds will be designed within consideration of the activities that will occur within them and the relevant noise management levels in adjacent areas. Monitoring will be carried out to confirm that the actual acoustic performance of the sheds is consistent with predicted acoustic performance.	Construction
Vibration impacts	NV8	A Blast Management Strategy will be prepared and implemented for the project if blasting is proposed. The strategy will: • Identify relevant performance criteria in relation to potential noise and vibration impacts due to blasting with reference to (as a minimum) *Technical Basis for Guidelines to Minimise Annoyance Due to Blasting Overpressure and Ground Vibration* (ANZEC, 1990) and Australian Standard AS 2187.2-2006 *Explosives - Storage, transport and use, Part 2: Use of explosives* • Describe trials that will be carried out to confirm vibration levels from blasting and facilitate development of predictive tools to allow potential noise and vibration impacts to be identified • Include details of management measures that will be implemented to ensure compliance with relevant performance criteria. The Blast Management Strategy will be implemented for all blasting carried out as part of the project.	Construction

Impact	No.	Environmental management measure	Timing
Operational noise impacts	NV9	Receivers that qualify for assessment for at receiver treatment in relation to operational noise that are also predicted to experience significant exceedances of noise management levels due to construction will be given priority preference for assessment. When at receiver treatments are found to be appropriate, the application of the treatment will be expedited.	Construction
	NV10	Where reasonable and feasible, operational noise mitigation such as noise barriers, berms and at-property treatments identified during detailed design should be installed early in the project so as to provide a benefit to receivers during the construction phase of the project.	Construction
Road traffic noise	NV11	The use of low noise pavement to further reduce road traffic noise at the source will be investigated during detailed design taking into account whole-life engineering considerations and the overall social, economic and environmental effects. If low noise pavement is found to be appropriate, it would be considered as a management measure when assessing operation noise impacts based on the detailed design.	Construction
	NV12	The area in the vicinity of the western portal of the Iron Cove Link, Rozelle, will be assessed further during development of the detailed design to identify appropriate noise mitigation measures to address predicted increases in road traffic noise to the project. The measures that will be considered will include low road noise pavement, noise barriers, at-property treatments and the project design.	Construction
Operation			
Operational noise performance	ON13	Potential operational noise performance of the project based on the detailed design will be assessed and appropriate management measures will be confirmed and implemented.	Construction
	ONV14	Within 12 months of the commencement of the operation of the project, actual operational noise performance will be compared to predicted operational noise performance. The need for any additional management measures to address any identified operational performance issues and meet relevant operational noise criteria will be assessed and implemented where reasonable and feasible.	Operation

11 Human health risk

This chapter outlines the potential human health impacts and quantifies the risks to human health associated with the M4-M5 Link project (the project), including:

- An outline of the methodology used to undertake the human health risk assessment
- A summary of the existing environment relevant to human health
- A description of the potential impacts of the project on human health during construction and operation
- Environmental management measures to be implemented to minimise any potential impacts of the project on human health.

A detailed human health risk assessment has been prepared and is included in **Appendix K** (Technical working paper: Human health risk assessment).

The Secretary of the NSW Department of Planning and Environment (DP&E) has issued environmental assessment requirements for the project. These are referred to as Secretary's Environmental Assessment Requirements (SEARs). **Table 11-1** sets outs these requirements and the associated desired performance outcomes that relate to human health, and identifies where they have been addressed in this environmental impact statement (EIS).

Table 11-1 SEARs – human health

Desired Performance Outcome	SEARs	Where addressed in the EIS
3. Health and Safety The project avoids or minimises any adverse health impacts arising from the project. The project avoids, to the greatest extent possible, risk to public safety.	1. The Proponent must assess the potential health impacts of the project, in accordance with the current guidelines.	Potential health impacts during construction and operation are discussed in **section 11.4**, **section 11.5, section 11.6** and **11.9**.
	2. The assessment must: (a) describe how the design of the proposal minimises adverse health impacts;	**Section 11.2** describes the key design aspects of the project that minimise adverse health impacts.
	(b) assess human health impacts from the operation and use of the tunnel under a range of conditions, including worst case operating conditions and the full length of all tunnels in the WestConnex scheme;	Human health impacts from the operation and use of the tunnel are discussed in **section 11.5**.
	(c) human health risks and costs associated with the proposal, including those associated with air quality, noise and vibration, and social impacts on the adjacent and surrounding areas during the construction and operation of the proposal;	Human health risks and costs associated with the proposal are described in **sections 11.4.1** (air quality) **11.4.2** (noise and vibration and **11.6** (social and economic impacts).
	(d) include both incremental changes in exposure from existing background pollutant levels and the cumulative impacts of project specific and existing pollutant levels at the location of the receivers (including public open space areas);	Incremental changes in exposure from existing background pollutant levels and the cumulative impacts of the project are discussed in **section 11.5** and **section 11.6**.

Desired Performance Outcome	SEARs	Where addressed in the EIS
	(e) assess the likely risks of the project to public safety, paying particular attention to pedestrian safety, subsidence risks, bushfire risks and the handling and use of dangerous goods;	The likely risks of the project to public safety are discussed in **section 11.5.3**. Assessment of subsidence risks is provided in **Chapter 19** (Groundwater).
	(f) include a cumulative human health impact assessment inclusive of in-tunnel, local and regional impacts due to the operation of and potential continuous travel through the M4 East and New M5 Motorways and surface roads.	Cumulative operational human health impacts are discussed in **section 11.5.1** and in **Chapter 26** (Cumulative impacts).

11.1 Assessment methodology

The methodology for the human health risk assessment is based on defining, quantifying where feasible, and assessing the potential risks to human health from the construction and operation of the project. The assessment focussed on the key impacts on local and regional air quality, in-tunnel air quality for tunnel users, noise and vibration and social changes.

11.1.1 Overview

The methodology adopted for the human health risk assessment is in accordance with national and international guidance that is endorsed or accepted by Australian health and environmental authorities, and includes, but is not limited to:

- Air Quality in and Around Traffic Tunnels (National Health and Medical Research Council (NHMRC) 2008)
- *Environmental Health Risk Assessment: Guidelines for Assessing Human Health Risks from Environmental Hazards: 2012* (enHealth 2012b)
- *Health Impact Assessment Guidelines* (enHealth 2001)
- *Health Impact Assessment: A Practical Guide* (NSW Health 2007)
- *Australian Exposure Factors Guide* (enHealth 2012a)
- *Schedule B8 Guideline on Community Engagement and Risk Communication* (National Environment Protection Council Schedule (NEPC) 1999 amended 2013a)
- National Environmental Protection (Air Toxics) Measure, Impact Statement for the National Environment Protection (Air Toxics) Measure (NEPC 2003)
- *Risk Assessment Guidance for Superfund: Volume I Human Health Evaluation Manual (Part F, Supplemental Guidance for Inhalation Risk Assessment)* (United States Environmental Protection Agency (USEPA) 2009b)
- State Environmental Planning Policy (SEPP) No. 33 – Hazardous and Offensive Development (NSW).

More specifically, in relation to the assessment of health impacts associated with exposure to nitrogen dioxide and particulate matter, guidelines available from the NEPC (Burgers & Walsh 2002; NEPC 1998, 2002, 2003, 2009, 2010), World Health Organization (WHO) (Ostro 2004; WHO 2003, 2006b, 2006a, 2013b) and the USEPA (USEPA 2005b, 2009b) have been used as required. In addition, the following has been considered:

- Building NSW Better Health, Health considerations for urban development and renewal in the Sydney Local Health District (NSW Health 2016)

- *Healthy Urban Development Checklist, A guide for health services when commenting on development policies, plans and proposals* (NSW Health 2009)
- Methodology for Valuing the Health Impacts of Changes in Particle Emissions (NSW Environment Protection Authority (NSW EPA) 2013).

This chapter considers the following issues in relation to the assessment of human health impacts:

- Existing conditions (in relation to air quality and noise)
- How the design of the project minimises adverse health impacts
- Human health risks and costs associated with the project, including those associated with air quality, noise and vibration, and social impacts, during the construction and operation of the proposal and estimation of short-term (acute) and long-term (chronic) impacts during construction and operation of the project
- Human health impacts on users of the tunnels and external receivers of air and noise emissions from the operation of the tunnels under a range of conditions, including a worst case operating condition
- Consideration of cumulative impacts includes the project, the other approved stages of WestConnex, and other related projects comprising the proposed future Sydney Gateway Western Harbour Tunnel and Beaches Link and F6 Extension projects.

The detailed principles, methodology and limitations of the toxicity and risk assessment are provided in section 3 of **Appendix K** (Technical working paper: Human health risk assessment).

11.1.2 Study area

The study area for the human health risk assessment overlaps with study areas considered in the M4 East and New M5 projects and is consistent with the area over which impacts on air quality have been considered, referred to as the GRAL domain. The domain extends well beyond the project footprint to allow for the traffic interactions between the project, other WestConnex projects (in particular the M4 East and New M5) and other future projects (Sydney Gateway, Western Harbour Tunnel and Beaches Link and F6 Extension). The study area is the area shown within the black line in **Figure 11-1**. A smaller study area closer to the project footprint has been considered for the assessment of soil and noise and vibration impacts.

The population considered in this assessment include those who live or work within the vicinity of the project footprint as well as the broader population associated with the overall WestConnex program of works. The study area covers a large number of individual suburbs that sit within the following local government areas (LGAs):

- Canada Bay
- Strathfield
- Burwood
- Inner West (amalgamation of former Ashfield, Leichhardt and Marrickville LGAs)
- City of Sydney
- Botany Bay
- Rockdale
- Canterbury
- Georges River (amalgamation of former Hurstville and Kogarah LGAs).

The above LGAs reflect those defined in 2016 following amalgamations and are consistent with the LGAs for which NSW Health provide some data. Some health data relates to the former LGAs.

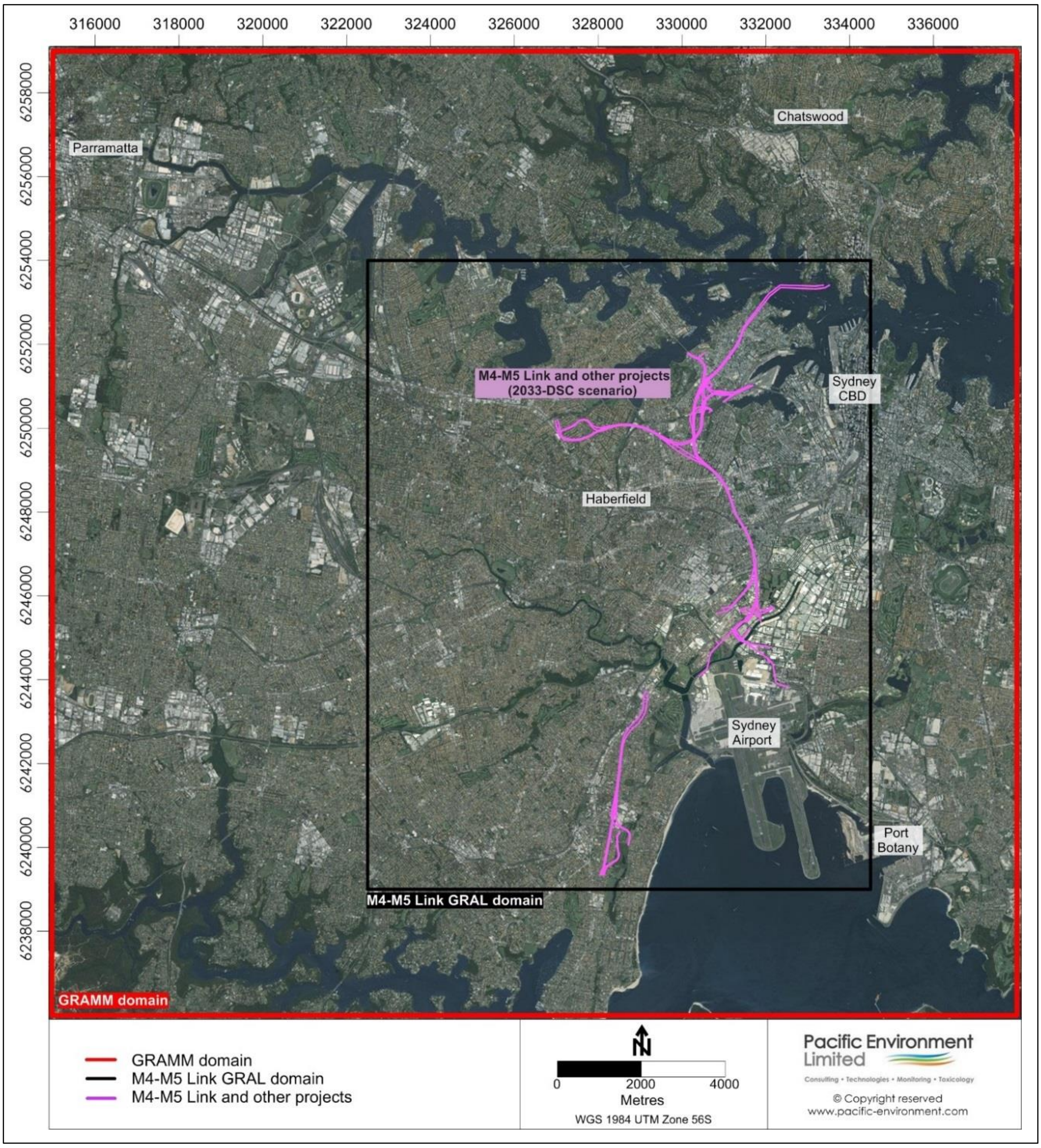


Figure 11-1 Human health risk assessment study area

11.1.3 Sensitive receivers

The assessment of potential impacts on the surrounding community, particularly in relation to air quality, has considered the location where maximum impacts from the project may occur. In addition, impacts on the wider community have also been considered. Within the wider community, a number of additional locations, referred to as ‘community receivers’, have been identified in the suburbs close to the project.

Community receptors are locations in the local community where more sensitive members of the population, such as infants and young children, the elderly or those with existing health conditions or illnesses, may spend a significant period of time. These locations may comprise hospitals, child care facilities, schools and aged care homes/facilities. **Table 11-2** presents a list of the community receptors included in this assessment. This is representative only and is not intended to comprise an exhaustive list of community receptors in the study area. The location of the sensitive or community receptors is presented in **Figure 11-2**.

Table 11-2 Community receptors included in human health risk assessment

	Receptor name	Type of receptor	Suburb
CR01	The Jimmy Little Community Centre	Community	Lilyfield
CR02	Balmain Cove Early Learning Centre	Child care	Rozelle
CR03	Rosebud Cottage Child Care Centre	Child care	Rozelle
CR04	Sydney Community College	Higher education	Rozelle
CR05	Rozelle Total Health	Health	Rozelle
CR06	Laurel Tree House Child Care Centre	Child care	Glebe
CR07	Bridge Road School	School - Primary	Camperdown
CR08	NHMRC Clinical Trials Centre	Health	Camperdown
CR09	Annandale Public School	School - Primary	Annandale
CR10	The University of Notre Dame Australia	Higher education	Chippendale
CR11	Laverty Pathology	Health	Annandale
CR12	Little VIP's Childcare Centre	Child care	Haberfield
CR13	Dobroyd Point Public School	School - Primary	Haberfield
CR14	Peek A Boo Early Learning Centre	Child care	Haberfield
CR15	Rozelle Child Care Centre	Child care	Lilyfield
CR16	Sydney Secondary College Leichhardt Campus	School - Secondary	Leichhardt
CR17	Rose Cottage Child Care Centre	Child care	Leichhardt
CR18	Inner Sydney Montessori	School - Primary	Lilyfield
CR19	Leichhardt Little Stars Nursery & Early Learning Centre	Child care	Leichhardt
CR20	Leichhardt Montessori Academy	Child-care	Leichhardt
CR21	St Basil's Sister Dorothea Village	Aged care	Annandale
CR22	St Thomas Child Care Centre	Child care	Rozelle
CR23	Billy Kids Lilyfield Early Learning Centre	Child care	Lilyfield
CR24	Little Learning School	Child care	Alexandria
CR25	Newtown Public School Combined Out of School Hours Care	School - Primary	Newtown
CR26	The Athena School	School – K to year 10	Newtown
CR27	Camdenville Public School	School - Primary	Newtown
CR28	St Joan of Arc Home for the Aged	Aged care	Haberfield
CR29	Inner West Education Centre	Education – K to year 8	Haberfield
CR30	St Peters Community Pre-school	Pre-school	St Peters
CR31	Rozelle Public School	School - Primary	Rozelle
CR32	Lilyfield Early Learning Centre	Child-care	Lilyfield
CR33	Sydney Secondary College Blackwattle Bay	School – Years 11 and 12	Glebe
CR34	Erskineville Public School	School - Primary	Erskineville
CR35	Haberfield Public School	School - Primary	Haberfield
CR36	The Infants Home	Early childhood including children with special needs	Ashfield
CR37	St Peters Public School	School - Primary	St Peters
CR38	Active Kids	Child-care	Mascot
CR39	Alexandria Early Learning Centre	Child-care	Alexandria
CR40	Sydney Park Childcare Centre	Child-care	Alexandria

In addition to these community receptors, about 86,375 individual receptors have been modelled in the streets/suburbs located in the study area. These individual receptors represent a range of uses including residential, workplaces or recreational (open space) areas in the surrounding community, as detailed in **Table 11-3**.

Table 11-3 Summary of RWR receptor types

Receptor type	Number	% of total
Aged care	20	0.02%
Child care/pre-school	129	0.15%
Commercial	2,766	3.20%
Community	1,941	2.25%
Further education	18	0.02%
Hospital	4	0.00%
Hotel	30	0.03%
Industrial	2,093	2.42%
Medical practice	125	0.14%
Mixed use	514	0.60%
Park/sport/recreation	1,018	1.18%
Place of worship	106	0.12%
Residential	75,157	87.01%
School	206	0.24%
Other[1]	2,248	2.60%
Total	**86,375**	**100.00%[2]**

Note:

1 'Other' includes car parks, garages, veterinary practices, construction sites, certain zoning categories (DM – Deferred Matter; G – Special Purposes Zone – Infrastructure; SP1 – Special Activities; SP2 – Infrastructure) and any other unidentified types

2 Total of receptor types does not add up to exactly 100 per cent due to rounding

These receptors are referred to as residential, workplace and recreational (RWR) receivers. The RWR includes all other community receivers located in the study area, not specifically included in **Table 11-2**. The maximum impacts from all the RWR receivers have also been evaluated so that all exposures that may occur within the community are addressed.

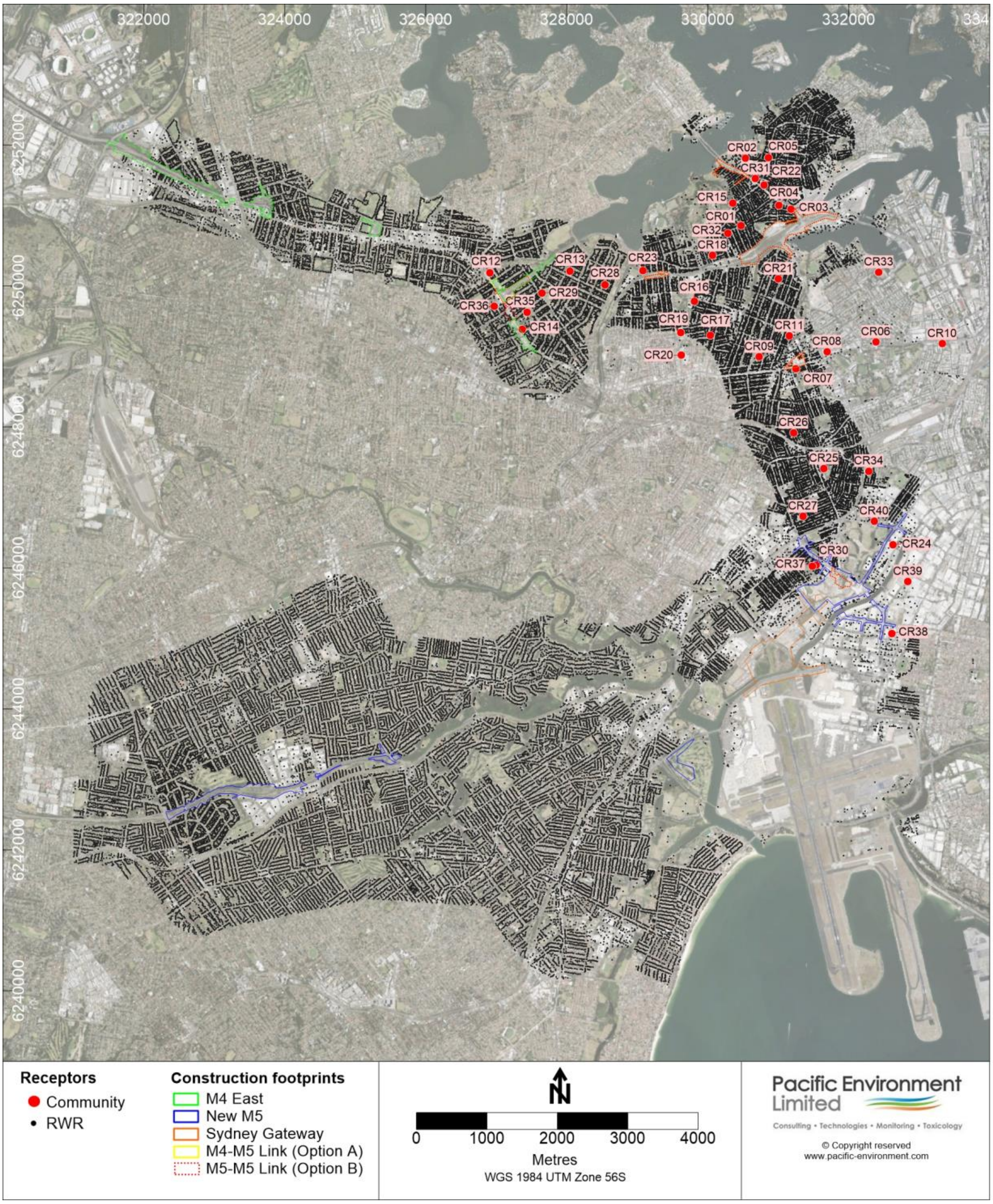


Figure 11-2 Community receptors evaluated in the human health risk assessment

11.2 Project design to minimise health impacts

The majority of the project footprint is underground. This includes the mainline tunnels as well as the Rozelle interchange and the Iron Cove Link. This means that road traffic noise is avoided during operation of the project except where entry and exit ramps come to the surface. It also means that emissions from vehicles are removed from surface roads and dispersed from elevated ventilation outlets with minimal impact on local air quality (see **section 11.5.1** and refer to **Chapter 9** (Air quality)).

Improved active transport links and new open space would be provided on completion of the project (see **sections 11.6.1** and **11.6.3**).

11.3 Existing environment

11.3.1 Population profile

The population within the study area comprise residents and workers as well as those attending schools, day care, hospitals and recreational areas. The composition of the populations located within the study area is expected to be generally consistent with population statistics for the larger individual suburbs that are wholly or partially included in the study area.

Population statistics for the LGAs (based on statistical areas SA3, which differ from the 2016 LGAs) are available from the Australian Bureau of Statistics (ABS) for the Census year 2011 and are summarised in **Table 11-4.** For the purpose of comparison, the population statistics presented also include the statistics for larger statistical population groups in the area (defined by the ABS SA4) and the larger statistical areas of Greater Sydney and the rest of the NSW (excluding Greater Sydney) (as defined by the ABS).

Table 11-4 Summary of population statistics in the study area

Location	Total population		% Population by key age groups					
	Male	Female	0–4	5–19	20–64	65+*	1–14*	30+*
Local statistical areas (SA3)								
Canada Bay	35,938	38,218	6.9	14.9	64.2	14.0	15.5	63.4
Strathfield – Burwood – Ashfield	67,285	69,922	5.7	15.3	65.9	13.1	14.3	59.8
Leichhardt	24,726	27,471	8.2	11.7	69.9	10.2	14.9	67.2
Sydney Inner City	92,089	82,483	3.7	7.0	81.6	7.8	6.2	59.1
Marrickville, Sydenham and Petersham	25,275	25,338	6.5	12.1	70.4	11.1	13.3	63.8
Canterbury	63,067	62,359	7.8	18.9	60.3	13.0	19.2	58.2
Botany	19,492	19,865	6.7	17.1	61.8	14.4	16.8	61.6
Hurstville	56,553	60,050	6.0	17.8	60.8	15.4	16.4	61.2
Kogarah and Rockdale	60,465	62,035	6.6	16.1	62.5	14.8	16.0	61.7
Larger local statistical areas (SA4 – includes SA3 areas)								
Sydney – Inner West	127,950	135,610	6.5	14.5	66.0	12.9	14.8	62.3
Sydney Inner South West	258,320	265,288	7.1	18.6	60.1	14.2	18.2	59.5
Sydney City and Inner South	136,858	127,686	4.7	9.4	76.5	9.4	9.1	60.4
Statistical areas of Sydney and NSW								
Greater Sydney	2,162,221	2,229,453	6.8	18.7	61.7	12.9	17.9	60.0
Rest of NSW (excluding Greater Sydney)	1,239,007	1,273,942	6.3	19.7	55.9	18	18.2	63.0

Notes:

SA = statistical area

SA3 are larger statistical areas that are aggregates of SA2 areas with populations between 30,000 and 130,000

SA4 are larger statistical areas that are aggregates of SA3 areas with populations in excess of 100,000

* Age groups specifically relevant to the characterisation of risk

Based on general population data, the populations in the study area are generally similar to Greater Sydney with the exception of the following:

- Sydney – Inner City, as well as the larger area of Sydney City and Inner South, have a lower proportion of young children, a higher proportion of working aged individuals and a lower proportion of individuals aged over 65 years
- Areas of Marrickville, Sydenham and Petersham, Strathfield, Burwood and Ashfield, Canada Bay and Leichhardt also have a slightly lower proportion of young children.

The estimated population growth from 2011 to 2036 for these areas is:

- Canada Bay: 53.5 per cent
- Strathfield: 74.2 per cent
- Burwood: 68.3 per cent
- Inner West (Ashfield, Leichhardt and Marrickville): 27.7 per cent
- City of Sydney: 72.0 per cent
- Botany: 75.2 per cent
- Canterbury-Bankstown: 49.7 per cent
- Rockdale: 50.2 per cent
- Georges River (Hurstville and Kogarah): 28.5 per cent.

11.3.2 Health of existing population

The health of the community is influenced by a complex range of interacting factors including age, socio-economic status, social networks, behaviours, beliefs and lifestyle, life experiences, country of origin, genetic predisposition and access to health and social care.

Information in relation to health related behaviours (that are linked to poorer health status and chronic disease including cardiovascular and respiratory diseases, cancer, and other conditions that account for much of the burden of morbidity and mortality in later life) is available for the larger populations within the local area health services in Sydney and NSW. This includes risky alcohol drinking, smoking, inadequate consumption of fruit and vegetables, being overweight or obese, and inadequate physical activity.

The study population is largely located within the Sydney Area Health Service and the South Eastern Sydney Area Health Service. The incidence of these health-related behaviours in this area, compared with other health areas in NSW, and the state of NSW (based on data from 2015 and 2016) is illustrated in Figure 4-3 of **Appendix K** (Technical working paper: Human health risk assessment).

Review of this data generally indicates that the population in the Sydney and South Eastern Sydney Area Health Service areas (that include the study area) have:

- Similar rates of risky alcohol drinking and smoking and similar intakes of recommended consumption of fruit and vegetables compared with NSW
- Higher rates of adequate physical activity and lower rates of being overweight and obese compared with NSW.

A review of the data obtained from Health Statistics NSW generally indicates that for the population in the study area, the health statistics (including mortality rates and hospitalisation rates for most categories) are variable but generally similar to those reported in the larger area health services of Sydney and South Eastern Sydney, the wider Sydney metropolitan area and the whole of NSW.

Section 4.5 of **Appendix K** (Technical working paper: Human health risk assessment) provides further details on health related behaviours and health indicators for the study area.

11.3.3 Existing air quality

The project is situated within an urbanised area of Sydney. In large urban areas there is usually a complex interaction of pollution sources, substantial concentration gradients, variable meteorological conditions and local topography, all affecting the quality of the air.

Air quality in the Sydney region has improved over the last few decades. The improvements have been attributed to initiatives which aim to reduce emissions from industry, motor vehicles, businesses and residences. While levels of nitrogen dioxide (NO_2), sulfur dioxide (SO_2) and carbon monoxide (CO) continue to be below national standards, levels of ozone and particulate matter ($PM_{2.5}$ and PM_{10}) can occasionally exceed the standards.

For these pollutants there are a large number of sources in the study area including combustion sources other than from the project, other local construction/earthworks and personal exposures (such as smoking) and risk-taking behaviours that have the potential to affect the health of any population.

More information about existing air quality within the study area is provided in **Chapter 9** (Air quality).

11.3.4 Existing noise and vibration

The noise levels at unattended monitoring locations showed a typical daily trend with lower noise levels during the night-time compared to the daytime and evening periods. This is characteristic of urban and suburban areas where the ambient noise environment is primarily influenced by road traffic. The data is also consistent with observed traffic flows on the adjacent arterial roads which have a relatively small reduction in traffic volumes during the evening compared to the daytime period, and a more significant reduction in volumes during the night-time.

The measured noise levels have been used with consideration of the existing road traffic flows to calibrate the operational noise model and also to establish construction noise management levels for the project.

Background noise levels during construction have been established for the daytime (7.00 am to 6.00 pm, varying from 45 to 68 decibels (dB(A)), evening (6.00 pm to 10.00 pm, varying from 43 to 67 dB(A) and night-time (10.00 pm to 7.00 am, varying from 32 to 51 dB(A)) periods as rating background level (RBL) values determined on the basis of adopted guidelines.

Background noise levels during operation have been established for the daytime (7.00 am to 10.00 pm varying from 54 to 73 dB(A)) as L_{Aeq}(15 hour) and night-time (10.00 pm to 7.00 am varying from 50 to 70 dB(A)) as $L_{Aeq(9\ hour)}$.

More information about the existing noise environment is provided in **Chapter 10** (Noise and vibration).

11.4 Assessment of potential construction impacts

11.4.1 Air quality

Impacts on air quality that may occur during construction as a result of tunnelling activities and surface works has been considered in **Chapter 9** (Air quality).

The assessment of construction air quality was carried out using a qualitative assessment approach. For almost all construction activities, significant impacts on receivers would be avoided through project design and the implementation of effective, industry standard mitigation and management measures. However, dust management measures may not be effective all of the time. In situations where the construction air quality management measures are not fully effective, impacts on the community would generally be temporary and short-term and are not considered to be significant.

Dust management procedures would be included as part of the Construction Environmental Management Plan (CEMP). Measures to manage dust impacts include site management, preparing and maintaining construction sites, maintenance and controls on vehicles and machinery, and waste management (refer to **Chapter 9** (Air quality) for further details). The effectiveness of dust control measures would be monitored and adjusted as required. Where the dust mitigation measures are effectively implemented, impacts on the health of the community would be minimised.

11.4.2 Noise and vibration

As described in **Chapter 10** (Noise and vibration), a worst case noise and vibration assessment (assuming no additional mitigation measures are implemented) was carried out in accordance with the *Interim Construction Noise Guidelines* (NSW Department of Environment and Climate Change (DECC) 2009). For each area assessed, the noise levels at the most affected receivers have been used to represent the whole area.

Potential noise impacts from movement of construction vehicles

Potential increases in noise for sensitive receivers (as defined in **section 11.1.3**) due to construction traffic has been assessed separately from the assessment of noise from other construction activities. Heavy vehicles involved in construction are expected to travel via existing arterial roads (figures showing spoil haulage routes are provided in **Chapter 6** (Construction work)). In all areas evaluated, there are no noticeable increases in noise from construction traffic on the proposed routes during the daytime or night-time.

Ground-borne construction noise

Ground-borne noise occurs when works are being undertaken underground or in some other fashion that results in the vibrations from noise moving through the ground rather than the air. This project involves tunnelling, so many of the more significant noise activities would take place at depth (with a large proportion of the mainline tunnels at depths between around 30 to 60 metres), where activities are expected to occur 24 hours per day.

The roadheader excavation would typically progress at around 20 to 25 metres per week subject to local geology and confirmation of the tunnel excavation methods. Ground-borne noise from roadheader activity is expected to impact about 494 properties, mostly where the tunnel entry and exit ramps would approach the surface road network around the Wattle Street interchange, the Rozelle interchange, the Iron Cove Link and on the approach to the St Peters interchange. It is likely that the excavation by the roadheaders may be perceptible in the evening and during the night for up to about 20 days at each affected receiver as the roadheader passes them, with exceedances of ground-borne noise goals at affected receivers during these periods. Roadheader advance rates would reduce to two to five metres a day around the portals, which may slightly increase the duration of exposure for receivers in these areas.

The modelling addressed the worst-case situation when the tunnelling is occurring immediately beneath a sensitive receiver. Exceedance of the night-time criteria has been identified for sensitive receptors near key construction areas, specifically the Darley Road civil and tunnel site (C4) (with exceedance up to four dB (A)) and the Pyrmont Bridge Road tunnel site (C9) (with exceedance up to five dBA).

Mitigation and management measures include the validation of predicted impacts from the noise and vibration modelling (which is based on a conservative worst-case assessment) and notifying the community of noise impacts anticipated at specific times. At two residential locations, night-time ground-borne noise is predicted to exceed the criteria by 10 dBA or more. At these receivers, additional mitigation measures have been identified that include providing individual briefings on impacts and mitigation measures, providing respite periods, and alternate accommodation.

Vibration impacts

Some items of equipment to be used during construction have the potential to cause unacceptable levels of vibration. Managing the potential for such vibration to actually cause discomfort or structural damage at sensitive receiver locations is based on ensuring suitable separation distances between the equipment and the receiver locations.

The proposed management of vibration impacts involves monitoring of the predicted impacts, advising the community of impacts and offering respite periods to affected residents where human comfort levels are to be exceeded for an extended period of time during any one day.

Blasting

Blasting would be carried out along the length of the tunnel alignment during excavation and would be carefully planned to ensure blast limits are satisfied. Blasting would be undertaken during reduced standard construction hours (between 9.00 am and 5.00 pm, Monday to Friday and 9.00 am to 1.00 pm on Saturday) and would be subject to the provision of respite periods. A description of how blasting would be carried out is provided in **Chapter 6** (Construction work). Further detailed assessment and a blast trial process would be described in a Blast Management Strategy, which would be prepared during the detailed design of the project. An assessment of the impacts of blasting on receivers is provided in **Chapter 10** (Noise and vibration).

11.4.3 Public safety

A range of possible hazards have been identified that have the potential to affect public safety during construction. These are outlined in **Table 11-5** along with discussion on the risks that may be posed by these hazards. Not all the hazards identified in the hazard and risk assessment have been included in the table, only those where there is the potential for risks to public safety. Further detail on project hazards is provided in **Chapter 25** (Hazard and risk).

Table 11-5 Overview of public safety hazards and risks: Construction

Hazard: Public safety	Risk to public safety	Management measures
Storage and handling of dangerous goods on construction sites that may impact the community in the case of a spill or leak.	**Low** The storage volume of dangerous goods on any one construction site is low. In the event of an incident, there would very low potential for an off-site risk.	All materials would be stored in accordance with the Australian Dangerous Goods Code that includes the use of bunding, ventilation of areas where gases are stored, locating stores of these materials away from sensitive areas, and maintaining a register and inventory.
Incidents related to the transport of dangerous goods and hazardous substances on public roads.	**Low** The quantities and frequency of transport for these chemicals is low. All transport would involve using trucks that are suitable to transport these materials, with procedures in place to manage any leaks or spills during an accident.	All materials would be transported in accordance with the Storage and Handling of Dangerous Goods Code of Practice (WorkCover NSW 2005), *Dangerous Goods (Road and Rail Transport) Act 2008* (NSW), Dangerous Goods (Road and Rail Transport) Regulation 2014 (NSW) and relevant Australian Standards.
Tunnel collapse that may affect areas overlying the tunnel alignment.	**Low**	All tunnelling would be undertaken under a permit to tunnel system that requires detailed consideration of ground support performance as well as geotechnical and groundwater conditions for each tunnel section.
Potential acid sulfate soils may result in acidification and the mobilisation of metals, adversely impacting the water quality of waterways used by the public.	**Low**	Standard construction and mitigation measures would be applied to mitigate the potential risks associated with the disturbance of acid sulfate soils.

Hazard: Public safety	Risk to public safety	Management measures
Contamination, specifically the presence of hazardous materials (such as asbestos) and works in areas where contamination is present in soil, which may result in contaminants migrating off-site onto neighbouring properties or into waterways.	**Low**	Removal of asbestos would be required to be undertaken in accordance with procedures detailed in an Asbestos Management Plan for the project, which meet national legislation and guidance.
Flooding of land downgradient of construction sites due to changes to local landform and/or water diversions.	**Low** Flooding risks to off-site areas evaluated though modelling indicate no significant impacts.	Construction sites and permanent operational infrastructure would be designed to minimise the potential for off-site flooding impacts.
Damage to underground utilities, affecting public roadways and services provided to the community.	**Low**	A Utilities Management Strategy (refer to **Appendix F** (Utilities Management Strategy)) has been prepared for the project that identifies management options, including relocation or adjustment of the utilities. This includes consultation with utilities and service infrastructure providers to mitigate the risk of unplanned or unexpected disturbance of utilities.
Bushfire or fire risks that may spread off-site and affect neighbouring properties.	**Low**	The project is in a highly urbanised area that is not in or near a bushfire prone area. Management of construction facilities and activities involving flammable materials and ignition sources would be undertaken to minimise fire risks. High risk construction activities, such as welding and metal work, would be subject to a risk assessment on total fire ban days, and restricted or ceased as appropriate.
Aviation risks, specifically works that may affect the safety of aircraft using Sydney Airport.	**Low**	Construction activities would be carried out to ensure that equipment such as cranes and materials do not intrude into the obstacle limitation surface (OLS) or procedures for air navigation systems operations (PANS-OPS) for Sydney Airport. Ongoing consultation would be undertaken with Australian Government regulatory agencies and Sydney Airport Corporation Limited to ensure all legal obligations and other requirements would be met.

Hazard: Public safety	Risk to public safety	Management measures
Traffic and trucks on surface roads have the potential to increase the risk to public safety due to road incidents.	**Low** Changes to the surface road network may require temporary traffic detours. Construction road traffic volumes are low compared with existing traffic volumes, which is not expected to significantly impact on road safety.	Heavy vehicle movements would involve the use of major roads including Parramatta Road, City West Link, Victoria Road, Pyrmont Bridge Road and the Princes Highway. All traffic detours would be undertaken in accordance with approvals by Roads and Maritime, local councils and the Transport for NSW Transport Management Centre. Property access would be maintained, or alternative access provided. A Construction Traffic and Access Management Plan (CTAMP) would be prepared as part of the CEMP to manage these impacts.
Changes to local roads and active transport pathways may affect pedestrian and cyclist safety.	**Low** Construction and surface road works may require detours by pedestrians and cyclists but these would be temporary.	Alternative safe pedestrian and cyclist access would be provided where it is practical and safe to do so. This would be addressed in the CTAMP.
Subsidence.	**Low** Tunnel induced ground movement that may result in ground settlement is considered to be low along most of the tunnel alignment. In some areas, where shallow tunnelling or multiple tunnels are proposed close to each other, higher levels of settlement are predicted. In these areas, potential settlement impacts require further assessment and potential management.	Further assessment of potential settlement impacts, including modelling would be required during the detailed design. Where ground movement in excess of settlement criteria are predicted a range of design, construction and ground improvement measures (as outlined in Chapter 12 of the EIS) would be considered to reduce impacts. In addition, a range of management measures would be implemented (as detailed in Chapter 12 of the EIS). This includes the preparation and implementation of a Settlement Monitoring Plan, preparation of building condition surveys, repair of cracking or property damage deemed to have occurred from the construction of the project, and preparation of agreements with utility owners and infrastructure owners identifying acceptable levels of settlement, monitoring requirements and measures to be implemented where levels are exceeded.

On the basis of the above there are not considered to be any issues related to construction that have the potential to result in significant safety risks to the public.

11.5 Assessment of potential operational impacts

11.5.1 Air quality

The assessment of impacts on air quality associated with the operation of the project has considered a range of scenarios that include the existing situation and operation for the future years 2023 and 2033; both with and without the project. The operational air quality assessment has focused on the following key pollutants associated with vehicle emissions:

- Volatile organic compounds (VOCs)

- Polycyclic aromatic hydrocarbons (PAH)
- CO
- NO_2
- Particulate matter ($PM_{2.5}$ and PM_{10}).

Assessment of emissions to air from the project has involved the calculation of emissions from vehicles using the tunnel, and other approved WestConnex project tunnels, under expected traffic conditions (ie operating normally with traffic volumes fluctuating over the day with peak and out of peak traffic loads). In addition, a regulatory worst case scenario has been evaluated. The regulatory worst case assumes that the tunnel(s) is full of vehicles, such that the emissions from the ventilation outlets are at the maximum level, at all hours of the day. This is not a realistic scenario however it is used to demonstrate compliance with regulatory assessment requirements. Additional details on the assessment scenarios and the emission sources considered are provided in **Appendix K** (Technical working paper: Human health risk assessment). Assessment of project related air emissions included a calculation of the changes in emissions to air due to the traffic changes across the network resulting from operation of the project (refer to **Chapter 9** (Air quality)).

There are in-tunnel air quality limits and ventilation outlet emission limits that are required to be met under all operational circumstances (except emergencies such as fire). The tunnel ventilation system and tunnel operational parameters are designed to ensure that the in-tunnel concentration limits are not exceeded and to control the concentration of pollutants discharged to the external environment. Additional details on the operational air quality assessment scenarios, locations of air quality monitoring stations and the emission sources and limits considered are provided in **Chapter 9** (Air quality).

Vehicle emissions

Emissions from vehicles using the project tunnels have been estimated based on an emissions inventory model developed by the NSW EPA (as described in **Appendix I** (Technical working paper: Air quality)) which includes projected emissions improvements up to 2033.

Volatile organic compounds and polycyclic aromatic hydrocarbons

VOCs and PAHs are associated with emissions from vehicles using the mainline tunnels and the local surface road network, with levels dependent on the mix of vehicles. Most of the VOC emissions comprise a range of hydrocarbons. From a toxicity perspective, the key VOCs that have been considered for the vehicle emissions are benzene, toluene, ethylbenzene, and xylenes (BTEX), 1,3-butadiene, acetaldehyde and formaldehyde (consistent with those identified and targeted in studies conducted in Australia on vehicle emissions (Australian Government Department of the Environment 2003 and NSW EPA 2012)).

The maximum increase in total VOCs and PAHs in the community is equal to or lower where the project is operating compared with the situation of no project (ie the project results in no change or a lower total impact of VOCs and PAHs in the community).

The change in VOC and PAH concentrations associated with the project is a decrease for most receptors, however in some areas there is an increase in concentrations associated with the redistribution of emissions from vehicles (primarily associated with surface roads). The following evaluation has been undertaken to assess the potential health impacts associated with the maximum increases predicted.

The assessment of potential health impacts associated with exposure to changes in VOCs and PAHs concentrations in air within the community has been assessed on the basis of the following:

- For VOCs and PAHs that are considered to be genotoxic carcinogens (consistent with guidance provided by enHealth (enHealth 2012b)) an incremental lifetime carcinogenic risk has been calculated. For the VOCs and PAHs evaluated in this assessment a carcinogenic risk calculation has been adopted for the assessment of maximum potential (incremental) increase in benzene, 1,3-butadiene and carcinogenic PAHs (as a benzo(a)pyrene toxicity equivalent (TEQ)). The assessment undertaken has adopted the calculation methodology outlined in Annexure B of **Appendix K** (Technical working paper: Human health risk assessment)

- For other VOCs and PAHs, where the health effects are associated with a threshold (ie a level below which there are no effects), the maximum predicted concentration from all sources (ie background plus the project) of individual VOCs and PAHs associated with the project have been compared against published peer-reviewed health based guidelines that are relevant to acute and chronic exposures (where relevant). The health based guidelines adopted (identified on the basis of guidance from enHealth 2012) are relevant to exposures that may occur to all members of the general public (including sensitive individuals) with no adverse health effects. The guidelines available relate to the duration of exposure and the nature of the health effects considered where:
  - Acute guidelines are based on exposures that may occur for a short period of time (typically between one hour, or up to 14 days). These guidelines are available to assess peak exposures (based on the modelled one-hour average concentration) that may be associated with VOCs in the air
  - Chronic guidelines are based on exposures that may occur all day, every day for a lifetime. These guidelines are available to assess long-term exposures (based on the modelled annual average concentration) that may be associated with VOCs and PAHs in the air.

Table 6-4 and Table 6-5 in **Appendix K** (Technical working paper: Human health risk assessment) provide the adopted acute and chronic health based inhalation guideline criteria for the compounds used as part of the assessment.

Table 11-6 to **Table 11-11** present a summary of the maximum predicted one-hour or annual average concentrations of VOCs and PAHs assessed on the basis of a threshold with comparison against acute and chronic health based guidelines. The table also presents a Hazard Index (HI) which is the ratio of the maximum predicted concentration to the guideline.

Each individual HI is added up to obtain a total HI for all the threshold VOCs and PAHs considered. The total HI is a sum of the potential hazards associated with all the threshold VOCs and PAHs together assuming the health effects are additive, and is evaluated as follows:

- A total HI less than or equal to one means that all the maximum predicted concentrations are below the health based guidelines and there are no additive health impacts of concern
- A total HI greater than one means that the predicted concentrations (for at least one individual compound) are above the health based guidelines, or that there are at least a few individual VOCs or PAHs where the maximum predicted concentrations are close to the health based guidelines such that there is the potential for the presence of all these together (as a sum) to result in adverse health effects.

The assessment of acute exposures, presented in **Table 11-6** and **Table 11-7**, has compared the maximum predicted total (background plus existing roads and the project) one-hour average concentration against the relevant acute guidelines. This is the maximum one-hour average concentration reported anywhere in the study area, regardless of land use.

The assessment of chronic exposures, presented in **Table 11-8** and **Table 11-9**, has compared the maximum predicted total annual average concentration relevant to residential land use against the relevant chronic guidelines. For exposures in other areas, **Table 11-8** and **Table 11-9** also presents the maximum calculated HI relevant to exposures in commercial/industrial areas, where the maximum change in VOC concentrations is predicted. The calculated HI takes into account that these exposures occur for eight hours per day over 240 days per year.

Table 11-10 and **Table 11-11** presents a summary of the calculated incremental lifetime carcinogenic risk associated with exposure to the maximum predicted change in concentrations of benzene, 1,3-butadiene and carcinogenic PAHs (as benzo(a)pyrene TEQ) in residential areas. The calculation presented assumes residents are exposed to these pollutants all day, every day for a lifetime. The calculated carcinogenic risk for these compounds has been summed, in accordance with enHealth guidance.

The tables also present the calculated total carcinogenic risk relevant to exposures in commercial/industrial areas, where the maximum change in VOCs and PAHs is predicted to occur. This calculation assumes workers are exposed eight hours per day, 240 days per year for 30 years. The calculated risks are considered in conjunction with what are considered negligible, tolerable/acceptable and unacceptable risks. Refer to Annexure C of **Appendix K** (Technical working paper: Human health risk assessment) for further information on what constitutes a negligible, tolerable/acceptable or unacceptable risk.

The values presented in the tables have been rounded to two significant figures for individual calculations and one significant figure for the total HI and total carcinogenic risk, reflecting the level of uncertainty in the calculations presented.

Table 11-6 Assessment of acute exposures to VOCs – maximum impacts in community associated with project: 2023

Key VOC	Maximum predicted 1-hour average concentration associated with project (background plus project) and calculated HI					
	2023: Without project		2023: With project		2023: Cumulative	
	Maximum concentration (µg/m^3)	HI	Maximum concentration (µg/m^3)	HI	Maximum concentration (µg/m^3)	HI
Benzene	17.3	0.030	21.3	0.037	16.5	0.028
Toluene	31.8	0.0021	39.3	0.0026	30	0.0020
Xylenes	26.2	0.0035	32.4	0.0044	25	0.034
1,3-Butadiene	4.6	0.0070	5.7	0.0086	4.4	0.0067
Formaldehyde	12.1	0.24	15.0	0.30	11.6	0.23
Acetaldehyde	7.8	0.017	9.6	0.020	7.0	0.015
Total HI		**0.3**		**0.4**		**0.3**

Table 11-7 Assessment of acute exposures to VOCs – maximum impacts in community associated with project: 2033

Key VOC	Maximum predicted 1-hour average concentration associated with project (background plus project) and calculated HI					
	2033: Without project		2033: With project		2033: Cumulative	
	Maximum concentration (µg/m^3)	HI	Maximum concentration (µg/m^3)	HI	Maximum concentration (µg/m^3)	HI
Benzene	9.7	0.017	9.4	0.016	8.3	0.014
Toluene	17.2	0.0011	16.7	0.0011	14.7	0.0010
Xylenes	14.2	0.0019	13.7	0.0019	12.1	0.0016
1,3-Butadiene	2.6	0.0039	2.6	0.0039	2.3	0.0035
Formaldehyde	11.4	0.23	11.0	0.22	9.7	0.19
Acetaldehyde	5.1	0.011	4.9	0.010	4.1	0.0087
Total HI		**0.3**		**0.3**		**0.2**

Table 11-8 Assessment of chronic exposures to VOCs and PAHs – maximum impacts in community associated with project: 2023

Key VOCs and PAHs	Maximum predicted annual average concentration associated with project (background plus project) and calculated HI – Residential Exposures					
	2023: Without project		2023: With project		2023: Cumulative	
	Max concentration (µg/m^3)	HI	Max concentration (µg/m^3)	HI	Max concentration (µg/m^3)	HI
Benzene	2.2	0.075	2.1	0.071	2.2	0.073
Toluene	9.3	0.0019	9.0	0.0018	9.1	0.0018
Xylenes	6.25	0.028	6.0	0.027	6.1	0.028
Formaldehyde	0.53	0.16	0.43	0.13	0.47	0.14
Acetaldehyde	0.238	0.0264	0.28	0.031	0.29	0.032
Naphthalene	0.085	0.028	0.069	0.023	0.076	0.025
Acenaphthylene	0.0059	3.0×10^{-5}	0.0048	2.4×10^{-5}	0.0053	2.7×10^{-5}
Acenaphthene	0.0024	1.2×10^{-5}	0.002	9.9×10^{-6}	0.0022	1.1×10^{-5}
Fluorene	0.0060	4.3×10^{-5}	0.0049	3.5×10^{-5}	0.0054	3.9×10^{-5}

Key VOCs and PAHs	Maximum predicted annual average concentration associated with project (background plus project) and calculated HI – Residential Exposures					
	2023: Without project		2023: With project		2023: Cumulative	
	Max concentration (µg/m^3)	HI	Max concentration (µg/m^3)	HI	Max concentration (µg/m^3)	HI
Phenanthrene	0.0041	2.9 x10^{-5}	0.0034	2.4 x10^{-5}	0.0037	2.6 x10^{-5}
Anthracene	0.00059	5.9 x10^{-7}	0.00048	4.8 x10^{-7}	0.00053	5.3 x10^{-7}
Fluoranthene	0.00054	3.9 x10^{-6}	0.00045	3.2 x10^{-6}	0.00049	3.5 x10^{-6}
Pyrene	0.00086	8.6 x10^{-6}	0.00070	7.0 x10^{-6}	0.00077	7.7 x10^{-6}
Total HI – Residential		**0.2**		**0.2**		**0.2**
Max HI – Commercial/Industrial		**0.06**		**0.06**		**0.06**

Table 11-9 Assessment of chronic exposures to VOCs and PAHs – maximum impacts in community associated with project: 2033

Key VOCs and PAHs	Maximum predicted annual average concentration associated with project (background plus project) and calculated HI – Residential Exposures					
	2033: Without project		2033: With project		2033: Cumulative	
	Max concentration (µg/m^3)	HI	Max concentration (µg/m^3)	HI	Max concentration (µg/^{m3})	HI
Benzene	1.9	0.063	1.85	0.062	1.8	0.061
Toluene	8.6	0.0017	8.52	0.0017	8.5	0.0017
Xylenes	5.67	0.026	5.61	0.026	5.6	0.025
Formaldehyde	0.46	0.14	0.41	0.12	0.41	0.12
Acetaldehyde	0.14	0.016	0.19	0.021	0.17	0.019
Naphthalene	0.085	0.028	0.069	0.023	0.076	0.025
Acenaphthylene	0.0059	3.0 x10^{-5}	0.0048	2.4 x10^{-5}	0.0053	2.7 x10^{-5}
Acenaphthene	0.0024	1.2 x10^{-5}	0.002	9.9 x10^{-6}	0.0022	1.1 x10^{-5}
Fluorene	0.0060	4.3 x10^{-5}	0.0049	3.5 x10^{-5}	0.0054	3.9 x10^{-5}
Phenanthrene	0.0041	2.9 x10^{-5}	0.0034	2.4 x10^{-5}	0.0037	2.6 x10^{-5}
Anthracene	0.00059	5.9 x10^{-7}	0.00048	4.8 x10^{-7}	0.00053	5.3 x10^{-7}
Fluoranthene	0.00054	3.9 x10^{-6}	0.00045	3.2 x10^{-6}	0.00049	3.5 x10^{-6}
Pyrene	0.00086	8.6 x10^{-6}	0.00070	7.0 x10^{-6}	0.00077	7.7 x10^{-6}
Total HI – Residential		**0.2**		**0.2**		**0.2**
Max HI – Commercial/Industrial		**0.05**		**0.05**		**0.05**

Table 11-10 Assessment of incremental lifetime carcinogenic risk – maximum impacts in community associated with project: 2023

Key VOC	Maximum predicted change in annual average concentration associated with project and cancer risk - Residential			
	2023: With project		2023: Cumulative	
	Maximum concentration (µg/m^3)	ILCR	Maximum concentration (µg/m^3)	ILCR
Benzene	0.061	2 x 10^{-7}	0.095	2 x 10^{-7}
1,3-Butadiene	0.016	3 x 10^{-9}	0.025	5 x 10^{-9}
Benzo(a)pyrene TEQ	0.00045	2 x 10^{-5}	0.00070	2 x 10^{-5}
Total carcinogenic risk - residential		**2 x 10^{-5}**		**2 x 10^{-5}**
Maximum carcinogenic risk – commercial/industrial		**6 x 10^{-6}**		**2 x 10^{-5}**

Note:

ILCR = incremental lifetime carcinogenic risk (refer to Annexure B of **Appendix K** (Technical working paper: Human health risk assessment) for calculation methodology and Table 6-5 of **Appendix K** (Technical working paper: Human health risk assessment) for inhalation unit risk values)

Table 11-11 Assessment of incremental lifetime carcinogenic risk – maximum impacts in community associated with project: 2033

Key VOC	Maximum predicted change in annual average concentration associated with project and cancer risk – Residential			
	2023: With project		2023: Cumulative	
	Maximum concentration (μg/m^3)	ILCR	Maximum concentration (μg/m^3)	ILCR
Benzene	0.04	1 x 10^{-7}	0.054	1 x 10^{-7}
1,3-Butadiene	0.011	2 x 10^{-9}	0.014	3 x 10^{-9}
Benzo(a)pyrene TEQ	0.00034	1 x 10^{-5}	0.00046	2 x 10^{-5}
Total carcinogenic risk – residential		**1 x 10^{-5}**		**2 x 10^{-5}**
Maximum carcinogenic risk – commercial/industrial		**5 x 10^{-6}**		**1 x 10^{-5}**

Note:

ILCR = incremental lifetime carcinogenic risk (refer to Annexure B of **Appendix K** (Technical working paper: Human health risk assessment) for calculation methodology and Table 6-5 of **Appendix K** (Technical working paper: Human health risk assessment) for inhalation unit risk values)

For the assessment of acute exposures to VOCs (**Table 11-6** and **Table 11-7**), the calculated HI associated with exposure to the maximum concentrations predicted is less than one for 2023, 2033 and the cumulative scenario. On this basis, there are no acute risk issues in the local community associated with the project.

For the assessment of chronic exposures to VOCs and PAHs (**Table 11-8** to **Table 11-11**), the calculated HI associated with exposure to the maximum concentrations predicted is less than or equal to one for 2023, 2033 and the cumulative scenario.

The calculated lifetime cancer risks associated with the maximum change in benzene, 1,3-butadiene and carcinogenic PAHs (as benzo(a)pyrene TEQ) are less than or equal to 2x10^{-5} and are considered to be tolerable. The calculations undertaken for PAHs is based on a conservative estimate of the fraction of emissions from vehicles that comprises PAHs (as a percentage of total VOCs). The approach adopted is therefore expected to overestimate concentrations of PAHs in air. Hence, the calculations presented are considered to be a conservative upper limit estimate.

On this basis, there are not considered to be any chronic health risk issues in the local community associated with the operation of project.

Carbon monoxide

Motor vehicles are the dominant source of CO in air (NSW Department of Environment, Climate Change and Water (DECCW) 2009). Adverse health effects of exposure to carbon monoxide are linked with carboxyhaemoglobin (COHb) in blood. In addition, association between exposure to CO and cardiovascular hospital admissions and mortality, especially in the elderly for cardiac failure, myocardial infarction and ischemic heart disease; and some birth outcomes (such as low birth weights), have been identified (NEPC 2010).

Guidelines are available in Australia from NEPC (2003) and NSW EPA that are based on the protection of adverse health effects associated with CO. Review of these guidelines by NEPC (2010) identified additional supporting studies for the evaluation of potential adverse health effects and indicated that these should be considered in the current review of the National Ambient Air Quality NEPM (no interim or finalisation date available). The air guidelines currently available from NEPC are consistent with health based guidelines currently available from the WHO (2005) and the USEPA (2011), specifically listed to be protective of exposures by sensitive populations including asthmatics, children and the elderly). On this basis, the current NEPC guidelines are considered appropriate for the assessment of potential health impacts associated with the project.

The NEPC ambient air quality guideline for the assessment of exposures to carbon monoxide has considered lowest observed adverse effect level (LOAEL) and no observed adverse effect level (NOAEL) associated with a range of health effects in healthy adults, people with ischemic heart disease and foetal effects. In relation to these data, a guideline level of CO of nine parts per million (ppm) by volume (or 10 milligrams per cubic metre (mg/m^3) or 10,000 micrograms per cubic metre (µg/m^3)) over an eight-hour period was considered to provide protection (for both acute and chronic health effects) for most members of the population. An additional 1.5-fold uncertainty factor to protect more susceptible groups in the population was included. On this basis, the NEPC (and the NSW EPA) guideline is protective of adverse health effects in all individuals, including sensitive individuals.

The NSW EPA has also established a guideline for 15 minute average (100 mg/m^3) and one hour average (30 mg/m^3) concentrations of CO in ambient air. These guidelines are based on criteria established by the WHO (WHO 2000a) using the same data used by the NEPC to establish the guideline (above) with extrapolation to different periods of exposure on the basis of known physiological variables that affect CO uptake.

Table 11-12 presents a summary of the maximum predicted cumulative one-hour average and eight-hour average concentrations of CO for the assessment years 2023 and 2033, without the project, with the project and for the cumulative scenario.

Table 11-12 Review of potential acute and chronic health impacts – carbon monoxide

Scenario	Maximum 1-hour average concentration of carbon monoxide (mg/m^3)			Maximum 8-hour average concentration of carbon monoxide (mg/m^3)		
	Without project	With project	Cumulative	Without project	With project	Cumulative
2023						
Maximum	7.8	7.7	7.4	5.4	5.3	5.2
2033						
Maximum	6.4	6.9	6.0	4.4	4.8	4.2
Relevant health based guideline	**30**			**10**		

All the concentrations of CO presented in the above table are below the relevant health based guidelines. On this basis, it is considered that there would be no adverse health effects in relation to exposures (acute and chronic) to CO in the local area surrounding the project.

Nitrogen dioxide

Motor vehicles, along with industrial, commercial and residential (for example gas heating or cooking) combustion sources, are primary producers of nitrogen oxides, including NO_2. In Sydney, it was estimated that on-road vehicles account for about 62 per cent of emissions of nitrogen oxides, industrial facilities account for 12 per cent, other mobile sources account for about 22 per cent with the remainder from domestic/commercial sources (NSW EPA 2012b).

NO_2 is the only oxide of nitrogen that may be of concern to health (WHO 2000b). NO_2 can cause inflammation of the respiratory system and increase susceptibility to respiratory infection. Exposure to elevated levels of NO_2 has also been associated with increased mortality, particularly related to respiratory disease, and with increased hospital admissions for asthma and heart disease patients (WHO 2013a). Asthmatics, the elderly and people with existing cardiovascular and respiratory disease are particularly susceptible to the effects of NO_2. The health effects associated with exposure to NO_2 depend on the duration of exposure as well as the concentration.

Guidelines are available from the NSW EPA and NEPC (NEPC 2003) which indicate acceptable concentrations of NO_2. These guidelines are based on protection from adverse health effects following both short-term (acute) and longer-term (chronic) exposure for all members of the population including sensitive populations like asthmatics, children and the elderly.

Potential health effects associated with NO_2 consider both comparison with guidelines for cumulative exposure (acute and chronic) and an assessment of incremental impacts on health (associated with changes in air quality from the project).

Assessment of acute exposures

The guideline for the assessment of acute (short-term) exposure is 246 µg/m^3 (or 120 parts per billion by volume (ppbv)) and chronic (long-term or lifetime) exposures of 62 µg/m^3 (or 30 ppbv) is protective of adverse health effects in all individuals, including sensitive individuals.

Table 11-13 presents a summary of the maximum predicted cumulative one-hour average concentration of NO_2 for the modelled scenarios.

Table 11-13 Review of potential acute health impacts – NO_2

Location and scenario	Maximum one hour average concentration of NO_2 (µg/m^3) Without the project	With the project	Cumulative
2023			
Maximum	487	516	435
2033			
Maximum	387	430	415
Acute health based guideline	**246**	**246**	**246**

The maximum cumulative concentrations of NO_2 presented in **Table 11-13** exceed the acute NEPC guideline of 246 µg/m^3 for all the scenarios, with and without the project. The elevated levels listed above are not considered to be representative of exposure concentrations that would occur within the study area. This is due to the combined effect of the approach adopted for converting NOx to NO_2 (that overestimates short-term one-hour average concentrations), and the use of a contemporaneous assessment of background and project impacts. The contemporaneous approach assumes that the highest background concentrations may occur during the same hour as the maximum incremental change from the project. This results in a very high estimate of total NO_2 concentrations that is not likely to occur (refer to **Appendix I** (Technical working paper: Air quality) for more detailed discussion). As a result, the magnitude of the maximum total concentrations reported for NO_2over a one-hour average cannot be used to evaluate the potential for adverse health effects in the community.

As assessment of total concentrations of NO_2 cannot be used to determine the potential for adverse health impacts in the community, and because there is no clear threshold established for community exposures to NO_2, the assessment of incremental exposures is of most relevance. This assessment is discussed later in this section.

Assessment of chronic exposures

The NEPC ambient air quality guideline for the assessment of chronic (long-term) exposures to NO_2 relates to the maximum predicted total (cumulative) annual average concentration in air.

The guideline of 62 µg/m^3 (or 30 ppbv) is based on a LOAEL of the order of 40–80 ppbv (around 75–150 µg/m^3) during early and middle childhood years which can lead to the development of recurrent upper and lower respiratory tract symptoms, such as recurrent 'colds', a productive cough and an increased incidence of respiratory infection with resultant absenteeism from school.

An uncertainty factor of two was applied to the LOAEL to account for susceptible people within the population resulting in a guideline of 20–40 ppbv (38–75 µg/m^3) (NEPC 1998). On this basis, the NEPC (and the NSW Office of Environment and Heritage) chronic guideline is protective of adverse health effects in all individuals, including sensitive individuals.

Table 11-14 presents a summary of the maximum predicted cumulative annual average concentration of NO_2 for the modelled scenarios.

Table 11-14 Review of potential chronic health impacts – NO_2

Location and scenario	Maximum annual average concentration of NO_2 (µg/m^3)		
2023			
Maximum	44.3	43.7	42.9
2033			
Maximum	40.3	37.3	39.1
Chronic health based guideline	**62**		

All the concentrations of NO_2 presented in **Table 11-14** are below the chronic NEPC guideline of 62 µg/m^3. Therefore, no adverse health effects are expected in relation to chronic exposures to NO_2 in the local area surrounding the project.

Assessment of incremental exposures

Table 11-15 presents a summary of the health endpoints (or outcomes) considered in this assessment, being the β coefficient, or change in exposure relevant to the calculation of a relative risk. The assessment of risk has utilised exposure-response functions and relative risk values that relate to the more significant health endpoints where the most significant and robust relationships have been identified. Refer to Annexure A of **Appendix K** (Technical working paper: Human health risk assessment) for details on the calculation of a β coefficient from published studies).

The coefficients adopted for the assessment of impacts on mortality and asthma emergency department admissions are derived from the detailed assessment undertaken for the current review of health impacts of air pollution undertaken by NEPC (Golder 2013) and are considered to be robust.

Table 11-15 Adopted exposure-responses relationships for assessment of changes in NO_2 concentrations

Health endpoint	Exposure period	Age group	Adopted β coefficient (also as per cent) for 1 µg/m^3 increase in NO_2	Reference
Mortality, all causes (non-trauma)	Short-term	30+	0.00188 (0.19%)	Relationship derived from modelling undertaken for five cities in Australia and one day lag (EPHC 2010; Golder 2013)
Mortality, respiratory	Short-term	All ages*	0.00426 (0.43%)	Relationship derived from modelling undertaken for five cities in Australia and one day lag (EPHC 2010; Golder 2013)
Asthma emergency department admissions	Short-term	1–14 years	0.00115 (0.11%)	Relationship established from review conducted on Australian children (Sydney) for the period 1997 to 2001 (Golder 2013; Jalaludin et al. 2008)

Notes:

* Relationships established for all ages, including young children and the elderly.

β = regression/slope coefficient, or the slope of the exposure-response function which can also be expressed as the per cent change in response per one µg/m3 increase in particulate matter exposure.

While the maximum concentrations of NO_2 are lower in the local community with the operation of the project, the concentrations at individual receptors vary. While the concentrations at most receptors decrease with the operation of the project, there are some receptors where there is an increase, associated with the redistribution of emissions from vehicles using surface roads.

Table 11-16 presents the change in individual risk associated with changes in NO_2 at the maximum impacted receptors relevant to the various land uses in the community, as well as the community receptors, for the operational years 2023 and 2033, including the cumulative scenario (refer to **Appendix K** (Technical working paper: Human health risk assessment) for the methodology on the calculation of individual risks). The assessment assumes an individual is exposed at each maximum impacted location over all hours of the day, regardless of the land use. This has been undertaken to address any future changes in land use that may occur during redevelopment. Risks for all other receptors (including other sensitive receivers) are lower than the maximums presented.

All risks are presented to one significant figure, reflecting the level of uncertainty associated with the calculations presented. A summary of the calculated change in individual risk associated with changes in NO_2 concentrations at each community receptor location evaluated is presented in Figure 6-4 of **Appendix K** (Technical working paper: Human health risk assessment).

Table 11-16 Maximum calculated risks associated with short-term exposure to changes in NO_2 concentrations with operation of the project

Scenario and receptor	Maximum change in individual risk from short term exposure to nitrogen dioxide for the following health endpoints		
	Mortality: All causes (ages 30+)	**Mortality: Respiratory (all ages)**	**Asthma ED Admissions (1–14 years)**
2023 – with project			
Maximum residential	5×10^{-5}	6×10^{-6}	4×10^{-5}
Maximum workplace	1×10^{-4}	1×10^{-5}	8×10^{-5}
Maximum childcare and schools	3×10^{-5}	4×10^{-6}	2×10^{-5}
Maximum aged care	4×10^{-6}	5×10^{-7}	3×10^{-6}
Maximum hospitals/medical	3×10^{-5}	3×10^{-6}	2×10^{-5}
Maximum open space	5×10^{-5}	6×10^{-6}	4×10^{-5}
Maximum from sensitive receptors	3×10^{-5}	3×10^{-6}	2×10^{-5}
2023 – cumulative			
Maximum residential	5×10^{-5}	6×10^{-6}	4×10^{-5}
Maximum workplace	2×10^{-4}	2×10^{-5}	1×10^{-4}
Maximum childcare and schools	1×10^{-5}	2×10^{-6}	1×10^{-5}
Maximum aged care	2×10^{-6}	2×10^{-7}	2×10^{-6}
Maximum hospitals/medical	8×10^{-6}	1×10^{-6}	6×10^{-6}
Maximum open space	2×10^{-5}	2×10^{-6}	1×10^{-5}
Maximum from sensitive receptors	1×10^{-5}	1×10^{-6}	9×10^{-6}
2033 – with project			
Maximum residential	6×10^{-5}	7×10^{-6}	5×10^{-5}
Maximum workplace	1×10^{-4}	1×10^{-5}	9×10^{-5}
Maximum childcare and schools	4×10^{-5}	5×10^{-6}	3×10^{-5}
Maximum aged care	7×10^{-6}	8×10^{-7}	5×10^{-6}
Maximum hospitals/medical	4×10^{-5}	4×10^{-6}	3×10^{-5}
Maximum open space	6×10^{-5}	6×10^{-6}	4×10^{-5}
Maximum from sensitive receptors	4×10^{-5}	3×10^{-6}	2×10^{-5}
2033 – cumulative			
Maximum residential	4×10^{-5}	5×10^{-6}	3×10^{-5}
Maximum workplace	2×10^{-4}	2×10^{-5}	1×10^{-4}
Maximum childcare	2×10^{-5}	2×10^{-6}	1×10^{-5}
Maximum aged care	7×10^{-6}	8×10^{-7}	5×10^{-6}
Maximum hospitals/medical	1×10^{-5}	1×10^{-6}	1×10^{-5}
Maximum open space	3×10^{-5}	3×10^{-6}	2×10^{-5}
Maximum from sensitive receptors	7×10^{-6}	8×10^{-7}	5×10^{-6}

Scenario and receptor	Maximum change in individual risk from short term exposure to nitrogen dioxide for the following health endpoints
Negligible risks	**<1 x 10^{-6}**
Tolerable/acceptable risks	**≥1 x 10^{-6} and ≤1 x 10^{-4}**
Unacceptable risks	**>1 x 10^{-4}**

Note:

Shaded cell (purple) exceeds the criteria adopted for acceptable risks, refer to the discussion below

Table 11-17 presents a summary of the calculated change in incidence of the relevant health effects for the population living in the LGAs within the study area, associated with changes in $PM_{2.5}$ concentrations for 2023 and 2033. All calculations relevant to the LGAs, including calculation for each individual suburb considered in the LGAs, are presented in **Appendix K** (Technical working paper: Human health risk assessment).

Table 11-17 Calculated changes in incidence of health effects in population associated with changes in NO_2 concentrations

LGA	Change in population incidence – number of cases					
	2023			2033		
	Mortality – all causes	Mortality – respiratory	Morbidity – asthma ED admissions	Mortality – all causes	Mortality – respiratory	Morbidity – asthma ED admissions
	≥30 years	All ages	1–14 years	≥30 years	All ages	1–14 years
With project						
Canada Bay	-0.024	-0.0044	-0.0045	-0.041	-0.0074	-0.0076
Strathfield*	0.0030	0.00058	0.00055	0.018	0.0034	0.0032
Burwood	-0.016	-0.0031	-0.0029	-0.019	-0.0036	-0.0034
Sydney Inner West	-1.2	-0.20	-0.19	-1.1	-0.19	-0.18
Sydney	-0.35	-0.067	-0.027	-0.15	-0.028	-0.012
Botany	0.15	0.027	0.030	0.21	0.038	0.043
Rockdale	-0.18	-0.034	-0.036	-0.21	-0.039	-0.041
Canterbury-Bankstown	-0.13	-0.026	-0.033	-0.13	-0.025	-0.032
Georges River	-0.098	-0.018	-0.020	-0.12	-0.022	-0.0236
Total for all LGAs	**-2**	**-0.3**	**-0.3**	**-2**	**-0.3**	**-0.3**
Cumulative						
Canada Bay	0.011	0.0020	0.0021	-0.020	-0.0035	-0.0036
Strathfield*	-0.032	-0.0062	-0.0058	-0.019	-0.0037	-0.0035
Burwood	-0.025	-0.0047	-0.0045	-0.023	-0.0045	-0.0042
Sydney Inner West	-1.2	-0.20	-0.20	-1.2	-0.20	-0.19
Sydney	-0.60	-0.12	-0.048	-0.70	-0.14	-0.056
Botany	-0.053	-0.0099	-0.011	-0.022	-0.0041	-0.0046
Rockdale	-0.26	-0.048	-0.051	-0.36	-0.067	-0.071
Canterbury-Bankstown	-0.19	-0.038	-0.048	-0.20	-0.039	-0.050
Georges	-0.14	-0.026	-0.029	-0.15	-0.028	-0.031

LGA	Change in population incidence – number of cases					
	2023			2033		
	Mortality – all causes	Mortality – respiratory	Morbidity – asthma ED admissions	Mortality – all causes	Mortality – respiratory	Morbidity – asthma ED admissions
	≥30 years	All ages	1–14 years	≥30 years	All ages	1–14 years
River						
Total for all LGAs	**-2**	**-0.5**	**-0.4**	**-3**	**-0.5**	**-0.4**

Notes:

* Includes suburbs in Auburn LGA

ED = emergency department

Negative value indicates that there is a decrease in incidence associated with the project.

Review of the calculated impacts in terms of the change in incidence of the relevant health effects associated with exposure to nitrogen dioxide in the community indicates that the total change in the number of cases relevant to the health effects evaluated, for both 2023 and 2033 is negative, meaning a decrease in incidence as a result of the project. The number of cases is small (a decrease of up to three cases). Therefore the changes are unlikely to be measurable within the community.

Most individual LGAs show a total decrease in health incidence. There are a few LGAs where there is an increase. These increases and decreases are also small, less than two (as a decrease) in individual LGAs for all health effects considered. As a result, these changes are unlikely to be measurable in the community.

The incidence calculations presented in **Table 11-17** are the totals for each LGA. Within these LGAs are a number of smaller suburbs. Review of the incidence calculated for the individual suburbs indicates that these predominantly relate to small decreases in health incidence with some suburbs showing an increase. The largest increase in health incidence for any individual suburb is less than 0.25 cases. Hence there are no individual suburbs within the LGAs where there is a change incidence that is of significance or would be measurable.

Particulate matter

Particulate matter is a widespread air pollutant with a mixture of physical and chemical characteristics that vary by location, source and substance. Particulates can be derived from natural sources such as soil dust, pollen and moulds, and other sources that include combustion and industrial processes.

Secondary particulate matter is formed via atmospheric reactions of primary gaseous emissions. The gases that are the most significant contributors to secondary particulates include nitrogen oxides, ammonia, sulfur oxides, and certain organic gases (derived from vehicle exhaust, combustion sources, agricultural, industrial and biogenic emissions).

Particulate matter has been linked to adverse health effects after both short-term exposure (days to weeks) and long-term exposure (months to years). The health effects associated with exposure to particulate matter vary widely (with the respiratory and cardiovascular systems most affected) and include mortality and morbidity effects. The potential for particulate matter to result in adverse health effects is dependent on the size and composition of the particulate matter.

The particle size addressed in the human health risk assessment relate to the particulates most commonly measured in the urban air environment studies, including:

- PM_{10} (particulate matter below 10 micrometres in diameter)
- $PM_{2.5}$ (particulate matter below 2.5 micrometres in diameter).

The current NEPC and NSW EPA air quality goals and criteria for particulate matter are presented in **Table 11-18**.

Table 11-18 Air quality standards for particulate matter

Pollutant	Averaging period	Criteria (µg/m^3)	Reference
PM_{10}	24-hour	50	(NEPC 2016) (NSW EPA 2016)
	Annual	25	(NSW EPA 2016)
$PM_{2.5}$	24-hour	25 with goal of 20 by 2025	(NEPC 2016) (NSW EPA 2016)
	Annual	8 with goal of 7 by 2025	

Table 11-19 and **Table 11-20** present a summary of the maximum total 24-hour average and annual average concentrations of $PM_{2.5}$ and PM_{10} relevant to the assessment of emissions in 2023 and 2033, for the project and for the cumulative case.

Table 11-19 Review of total particulate matter concentrations – 24-hour average

Location and scenario	Maximum 24-hour average $PM_{2.5}$ concentration (µg/m^3)			Maximum 24-hour average PM_{10} concentration (µg/m^3)		
	Without project	With project	Cumulative	Without project	With project	Cumulative
2023						
Maximum	50.2	48.4	47.1	81.0	82.1	80.9
Maximum residential	40.7	40.9	41.7	70.8	70.9	70.7
Maximum commercial	50.2	44.8	46.4	81.0	80.1	80.7
2033						
Maximum	50.7	48.5	48.5	81.3	86.7	81.8
Maximum residential	40.6	39.5	39.3	70.9	70.9	74.4
Maximum commercial	45.9	43.6	48.5	80.1	77.0	81.8
Guideline	**25 20 by 2025 (goal)**			**50**		

Table 11-20 Review of total particulate matter concentrations – annual average

Location and scenario	Maximum annual average $PM_{2.5}$ concentration (µg/m^3)			Maximum annual average PM_{10} concentration (µg/m^3)		
	Without project	With project	Cumulative	Without project	With project	Cumulative
2023						
Maximum	13.2	14.1	13.6	25.1	26.5	25.9
Maximum residential	11.8	12.3	12.1	22.8	23.7	23.2
Maximum commercial	12.7	12.7	12.6	24.1	23.8	23.7
2033						
Maximum	13.2	14.2	13.5	25.3	26.1	25.8
Maximum residential	11.7	12.3	12	22.6	23.7	23.0
Maximum commercial	12.5	12.1	12.3	23.6	23.4	23.4
Guideline	**8 7 by 2025 (goal)**			**25**		

The maximum total/cumulative concentrations of $PM_{2.5}$ are above the guidelines for both a 24-hour average and an annual average (including the 2025 goal). This is due to the existing levels of $PM_{2.5}$ in air within the current urban environment. These elevated background levels would be present in the community regardless of the construction and operation of the project. Concentrations of total $PM_{2.5}$, however, are essentially unchanged within the local community with the operation of the project.

The maximum cumulative concentrations of PM_{10} presented in the above tables are above the 24-hour average and annual average guidelines. The maximum concentrations in residential and commercial/industrial (workplace) areas are below the annual average guideline. The elevated levels of total PM_{10} are due to the existing levels of PM_{10} in air within the current urban environment. These elevated background levels would be present in the community regardless of the construction and operation of the project. Concentrations of total PM_{10} are essentially unchanged within the local community with the construction and operation of the project.

The assessment of changes in incidence of particular health indicators in the community results in the calculation of a change in the number of cases (of mortality, hospital or emergency department admissions) within the population evaluated.

Where the number of cases (mortality or hospitalisations) associated with changes in air quality are well below 10 cases per year, they are considered to be within the normal variability of health statistics, and these changes would not be measurable in any health statistics for the area. For evaluating impacts from the project, a more conservative ten-fold margin of safety was included to determine what changes in incidence may be considered negligible within the study population. This means that changes in the population incidence of any evaluated health effect that are less than one case per year are considered negligible.

Table 11-21 and **Table 11-22** present the calculated individual risk associated with changes in $PM_{2.5}$ and PM_{10} concentrations at the maximum impacted residential, child care, schools, aged care, hospital, commercial/industrial and open space areas as well as the minimum impacted community receptor, for the operational years 2023 and 2033. The change in $PM_{2.5}$ and PM_{10} concentration considered in the risk calculations are also included in the tables.

The calculated change in risk at the maximum receptors represents the worst-case impact associated with the project. Risks for all other receptors would be lower than calculated for the maximum receptors. All calculated individual risks are presented in **Appendix K** (Technical working paper: Human health risk assessment).

Table 11-23 and **Table 11-24** present a summary of the calculated change in incidence of the relevant health effects for the population living in the LGAs within the study area, associated with changes in $PM_{2.5}$ concentrations for 2023 and 2033. All calculations relevant to the LGAs, including calculation for each individual suburb considered in the LGAs, are presented in **Appendix K** (Technical working paper: Human health risk assessment).

Table 11-21 Calculated individual risk associated with changes in $PM_{2.5}$ and PM_{10} concentrations – project operations in 2023

Receptor	Change in annual average concentration (µg/m³)		Calculated risks for health endpoints									
			$PM_{2.5}$: Mortality, all causes	$PM_{2.5}$: Cardiovascular hospitalisations	$PM_{2.5}$: Respiratory hospitalisations	PM_{10}: Mortality, all causes	$PM_{2.5}$: Mortality, all causes	$PM_{2.5}$: Mortality, cardiopulmonary	$PM_{2.5}$: Mortality, cardiovascular	$PM_{2.5}$: Mortality, respiratory	$PM_{2.5}$: Asthma emergency department hospitalisations	DPM Lung cancer
	PM_{10}	$PM_{2.5}$	LT	ST	ST	ST	ST	LT	ST	ST	ST	LT
			≥30 yrs	≥65 yrs	≥65 yrs	all	all	≥30 yrs	all	all	1–14 yrs	all
2023 with project												
Maximum residential	0.85	0.51	3×10^{-5}	4×10^{-5}	8×10^{-6}	3×10^{-6}	2×10^{-6}	3×10^{-5}	7×10^{-7}	5×10^{-7}	9×10^{-6}	2×10^{-5}
Maximum childcare	0.33	0.43	3×10^{-5}	3×10^{-5}	7×10^{-6}	1×10^{-6}	2×10^{-6}	2×10^{-5}	6×10^{-7}	4×10^{-7}	8×10^{-6}	1×10^{-5}
Maximum schools	0.29	0.12	7×10^{-6}	9×10^{-6}	2×10^{-6}	9×10^{-7}	6×10^{-7}	6×10^{-6}	2×10^{-7}	1×10^{-7}	2×10^{-6}	4×10^{-6}
Maximum aged care	0.06	0.06	4×10^{-6}	4×10^{-6}	1×10^{-6}	2×10^{-7}	3×10^{-7}	3×10^{-6}	8×10^{-8}	6×10^{-8}	1×10^{-6}	2×10^{-6}
Maximum hospital	0.69	0.20	1×10^{-5}	1×10^{-5}	3×10^{-6}	2×10^{-6}	9×10^{-7}	1×10^{-5}	3×10^{-7}	2×10^{-7}	4×10^{-6}	7×10^{-6}
Maximum commercial/ industrial	1.70	1.16	7×10^{-5}	9×10^{-5}	2×10^{-5}	5×10^{-6}	5×10^{-6}	6×10^{-5}	2×10^{-6}	1×10^{-6}	2×10^{-5}	4×10^{-5}
Maximum open space	1.24	0.78	5×10^{-5}	6×10^{-5}	1×10^{-5}	4×10^{-6}	4×10^{-6}	4×10^{-5}	1×10^{-6}	7×10^{-7}	1×10^{-5}	3×10^{-5}
Maximum community receptors	0.19	0.15	2×10^{-5}	3×10^{-5}	6×10^{-6}	1×10^{-6}	2×10^{-6}	2×10^{-5}	5×10^{-7}	3×10^{-7}	6×10^{-6}	1×10^{-5}
2023 cumulative												
Maximum residential	1.60	0.62	4×10^{-5}	5×10^{-5}	1×10^{-5}	3×10^{-6}	3×10^{-6}	3×10^{-5}	8×10^{-7}	6×10^{-7}	1×10^{-5}	2×10^{-5}
Maximum childcare	0.36	0.26	2×10^{-5}	2×10^{-5}	4×10^{-6}	1×10^{-6}	1×10^{-6}	1×10^{-5}	3×10^{-7}	2×10^{-7}	5×10^{-6}	9×10^{-6}
Maximum schools	0.26	0.15	9×10^{-6}	1×10^{-5}	2×10^{-6}	8×10^{-7}	7×10^{-7}	8×10^{-6}	2×10^{-7}	1×10^{-7}	3×10^{-6}	5×10^{-6}
Maximum aged care	0.10	0.08	5×10^{-6}	6×10^{-6}	1×10^{-6}	3×10^{-7}	4×10^{-7}	4×10^{-6}	1×10^{-7}	8×10^{-8}	1×10^{-6}	3×10^{-6}
Maximum hospital	0.23	0.12	7×10^{-6}	9×10^{-6}	2×10^{-6}	7×10^{-7}	6×10^{-7}	6×10^{-6}	2×10^{-7}	1×10^{-7}	2×10^{-6}	4×10^{-6}
Maximum commercial/ industrial	3.36	2.25	1×10^{-4}	2×10^{-4}	4×10^{-5}	1×10^{-5}	1×10^{-5}	1×10^{-4}	3×10^{-6}	2×10^{-6}	4×10^{-5}	8×10^{-5}
Maximum open space	1.05	0.54	3×10^{-5}	4×10^{-5}	9×10^{-6}	3×10^{-6}	3×10^{-6}	3×10^{-5}	7×10^{-7}	5×10^{-7}	1×10^{-5}	2×10^{-5}
Maximum community receptors	0.14	0.18	1×10^{-5}	1×10^{-5}	3×10^{-6}	7×10^{-7}	9×10^{-7}	1×10^{-5}	3×10^{-7}	2×10^{-7}	3×10^{-6}	7×10^{-6}
Negligible risks			**$<1 \times 10^{-6}$**									
Tolerable/acceptable risks			**$\geq 1 \times 10^{-6}$ and $\leq 1 \times 10^{-4}$**									
Unacceptable risks			**$>1 \times 10^{-4}$**									

Notes: DPM = diesel particulate matter; LT = long term; ST = short term. Shaded cell exceeds the criteria adopted for acceptable risks, refer to the discussion below.

Table 11-22 Calculated individual risk associated with changes in $PM_{2.5}$ and PM_{10} concentrations – project operations in 2033

Receptor	Change in annual average concentration ($\mu g/m^3$)		Calculated risks for health endpoints: $PM_{2.5}$: Mortality, all causes	$PM_{2.5}$: Cardiovascular hospitalisations	$PM_{2.5}$: Respiratory hospitalisations	PM_{10}: Mortality, all causes	$PM_{2.5}$: Mortality, all causes	$PM_{2.5}$: Mortality, cardiopulmonary	$PM_{2.5}$: Mortality, cardiovascular	$PM_{2.5}$: Mortality, respiratory	$PM_{2.5}$: Asthma emergency department hospitalisations	DPM Lung cancer
	PM_{10}	$PM_{2.5}$	LT	ST	ST	ST	ST	LT	ST	ST	ST	LT
			≥30 yrs	≥65 yrs	≥65 yrs	all	all	≥30 yrs	all	all	1–14 yrs	all
2033 with project												
Maximum residential	1.12	0.56	3×10^{-5}	4×10^{-5}	9×10^{-6}	3×10^{-6}	3×10^{-6}	3×10^{-5}	7×10^{-7}	5×10^{-7}	1×10^{-5}	2×10^{-5}
Maximum childcare	0.67	0.39	2×10^{-5}	3×10^{-5}	6×10^{-6}	2×10^{-6}	2×10^{-6}	2×10^{-5}	5×10^{-7}	4×10^{-7}	7×10^{-6}	1×10^{-5}
Maximum schools	0.37	0.15	9×10^{-6}	1×10^{-5}	2×10^{-6}	1×10^{-6}	7×10^{-7}	8×10^{-6}	2×10^{-7}	1×10^{-7}	3×10^{-6}	5×10^{-6}
Maximum aged care	0.11	0.11	7×10^{-6}	8×10^{-6}	2×10^{-6}	3×10^{-7}	5×10^{-7}	6×10^{-6}	1×10^{-7}	1×10^{-7}	2×10^{-6}	4×10^{-6}
Maximum hospital	0.42	0.33	2×10^{-5}	2×10^{-5}	5×10^{-6}	1×10^{-6}	2×10^{-6}	2×10^{-5}	4×10^{-7}	3×10^{-7}	6×10^{-6}	1×10^{-5}
Maximum commercial/ industrial	1.94	1.43	9×10^{-5}	1×10^{-4}	2×10^{-5}	6×10^{-6}	7×10^{-6}	8×10^{-5}	2×10^{-6}	1×10^{-6}	3×10^{-5}	5×10^{-5}
Maximum open space	1.40	0.83	5×10^{-5}	6×10^{-5}	1×10^{-5}	4×10^{-6}	4×10^{-6}	4×10^{-5}	1×10^{-6}	8×10^{-7}	1×10^{-5}	3×10^{-5}
Maximum community receptors	0.23	0.14	3×10^{-5}	4×10^{-5}	9×10^{-6}	2×10^{-6}	3×10^{-6}	3×10^{-5}	7×10^{-7}	5×10^{-7}	1×10^{-5}	1×10^{-5}
2033 cumulative												
Maximum residential	1.26	0.55	3×10^{-5}	4×10^{-5}	9×10^{-6}	3×10^{-6}	3×10^{-6}	3×10^{-5}	7×10^{-7}	5×10^{-7}	1×10^{-5}	2×10^{-5}
Maximum childcare	0.22	0.20	1×10^{-5}	1×10^{-5}	3×10^{-6}	7×10^{-7}	9×10^{-7}	1×10^{-5}	3×10^{-7}	2×10^{-7}	4×10^{-6}	7×10^{-6}
Maximum schools	0.29	0.19	1×10^{-5}	1×10^{-5}	3×10^{-6}	9×10^{-7}	9×10^{-7}	1×10^{-5}	2×10^{-7}	2×10^{-7}	3×10^{-6}	6×10^{-6}
Maximum aged care	0.16	0.06	4×10^{-6}	4×10^{-6}	1×10^{-6}	5×10^{-7}	3×10^{-7}	3×10^{-6}	8×10^{-8}	6×10^{-8}	1×10^{-6}	2×10^{-6}
Maximum hospital	0.52	0.31	2×10^{-5}	2×10^{-5}	5×10^{-6}	2×10^{-6}	1×10^{-6}	2×10^{-5}	4×10^{-7}	3×10^{-7}	6×10^{-6}	1×10^{-5}
Maximum commercial/ industrial	3.74	2.33	1×10^{-4}	2×10^{-4}	4×10^{-5}	1×10^{-5}	1×10^{-5}	1×10^{-4}	3×10^{-6}	2×10^{-6}	4×10^{-5}	8×10^{-5}
Maximum open space	0.92	0.56	3×10^{-5}	4×10^{-5}	9×10^{-6}	3×10^{-6}	3×10^{-6}	3×10^{-5}	7×10^{-7}	5×10^{-7}	1×10^{-5}	2×10^{-5}
Maximum community receptors	0.28	0.15	1×10^{-5}	1×10^{-5}	3×10^{-6}	1×10^{-6}	8×10^{-7}	1×10^{-5}	2×10^{-7}	2×10^{-7}	3×10^{-6}	6×10^{-6}
Negligible risks			**$<1 \times 10^{-6}$**									
Tolerable/acceptable risks			**$\geq 1 \times 10^{-6}$ and $\leq 1 \times 10^{-4}$**									
Unacceptable risks			**$>1 \times 10^{-4}$**									

Notes: DPM = diesel particulate matter; LT = long term; ST = short term. Shaded cell exceeds the criteria adopted for acceptable risks, refer to discussion below.

Table 11-23 Calculated changes in incidence of health effects in population associated with changes in $PM_{2.5}$ concentrations – project in 2023

LGA/ Local statistical areas	Change in population incidence – number of cases							
	Primary indicators			Secondary indicators				
	Mortality – all causes	Hospitalisations – cardiovascular	Hospitalisations – respiratory	Mortality – all causes	Mortality – cardiopulmonary	Mortality – cardiovascular	Mortality – respiratory	Morbidity – asthma ED admissions
	≥30 years	≥65 years	≥65 years	All ages	≥30 years	All ages	All ages	1–14 years
With Project								
Canada Bay	-0.000007	-0.0000020	-0.00000045	-0.00000075	-0.0000067	-0.00000022	-0.00000018	-0.00000055
Strathfield*	-0.0012	-0.00032	-0.000070	-0.00014	-0.0010	-0.000043	-0.000031	-0.000083
Burwood	-0.0018	-0.00048	-0.00011	-0.00026	-0.0016	-0.000066	-0.000046	-0.00013
Sydney Inner West	-0.38	-0.072	-0.016	-0.048	-0.34	-0.014	-0.0090	-0.026
Sydney	-0.0045	-0.00074	-0.00016	-0.00061	-0.0041	-0.00017	-0.00012	-0.00014
Botany	0.072	0.021	0.0046	0.0097	0.065	0.0029	0.0019	0.0059
Rockdale	-0.063	-0.019	-0.0041	-0.0086	-0.057	-0.0025	-0.0016	-0.0049
Canterbury-Bankstown	-0.041	-0.011	-0.0025	-0.0055	-0.037	-0.0016	-0.0011	-0.0041
Georges River	-0.015	-0.0046	-0.0010	-0.0018	-0.013	-0.00051	-0.00038	-0.0012
Total for all LGAs	**-0.4**	**-0.09**	**-0.02**	**-0.06**	**-0.4**	**-0.02**	**-0.01**	**-0.03**
Cumulative								
Canada Bay	0.030	0.0081	0.0018	0.0030	0.027	0.00086	0.00074	0.0022
Strathfield*	-0.0036	-0.0010	-0.00022	-0.00042	-0.0032	-0.00013	-0.00010	-0.00026
Burwood	-0.0013	-0.00036	-0.000079	-0.00019	-0.0012	-0.000050	-0.000035	-0.000095
Sydney Inner West	-0.32	-0.061	-0.013	-0.040	-0.29	-0.011	-0.0075	-0.021
Sydney	-0.044	-0.0073	-0.0016	-0.0060	-0.040	-0.0017	-0.0012	-0.0014
Botany	-0.015	-0.0044	-0.0010	-0.0021	-0.014	-0.00061	-0.00039	-0.0013
Rockdale	-0.071	-0.021	-0.0047	-0.0097	-0.064	-0.0028	-0.0018	-0.0055
Canterbury-Bankstown	-0.054	-0.015	-0.0033	-0.0072	-0.049	-0.0021	-0.0015	-0.0054
Georges River	-0.026	-0.0081	-0.0018	-0.0031	-0.023	-0.00090	-0.00067	-0.0021
Total for all LGAs	**-0.5**	**-0.1**	**-0.02**	**-0.07**	**-0.5**	**-0.02**	**-0.01**	**-0.04**

Notes:

* Includes suburbs in Auburn LGA.

ED = emergency department

Negative value indicates that there is a decrease in incidence associated with the project.

Table 11-24 Calculated changes in incidence of health effects in population associated with changes in $PM_{2.5}$ concentrations– project in 2033

LGA/Local statistical areas	Change in population incidence – number of cases							
	Primary Indicators			Secondary Indicators				
	Mortality – all causes	Hospitalisations – cardiovascular	Hospitalisations – respiratory	Mortality – all causes	Mortality – cardiopulmonary	Mortality – cardiovascular	Mortality – respiratory	Morbidity – asthma ED admissions
	≥30 years	≥65 years	≥65 years	All ages	≥30 years	All ages	All ages	1–14 years
With Project								
Canada Bay	0.0016	0.00043	0.000094	0.00016	0.0014	0.000046	0.000039	0.00011
Strathfield*	-0.0022	-0.00061	-0.00013	-0.00026	-0.0020	-0.000082	-0.000059	-0.00016
Burwood	-0.00094	-0.00026	-0.000056	-0.00014	-0.00085	-0.000035	-0.000025	-0.000068
Sydney Inner West	-0.34	-0.064	-0.014	-0.043	-0.31	-0.012	-0.0080	-0.023
Sydney	0.021	0.0034	0.00075	0.0028	0.019	0.00080	0.00055	0.00066
Botany	0.084	0.024	0.0054	0.011	0.076	0.0033	0.0022	0.0069
Rockdale	-0.070	-0.021	-0.0046	-0.0095	-0.063	-0.0028	-0.0018	-0.0054
Canterbury-Bankstown	-0.033	-0.0092	-0.0020	-0.0044	-0.030	-0.0013	-0.00090	-0.0033
Georges River	-0.023	-0.0073	-0.0016	-0.0028	-0.021	-0.00082	-0.00060	-0.0019
Total for all LGAs	**-0.4**	**-0.07**	**-0.02**	**-0.05**	**-0.3**	**-0.01**	**-0.009**	**-0.03**
Cumulative								
Canada Bay	0.033	0.0090	0.0020	0.0033	0.030	0.0010	0.00082	0.0024
Strathfield*	-0.00063	-0.00017	-0.000038	-0.000073	-0.00056	-0.000023	-0.000017	-0.000045
Burwood	0.0067	0.0018	0.00040	0.0010	0.0060	0.00025	0.00018	0.00048
Sydney Inner West	-0.24	-0.045	-0.0099	-0.030	-0.21	-0.0085	-0.0056	-0.016
Sydney	-0.042	-0.0068	-0.0015	-0.0056	-0.037	-0.0016	-0.0011	-0.0013
Botany	-0.012	-0.0034	-0.00076	-0.0016	-0.011	-0.00047	-0.00030	-0.0010
Rockdale	-0.080	-0.024	-0.0053	-0.011	-0.072	-0.0032	-0.0021	-0.0063
Canterbury-Bankstown	-0.059	-0.016	-0.0036	-0.0078	-0.053	-0.0023	-0.0016	-0.0058
Georges River	-0.014	-0.0045	-0.0010	-0.0017	-0.013	-0.00050	-0.00037	-0.0012
Total for all LGAs	**-0.4**	**-0.09**	**-0.02**	**-0.05**	**-0.4**	**-0.02**	**-0.01**	**-0.03**

Notes:

* Includes suburbs in Auburn LGA.

ED = emergency department

Negative value indicates that there is a decrease in incidence associated with the project.

Review of the calculated changes in risk indicates the following in relation to impacts associated with the expected operation of the project in 2023 and 2033:

- A number of the calculated individual risks for the community receptors are negative, meaning that the operation of the project would result in lower levels of risk, when compared with the situation where the project is not operating
- The maximum risks calculated for exposures in residential areas are less than $1x10^{-4}$ and considered to be tolerable/acceptable
- The maximum risks calculated for exposures in commercial/industrial areas are between $8x10^{-7}$ and $2x10^{-4}$. The maximum risk level of $2x10^{-4}$ exceeds the adopted criteria for determining unacceptable risks. Impacts that result in exceedance of the adopted risk criteria occur only in the existing industrial location north and northwest of Sydney Airport, between Airport Drive, Alexandria Canal and the Princes Highway. The calculation presented relates to exposures that occur at this location for all hours of the day, all of the time. As this area is a workplace, not somewhere people live, the calculated risk is expected to overestimate risks by a factor of about 4.5, hence actual risks in theses industrial areas are expected to be lower and tolerable. Given the proximity of these areas to Sydney Airport (runways and flight paths) it is considered unlikely that they would be rezoned for residential use, hence it is not relevant to evaluate future residential exposures at this location. In addition, the calculated risks relate to predicted increases in $PM_{2.5}$, principally related to the Sydney Gateway project. Surface road emissions related to the Sydney Gateway project have been estimated on the basis of provisional information in relation to roadway layout only. The maximum impacts predicted are on roadways/locations that may be within the future roadway alignments. The Sydney Gateway project would be subject to separate environmental assessment and approval, at which time a more detailed assessment of impacts in this area would be undertaken
- The worst case scenario for potential exposure is where a resident works at the maximum impacted workplace and lives at the maximum impacted residential location. Where this may occur, the maximum risk is just less than $1x10^{-4}$, which is considered tolerable/acceptable
- All maximum risks calculated for continuous exposures in child care centres, schools, aged care homes and open space areas are below $1x10^{-4}$ and considered to be tolerable/acceptable
- In relation to impacts on the health of the population in the local community, the calculated change in incidence of the health indicators evaluated shows that the increased incidence of the evaluated health effects occurring in the population in the study area ranges from 0.007 to 0.2 cases per year, which would not be measurable and is considered to be negligible.

Review of the calculated impacts in terms of the change in incidence of the relevant health effects for $PM_{2.5}$ in the community, indicates the following:

- The total change in the number of cases relevant to the health effects evaluated, for both 2023 and 2033 is negative, meaning a decrease in incidence as a result of the project. However, the number of cases is very small, being less than one for all health effects considered. As a result, these changes would not be measurable within the community
- Most individual LGAs show a total decrease in health incidence. There are a few LGAs where there is an increase. These increases and decreases are also very small, less than one for all health effects considered. As a result, these changes would not be measurable in the community
- The incidence calculations presented in **Table 11-23** and **Table 11-24** are the totals for each LGA. Within these LGAs are a number of suburbs. The calculated change in incidence relevant to each of these suburbs has also been evaluated. Review of the incidence calculated for the individual suburbs indicates that these predominantly relate to small decreases in health incidence with some suburbs showing an increase. The largest increase in health incidence for any individual suburb is less than 0.1 cases. Hence there are no individual suburbs within the LGAs where there is a change incidence that is of significance or would be measurable.

Elevated receivers

Further assessment of elevated receivers was undertaken in relation to potential health impacts at both 10 metres and 30 metres above ground level, representative of potential exposures that may occur in multi-storey buildings.

Impacts that are derived from changes in emissions from surface roads are expected to decrease with height above the roadway. However, in areas closest to the ventilation outlets there is the potential for increased impacts with height.

The assessment of potential impacts at 10 and 30 metres above ground level has focused on the worst case scenario, being the 2033 cumulative case, associated with impacts from all components of the WestConnex program of works plus other road related infrastructure projects. The maximum change in $PM_{2.5}$ relevant to this scenario was evaluated, which does not relate to any existing multi-storey building, rather the maximum value change anywhere in the study area. As the approach adopted in **Appendix I** (Technical working paper: Air quality) is a screening level assessment, no other pollutants have been evaluated. The results would be relevant to the construction of future multi-storey buildings in the study area.

Table 11-25 presents the calculated risks associated with the maximum predicted change in $PM_{2.5}$ concentrations at a height of 10 and 30 metres above ground level, throughout the study area. Impacts at existing multi-storey buildings are significantly lower than presented in this table, with changes in $PM_{2.5}$ annual average concentrations predicted to be <0.05 µg/m^3.

Table 11-25 Calculated individual risk associated with changes in $PM_{2.5}$ concentrations – cumulative scenario in 2033 for elevated receptors

Health Endpoint	Maximum calculated 10 m height	30 m height
Change in annual average concentration		
$PM_{2.5}$ (µg/m^3)	0.79	5.6
Primary health indicators: $PM_{2.5}$		
Mortality all causes (long-term effects, ages 30+)	5×10^{-5}	3×10^{-4}
Cardiovascular hospitalisations (short-term effects, ages 65+)	6×10^{-5}	4×10^{-4}
Respiratory hospitalisations (short-term effects, ages 65+)	1×10^{-5}	9×10^{-5}
Secondary health indicators: $PM_{2.5}$		
Mortality all causes (short-term effects, all ages)	4×10^{-6}	3×10^{-5}
Mortality, cardiopulmonary (long-term effects, ages 30+)	4×10^{-5}	3×10^{-4}
Mortality, cardiovascular (short-term effects, all ages)	1×10^{-6}	7×10^{-6}
Mortality, respiratory (short-term effects, all ages)	7×10^{-7}	5×10^{-6}
Asthma emergency department hospitalisations (1–14 years)	1×10^{-5}	1×10^{-4}
Negligible risks	**$<1 \times 10^{-6}$**	
Tolerable/acceptable risks	**$\geq 1 \times 10^{-6}$ and $\leq 1 \times 10^{-4}$**	
Unacceptable risks	**$>1 \times 10^{-4}$**	

Note:

Shaded cells indicate calculated risks that are considered unacceptable.

The calculations presented in **Table 11-25** indicate the following:

- At a height of 10 metres above ground level within the study area, the maximum change in $PM_{2.5}$ is lower than at ground level (refer to **Table 11-21** and **Table 11-22**) and results in risks that are considered to range from negligible to tolerable/acceptable
- At a height of 30 metres above ground level within the study area, the maximum change in $PM_{2.5}$ is significantly greater than at ground level and at 10 metres above ground level and results in risks that are considered to be unacceptable. Further review of the impacts predicted at 30 metres above ground level height indicates the following:
  - The impacts identified at 30 metres above ground level are localised and close to the ventilation outlets, with the maximum increases more specifically located adjacent to the Campbell Road ventilation facility at the St Peters interchange
  - The maximum increase in $PM_{2.5}$ at existing industrial premises was 1.8 µg/m^3, and the maximum increase at the closest residential area is 1.44 µg/m^3 which are associated with small changes in risk that are considered to be tolerable/acceptable
  - There are currently no buildings above 8.3 metres in height close to the St Peters interchange, hence the maximum risks calculated are hypothetical at this stage.

To address the potential health impacts identified, planning controls should be developed in the vicinity of the Campbell Road ventilation facility at St Peters interchange to ensure future developments at heights above 10 metres are not adversely impacted by the ventilation outlets. Development of planning controls would be supported by detailed modelling addressing all relevant pollutants and averaging periods.

Assessment of in-tunnel air quality impacts

In February 2016, the NSW Government Advisory Committee on Tunnel Air Quality (ACTAQ) issued a document entitled 'In-tunnel air quality (nitrogen dioxide) policy' (ACTAQ 2016). That document further consolidated the approach taken earlier for the NorthConnex, M4 East and New M5 projects. The policy wording requires tunnels to be *'designed and operated so that the tunnel average nitrogen dioxide (NO_2) concentration is less than 0.5 ppm as a rolling 15 minute average'*.

For the project and associated integrated analysis for the WestConnex program of works, the 'tunnel average' has been interpreted as a 'route average', being the 'length-weighted average pollutant concentration over a portal-to-portal route through the system'. Tunnel average NO_2 has been assessed for every possible route through the system under all circumstances with this assessment considering the highest average NO_2 concentration is reported.

The tunnel ventilation system would be designed and operated so that the in-tunnel air quality limits, consistent with those in the conditions of approval for NorthConnex and the approved WestConnex projects, are not exceeded. Further detail on the method for calculation of the length-weighted average for NO_2 is provided in Annexure L of **Appendix I** (Technical working paper: Air quality).

Concentrations in the tunnel are expected to vary depending on:

- Time of day: pollutant concentrations within the tunnels have been estimated to vary by a factor of up to 10 times (depending on the particular pollutant and location within the mainline tunnels) from periods of low traffic to peak traffic
- Location within the mainline tunnels and ventilation facilities: concentrations of pollutants would gradually increase from the tunnel entrance to the next offtake to a ventilation outlet. The average exposure for a motorist would be around half of the maximum concentration within the tunnel.

The assessment of potential exposures that may occur in the tunnel has been undertaken with consideration of these factors. In addition, the following has also been considered:

- M4-M5 Link mainline tunnels:
  - The time spent within the mainline tunnels would be limited, taking around five to six minutes to travel the full distance of the tunnel (when travelling at 80 kilometres per hour). During peak times the duration of travel may be slightly longer depending on the speed of traffic flow in the tunnel. As the pollutant concentrations are not the same in all parts of the tunnel, with concentrations increasing with distance from the entry portal, the amount of time exposed to the maximum concentration would be much lower (around one minute). The average exposure through the whole tunnel would be lower than about half the maximum (at the end of the tunnel)
  - The concentration of pollutants within the vehicle itself would be lower, particularly where all windows are closed when inside the tunnel, as most vehicles have filters on the air intake. Where the air conditioning/ventilation in the car is set to recirculation this would limit the contribution of air derived from within the tunnel to the air within the vehicle. Measurements conducted by NSW Health in relation to the M5 East tunnel (NSW Health 2003) identified that closing car windows and switching the ventilation to recirculation can reduce exposures by about 70–75 per cent for carbon monoxide and NO_2, 80 per cent for fine particulates and 50 per cent for VOCs
- Assessment of cumulative exposures in tunnels:
  - It is expected that users of the project may also use part of other connecting tunnels for their trip. This may include the M4 East or the New M5 tunnels, both of which directly connect into the M4-M5 Link mainline tunnels. There are other projects proposed that would also connect with the M4-M5 Link. This means motorists may be travelling inside a tunnel for a longer distance and duration. Given that the M4 East and New M5 both run east-west it is unlikely

anyone would utilise the full length of the tunnels, from the start of the M4 East to the end of the New M5 (or the other direction), during any one trip. It is more likely that trips may utilise either the M4 East or New M5 and part of, or all of, the M4-M5 Link

- There may be individuals who utilise the network of tunnels in the Sydney area on a frequent basis, throughout the day. This includes taxi drivers, courier drivers and some truck drivers. More frequent exposures in these tunnels have been considered below.

The following sections provide further discussion on the range of concentrations predicted within the mainline tunnels.

Carbon monoxide

The 2033 maximum one-hour concentration of CO predicted in the M4 East, M4-M5 Link and New M5 tunnels, including the proposed future F6 Extension (travelling in both directions), follow the same pattern and are similar in magnitude, with the exception that the M4-M5 Link maximum concentrations are slightly lower in 2033.

Detailed discussion of in-tunnel CO concentrations is provided in **Appendix K** (Technical working paper: Human health risk assessment). A summary is provided below:

- The maximum one-hour average concentration of CO in the tunnels is predicted to be less than 10 ppm in all scenarios. These concentrations are lower than the health based guideline of 25 ppm (one-hour average) established by the WHO (WHO 2010) and 34 ppm established by the USEPA (NHMRC 2008). The concentrations are lower than the Permanent International Association of Road Congress (PIARC) in-tunnel limits (Longley 2014)
- The tunnels are designed to meet in-tunnel limits for CO. While actual concentrations in the tunnels are expected to be lower than these limits, where the limits are met the following can be said:
  - The in-tunnel limit for CO of 87 ppm as a 15-minute average is equivalent to the health based guideline of 90 ppm (15-minute average) established by the WHO (WHO 2010)
  - The in-tunnel limit for CO of 50 ppm as a 30-minute average is the same as the health based guideline of 50 ppm (30-minute average) established by the WHO (WHO 2000c).

There are no health issues of concern in relation to in-tunnel exposures to CO, either in the M4-M5 Link mainline tunnels or during longer journeys that may include the M4 East, New M5 or other projects where exposures inside the tunnels may be potentially closer to 30 minutes.

Nitrogen dioxide

The 2033 maximum one-hour concentration of NO_2 predicted in the M4 East, M4-M5 Link and New M5 tunnels including the proposed future F6 Extension (travelling in both directions), follow the same pattern and are similar in magnitude, with the exception that the M4-M5 Link maximum concentrations are slightly lower in 2033.

Detailed discussion of in-tunnel NO_2 concentrations is provided in **Appendix K** (Technical working paper: Human health risk assessment).

The following summarises the NO_2 concentrations predicted within the combined project tunnels:

- The maximum concentrations in any of the tunnels varies depending on the direction and time of travel and location within the tunnels. Where there are major interchanges, air from the tunnels is exhausted to ambient air via the ventilation facilities and fresh air enters the tunnel. This results in a reduction in concentrations at these locations. The concentrations then increase again with further travel through subsequent tunnels. The maximum concentration that may be present inside any of the tunnels is estimated to be around 0.8 ppm in the M4 East tunnel, prior to exiting the tunnel at the Wattle Street interchange
- The average concentration that may be within each tunnel segment, or over a trip that involves travel through connecting tunnels, would be lower than the maximum concentrations noted above. The average concentration of NO2 would vary depending on the time of day and tunnels used. The time spent inside tunnels during these trips would also vary. As noted previously it is unlikely that anyone would travel the full length of the WestConnex tunnels (around 21.5 kilometres) in

any one trip. If the full length of the tunnels was used, travelling at 80 kilometres per hour, the time spent in the tunnels would be about 30 minutes. It is more likely that travel within the WestConnex tunnels would cover about half this distance, which may result in travel times inside the tunnels ranging from about 15 minutes at 80 kilometres per hour to 30 minutes when the traffic is slower at 40 kilometres per hour.

The concentrations discussed above relate to NO_2 levels inside the tunnels, not inside the vehicles. A study of NO_2 concentrations inside vehicles travelling in Sydney and using existing road tunnels was commissioned by Roads and Maritime in 2016 (Pacific Environment Limited 2016) to better understand the relationship between NO_2 outside the vehicle and inside the vehicle. The study involved a range of vehicles considered representative of the existing vehicle fleet, travelling through existing tunnels in Sydney and simulating travel times between 45 minutes and 60 minutes over a distance of 30 kilometres.

The concentration of NO_2 that entered a vehicle depended on the concentration outside the vehicle as well as the air exchange rate relevant to the individual vehicle. The air exchange rate depends on the ventilation, ie whether on recirculation or not, and a range of factors relevant to the vehicle air tightness.

The study found that the using the vehicle ventilation in recirculation mode can significantly reduce concentrations of NO_2 inside vehicles. The ratio of indoor to outdoor concentrations ranged from 0.06 to 0.32. This is consistent with the findings from a NSW Health study on vehicles using the M5 East tunnel, where an indoor to outdoor ratio of 0.25 to 0.3 was determined for NO_2 where ventilation is set to recirculation. When ventilation was not set to recirculation the concentration of NO_2 was higher inside the vehicles, and in some cases accumulated inside the vehicle after travelling through short tunnels.

Concentrations of NO_2 inside vehicle that may use different routes for travel under the expected traffic conditions, including the longest length of combined tunnels connecting the M4 to the M5 motorways, are generally well below the 15-minute average and one-hour average guidelines. There are two short travel segments where the average concentration of NO_2 exceeds the one-hour average concentration, however the time spent in these segments would be very short and hence it is not applicable to compare the average concentrations against a one-hour average. The concentrations of NO_2 in these segments is well below the 15-minute average guideline.

Under an extreme congestion scenario, where vehicles are travelling at 20 kilometres per hour, in-tunnel and potential in-vehicle NO_2 levels are higher. In addition, it is likely that the amount of time spent in the tunnel would be longer, with the longest travel segments potentially taking an hour to cover. The average concentrations of NO_2 in-vehicle range from 0.09 to 0.14 ppm. These averages are around the one-hour average guideline of 0.12 ppm, with some minor exceedance. It is highly unlikely that the extreme congestion conditions would occur, and that if it does occur, that it would persist for long journey of up to 21.7 kilometres inside the tunnels. Hence the assessment presented is expected to be conservative. On this basis, it is not considered likely that significant adverse health effects would occur as a result of travel that may occur during congested conditions.

In relation to travel by motorcycles, or passengers in vehicles where advice to keep windows up and ventilation on recirculation is not adopted, potential exposures within the tunnels during expected traffic conditions, over the various travel segments, varies between 0.009 to 0.47 ppm, with most of the concentrations in the range 0.1 to 0.3 ppm. The concentrations are below the 15-minute average guideline, which would be relevant for travel by motorcycle through most of the travel segments. Travel through longer segments (around 20 kilometres) may take longer, around 20 minutes (or slightly longer). The available health data does not suggest that exposures for a period of 20–30 minutes would be of greater concern than for 15-minutes. As such no significant health effects are expected to occur.

Particulate matter

There are no health based guidelines available for the assessment of short-duration exposures to particulate matter within a tunnel. In-tunnel criteria relate to visibility (and safety in using the tunnel). It is expected that the concentration of particulate matter within the tunnel would be higher than ambient air concentrations, and the concentration of particulate matter would increase with increasing distance travelled through the tunnel.

Potential concentrations of particulate matter inside the tunnel are derived from exhaust as well as non-exhaust sources. Non-exhaust sources include tyre and brake wear and dust from surface road wear and the resuspension of road dust. The modelling of particulate matter and visibility issues within the tunnel has considered both sources. **Table 11-26** presents a summary of the peak concentrations of particulate matter estimated inside the tunnels in 2023, for the expected traffic conditions.

Table 11-26 Predicted peak concentrations of particulate matter in-tunnel: 2023

Scenario/Tunnel segment	Peak particulate matter concentration (mg/m^3)			
	Exhaust		Non-exhaust sources	
	With project	Cumulative	With project	Cumulative
M4-M5				
M4 East	0.05	0.07	0.31	0.39
M4-M5 Link	0.07	0.09	0.42	0.52
New M5 including F6 Extension	0.07	0.08	0.56	0.64
M5-M4				
New M5 including F6 Extension	0.03	0.03	0.36	0.2
M4-M5 Link	0.06	0.07	0.35	0.44
M4 East	0.1	0.12	0.6	0.68

The characteristics of particulate matter derived from exhaust and non-exhaust sources would be different. The tunnel design and air quality assessment for the project is based on non-exhaust particulate matter emission factors that relate to PM_{10} and $PM_{2.5}$ from relevant emissions studies. Particulate matter from exhausts is expected to be largely fine particulates (ie PM_{10} and $PM_{2.5}$) that are of importance to health.

Detailed discussion of in-tunnel particulate matter concentrations is provided in **Appendix K** (Technical working paper: Human health risk assessment). A summary is provided below:

- The in-tunnel concentrations for particulate matter are taken to be PM_{10} concentrations where concentrations of $PM_{2.5}$ are likely to comprise a significant portion of the PM_{10} concentration, particularly for exhaust emissions
- PM10 concentrations within the tunnels are dominated by non-exhaust sources
- The maximum concentration of PM_{10} in the tunnels evaluated is up to 0.7 mg/m^3 for the project, and 0.8 mg/m^3 for the cumulative scenario. The average concentration in the tunnels would be lower than the peak concentration predicted, potentially up to 50 per cent of that reported as the peak concentration. When windows are up and vehicle ventilation is in recirculation mode, the average level of PM_{10} inside a vehicle would be lower, potentially up to 0.08 mg/m^3.

Carbon dioxide

To minimise in-vehicle exposure to carbon dioxide (CO_2) and particulate matter, tunnel signage and communications would advise motorists using the tunnels to wind up windows and place ventilation on recirculation. Health issues that may arise from such advice relate to the potential build-up of CO_2 inside the vehicle. An assessment of in-vehicle levels of CO_2 and potential effects on the health and safety of drivers travelling through tunnels over varying distances and durations was completed by Roads and Maritime in 2017. Based on this study for vehicles that may include between one and five occupants, travelling through tunnels for up to an hour, the levels of CO_2 were not expected to adversely affect driver safety.

Assessment of potential exposures that may occur for periods of time up to two hours, where ventilation is left on recirculation, indicates that there may be levels of CO_2 inside a vehicle where there are one or more passengers that may affect an already fatigued driver.

There is a general lack of guidance or regulations in terms of the design or use of vehicle ventilation systems in vehicles in Australia. Hence there is currently no advice to drivers on the suitable use of ventilation in various circumstances, to minimise the potential for effects on already fatigued drivers.

Where Roads and Maritime provides specific advice to drivers entering road tunnels to put ventilation on recirculation, it would also be necessary to provide advice that recirculation should be switched off and not left on for an extended period of time, after exiting the tunnel.

11.5.2 Noise and vibration

Environmental noise has been identified (I-INCE 2011; WHO 2011) as a growing concern in urban areas because it has negative effects on quality of life and wellbeing and it has the potential for causing harmful physiological health effects. With increasingly urbanised societies, impacts of noise on communities have the potential to increase over time.

Sound is a natural phenomenon that only becomes noise when it has some undesirable effect on people or animals. Unlike chemical pollution, noise energy does not accumulate either in the body or in the environment but it can have both short-term and long-term adverse effects on people. These health effects include:

- Sleep disturbance (sleep fragmentation that can affect psychomotor performance, memory consolidation, creativity, risk-taking behaviour and risk of accidents)
- Annoyance
- Hearing impairment
- Interference with speech and other daily activities
- Children’s school performance (through effects on memory and concentration)
- Cardiovascular health.

Other effects for which evidence of health impacts exists, but for which the evidence is weaker, include:

- Effects on mental health (usually in the form of exacerbation of existing issues for vulnerable populations rather than direct effects)
- Tinnitis (which manifests as a ringing in the ears when no physical noise is present, can also result in sleep disturbance, anxiety, depression, communication and listening problems, frustration, irritability, inability to work, reduced efficiency and a restricted participation in social life)
- Cognitive impairment in children (including deficits in long term memory and reading comprehension)
- Some evidence of indirect effects such as impacts on the immune system.

Annoyance can be a major consideration because it reflects the community’s dislike of noise and their concerns about the full range of potential negative effects from a project. It also affects the greatest number of people in the population.

Potential noise impacts have been assessed against Australian (more specifically NSW) criteria that have been established on the basis of the relationship between noise and health impacts. The criteria developed for use in the assessment for control of noise come from policy documents developed by the NSW Government including the *NSW Industrial Noise Policy* (INP) (NSW EPA 2009), the *NSW Interim Construction Noise Guideline* (DECC 2009), and the *NSW Road Noise Policy* (RNP) (DECCW 2011). All of these policies are based on the annoyance effects of noise, which may result in health impacts (subject to long-term exposure), as outlined in the reviews published by the following organisations:

- World Health Organization – *Guidelines on Community Noise – Health effects of noise* (WHO 1999)
- World Health Organization – *Night Noise Guidelines for Europe* (WHO 2009)
- International Institute of Noise Control Engineering – *Guidelines for Community Noise Impact Assessment and Mitigation* (I-INCE 2011)

- Environmental Health Council of Australia – *The health effects of environmental noise – other than hearing loss* (enHealth 2004).

The assessment of potential health impacts relating to noise has focused on whether the guidelines/criteria that have been established can be met. The NSW noise policies and guidelines against which this project is assessed are designed to protect the most sensitive receivers from annoyance and sleep disturbance. Where the guidelines cannot be met there is the potential to interfere with communication, disturb sleep and cause annoyance. Further, communities subjected to long-term exposure of acute noise levels may experience impairment of cardiovascular health and reduced cognitive performance in children.

The noise modelling for the project has been undertaken to address impacts associated with the operation of the project in 2023 and 2033, including a cumulative scenario. The modelling has evaluated noise impacts at the façade of all buildings, including on all floors of multi-storey buildings. An assessment was undertaken to determine how well the model estimated noise impacts based on a current scenario. The modelled and measured results were found to be within acceptable tolerances, which are ± two dB(A).

The assessment of operational noise impacts and the mitigation measures considered are described in **Chapter 10** (Noise and vibration).

For over 60 per cent of the receptors evaluated, noise levels will be reduced as a consequence of the project, resulting in associated health benefits. However, the worst case assessment also predicts that noise criteria and vibration criteria will be exceeded at a number of properties adjacent to the project during construction and operation without mitigation measures.

The worst-case levels estimated are sufficiently high for some receptors during some works that health impacts are likely to occur. These properties are located south of Victoria Road adjacent to the Iron Cove Link tunnel portals; and to the west of Victoria Road near Lilyfield Road. These are primarily related to the new road alignment being closer to residential homes, and the removal of buildings closest to the road (that previously were a barrier to noise from the roadway). A number of properties have also been identified where cumulative noise impacts exceed the relevant guidelines.

Without mitigation, a significant number of receivers have been identified in most noise catchment areas (NCA) where exceedances of the daytime and night-time noise criteria are predicted during construction. The change in noise levels are predicted up to two dB(A) at most receivers, with more significant increases up to five dB(A) at a smaller number of receivers (with less than one per cent of receivers experiencing noise increases of two to five dB(A)).

The detailed design for the mitigation measures will be outlined in the Construction Noise and Vibration Management Plan (CNVMP) as discussed in **Appendix J** (Technical working paper: Noise and vibration). The aim of the mitigation measures should be to reduce noise and vibration to levels that comply with the management goals established in this assessment. If it is not possible to achieve compliance with these goals, health impacts for the affected community are likely.

While these mitigation measures are required to ensure that the environment where people spend most of the day (ie indoors) is not associated with adverse health impacts from excessive noise, it does assume that residents take up in-property treatment measures and where they do, they keep external windows and doors shut and have minimal use of outdoor areas.

In urban areas particularly where existing levels of noise are dominated by road traffic noise, access to outdoor green space areas that are not (perceived to be) impacted by noise (eg where there is a quiet side of a specific property or there is access to a quiet green space areas close to the residential home) have been found to significantly improve wellbeing and lower levels of stress (Gidlöf-Gunnarsson & Öhrström 2007). Impacts on the use and enjoyment of outdoor areas due to increased noise may result in increased levels of stress at individual properties.

Where specific residents/properties do not take up the recommended in-property treatments to mitigate noise indoors there is the potential for noise levels at these properties to exceed the relevant guidelines/criteria. In these situations, there is the potential for adverse health effects, particularly annoyance and sleep disturbance, to occur.

Community consultation will be an important part of the process in addressing noise impacts for the project as there are a number of individual homes where in-property treatment would be required to enable the noise criteria to be met, and minimise the potential for adverse health effects associated with the project. However, such treatments may have other effects (as discussed above) which will also need to be managed/considered.

11.5.3 Public safety

A range of potential hazards have been identified that have the potential to affect public safety during the operation of the project, principally in relation to traffic accidents. These are outlined in **Table 11-27**, along with discussion on the risks that may be posed by these hazards. Not all the hazards identified in the hazard and risk assessment have been included in the table, only those where there is the potential for risks to public safety.

Table 11-27 Overview of public safety hazards and risks: Operation

Hazard: Public safety	Risk to public safety	Management measures
Storage, handling and transport of dangerous goods required for maintenance of the project, that may impact on the off-site community.	**Low** The storage volumes are very minor, with limited and infrequent transport of these materials required.	All materials would be stored and transported in accordance with relevant legislation and Australian Standards.
Transport of dangerous goods and hazardous substances in project tunnels.	**Low** The transport of these materials would be prohibited within the tunnels (as per Regulation Road Rules 2014, Regulation 300-2).	Signage would be provided near tunnel entry portals advising of the restrictions to ensure compliance with Regulation 300-2.
Traffic accidents in the tunnels.	**Low to moderate** All use of public roadways carries an inherent risk of vehicle collision. The project has been designed to minimise these risks for travel within the tunnels. The project also provides fire and life safety requirements.	Mitigation includes use of height detection systems prior to tunnel entry portals, tunnel barrier gates to prevent access if the tunnel is closed, closed-circuit television throughout the tunnel, adjustable speed signs, provision of breakdown bays and emergency phones, provision of pedestrian cross-passages to enable safe evacuation from the tunnel, automated fire detection, longitudinal ventilation to push smoke in the direction of traffic flow away from a fire source towards a ventilation facility or portal, and a water deluge system that can be activated manually or automatically. An Incident Response Plan would be developed and implemented in the event of an accident or incident in the tunnels.
Traffic accidents on surface roads.	**Moderate**, however the risk is considered to be reduced with the project.	While the design of the project has been developed to inherently minimise the likelihood of incidents and crashes, the project does not significantly change the design of existing surface road infrastructure. The project would involve a reduction in traffic on some roadways, which has the potential to reduce crash rates and improve pedestrian and cyclist safety.

Hazard: Public safety	Risk to public safety	Management measures
Electromagnetic fields (EMF) from new substations at motorway operations complexes at Darley Road (MOC1), Rozelle West (MOC2), Rozelle East (MOC3), Iron Cove Link (MOC4) and Campbell Road (MOC5).	**Low**	The detailed design of project substations would ensure that the exposure limits for the general public in the Draft Radiation Standard – Exposure Limits for Magnetic Fields (Australian Radiation Protection and Nuclear Safety Agency, December 2006) would not be exceeded at the boundary of the substation sites.
Bushfire risks.	**Low** The project is in a highly urbanised area that is not in or near a bushfire prone area.	Operational infrastructure is largely invulnerable to bushfires as it is not combustible. Regular maintenance would be undertaken at operational sites to prevent a build-up of natural fuel such as vegetation and debris.
Aviation risks, specifically works that may affect the safety of aircraft using Sydney Airport.	**Low**	The project design has considered airspace protection and associated risk and hazards. This includes the design of lighting and the ventilation facilities to ensure they meet the safety requirements set by the NSW Government and regulatory agencies.
Subsidence.	**Low** Tunnel induced ground movement that may result in ground settlement is considered to be low along most of the tunnel alignment. In some areas, where shallow tunnelling or multiple tunnels are proposed close to each other, higher levels of settlement are predicted. In these areas, potential settlement impacts require further assessment and potential management.	Further assessment of potential settlement impacts, including modelling would be required during the detailed design. Where ground movement in excess of settlement criteria are predicted a range of design, construction and ground improvement measures (as outlined in **Chapter 12** (Land use and property)) would be considered to reduce impacts. In addition, a range of management measures would be implemented (as detailed in **Chapter 12** (Land use and property)). This includes the preparation and implementation of a Settlement Monitoring Plan, preparation of building condition surveys, repair of cracking or property damage deemed to have occurred from the construction of the project, and preparation of agreements with utility owners and infrastructure owners identifying acceptable levels of settlement, monitoring requirements and measures to be implemented where levels are exceeded.

On the basis of the above there are not considered to be any issues related to the operation of the project that have the potential to result in significant safety risks to the community.

11.6 Assessment of potential social impacts on health

The WHO defines health as a dynamic state of complete physical, mental and social wellbeing and not merely the absence of disease or infirmity. Hence the assessment of health should include both the traditional/medical definition that focuses on illness and disease as well as the broader social definition that includes the general health and wellbeing of a population.

There are a range of other impacts associated with the project, other than the direct impacts from changes to air quality and levels of noise and vibrations that can affect the health and wellbeing of the community in a more indirect way. Changes within a community that may be associated with the project may be differentially distributed. Population groups that may be advantaged or disadvantaged based on age, gender, socio-economic status, geographic location, cultural background, aboriginality, current health status and existing disability may be affected in different ways by the project related changes. This aspect relates to the equity of the impacts in the local community (see **section 11.6.6**).

This section specifically evaluates changes that have the potential to indirectly affect the health and wellbeing of the community. In addition, this section provides a review of whether there are any impacts that are likely to be more significant in any section of the community, and if these areas may result in inequitable impacts on the health of the population. Further details can be found in **Chapter 14** (Social and economic).

11.6.1 Changes to traffic and transport

Construction

A number of changes to local roads are proposed during the construction phase of works. While it is expected that access to all properties on the local roads would be maintained during the construction works, some permanent and temporary closures or reduced capacity of some local roads may affect the movement of local traffic through the area. In relation to traffic changes around the project footprint during construction, most of the issues that are relevant to community health relate to public safety, which are addressed in **section 11.4.3** and **section 11.5.3**.

In addition to safety risks to the public, construction works are expected to result in some increases in travel times for motorists, bus travel, pedestrians and cyclists. These changes have the potential to result in increased levels of stress and anxiety in the local community (as discussed in **section 11.9**). These impacts, however, are expected to occur during the period of construction only.

A car parking and access strategy would be prepared as part of the CTAMP for the project, detailing temporary road closures and including traffic control procedures, signage requirements, construction traffic management requirements of the relevant Roads and Maritime manuals and procedures as well as Australian Standards.

Operations

Once the project is complete, it is expected that reductions in vehicle delays in a number of areas would occur. Traffic congestion and long commuting times can contribute to increased levels of stress and fatigue, more aggressive behaviour and increased traffic and accident risks on residential and local roads as drivers try to avoid congested areas (Hansson et al. 2011). Increased travel times reduce the available time to spend on heathy behaviours such as exercise, or engage in social interactions with family and friends. Long commute times are also associated with sleep disturbance, low self-rated health and absence from work (Hansson et al. 2011). Reducing travel times and road congestion is expected to reduce these health impacts.

Public transport

Access to public transport is important, particularly for people who cannot or are unable to drive (such as the elderly and those with disabilities). Lack of good access to public transport for these individuals can result in increased feelings of isolation, helplessness and dependence.

During construction of the project, public transport in and around the project footprint would be affected. The construction of the project would not directly affect heavy rail or light rail services. However, passenger access to stations may be affected by temporary traffic changes and congestion arising from the presence of construction works. Most impacts to public transport as a result of the project relate to bus travel, where construction activities would result in the relocation of some bus stops and bus travel times are forecast to increase along some routes in the peak periods.

Once the project is complete, from a public transport network perspective, the project is expected to generally facilitate faster and more reliable morning and evening outbound bus journeys in 2023 and 2033. However in some areas, some bus journey times are forecast to increase due to traffic congestion, for example along the Western Distributor and Anzac Bridge combined with increased demands to Bathurst Street and the Sydney Harbour Bridge.

Pedestrian and cyclist access

Walking and cycling have many health benefits including maintaining a healthy weight and improved mental status (Hansson et al. 2011; Lindström 2008; Wen & Rissel 2008; WHO 2000b).

There is currently a network of cyclist paths in the study area, comprising a mixture of separated cycleways and on road paths in areas of low to medium traffic. The current cycling network is predominantly oriented to recreational trips rather than commuter trips with dedicated cycleways concentrated within recreational spaces and along the Rozelle Bay/Blackwattle Bay foreshore.

As identified in the Active Transport Strategy in **Appendix N** (Technical working paper: Active transport strategy), significant and highly valued active transport networks include the Bay Run, Glebe foreshore, Anzac Bridge cycleway and the northern part of the Greenway (the active transport connection between Cooks River and Iron Cove). The shared path along Whites Creek to Buruwan Park is also used by cyclists and pedestrians. Shared pedestrian and cyclist paths also run both sides of Victoria Road with important overpasses provided at the city end of Victoria Road and across City West Link to provide connection to the water.

During construction, alterations to pedestrian and cyclist networks have the potential to affect commuter departure times, travel durations, movement patterns and accessibility. Construction and operation of the project would result in changes to pedestrian and cyclist access, including temporary and permanent closures or diversions of some pathways and pedestrian bridges.

Upgraded and additional facilities for pedestrians and cyclists would be provided as part of the project including the delivery of active transport links around permanent operational infrastructure. This would include two new bridges over City West Link connecting the communities of Rozelle, Balmain, Lilyfield, Glebe and Annandale, and an upgraded east-west connection between Lilyfield Road, the Rozelle Rail Yards, The Bays Precinct and Anzac Bridge.

The diversions and detours for active transport are described in **Chapter 8** (Traffic and transport).

Impacts on health and emergency services

The existing arterial roads and the local road network are currently used by emergency services to travel to and from call-outs. Construction of the project may require temporary traffic diversions, road occupation, temporary road closures and alternative property access arrangements.

The CTAMP for the project would be developed in consultation with relevant emergency services, ensuring that procedures are in place to maintain safe, priority access for emergency vehicles through construction zones. Additionally, local emergency services would be periodically updated on the staging and progress of construction works. The project would not impact access to health or emergency services.

11.6.2 Property acquisitions

The design of the project has been developed to minimise the need for surface property acquisition and impacts on other residential and open space areas. There would, however, be a number of property acquisitions as well as other temporary and permanent impacts on land use associated with the project.

The acquisition and relocation of households and businesses due to property acquisition can disrupt social networks and affect health and wellbeing due to raised levels of stress and anxiety. This includes increased levels of stress and anxiety during the process of negotiating reasonable compensation. The purchase of a new home and moving house can be one of the most significant events in a person’s life. Both a house and a workplace are central to daily routine with the location of these premises influencing how a person may travel to/from work or study, the social infrastructure and businesses they visit and the people they interact with.

All acquisition required for the project would be undertaken in accordance with the *Land Acquisition (Just Terms Compensation) Act 1991* (NSW), the *Land Acquisition Information Guide* (NSW Government 2014) and the land acquisition reforms announced by the NSW Government in 2016 (NSW Government, 2016), which can be viewed online.[1] Relocation and some other categories of expenses would be claimable under this Act.

11.6.3 Green space

Green space within urban areas includes green corridors (paths, rivers and canals), grassland, parks and gardens, outdoor sporting facilities, playing fields and children play areas. A review of international epidemiological studies shows a positive relationship between green space and health and wellbeing (de Vries et al. 2003; Health Scotland 2008; Kendal et al. 2016; Maas et al. 2006; Mitchell & Popham 2007). The outcomes of these studies did depend on the quality of the available green space. They showed that green space areas in low socio-economic areas often had poor facilities, higher levels of graffiti, vacant/boarded up buildings and lower levels of safety. These studies showed that such spaces had few health benefits.

The health benefits of green space in urban areas include the following (Health Scotland 2008; Kendal et al. 2016; Lee & Maheswaran 2011):

- Green space areas that include large trees and shrubs can protect people from environmental exposures associated with flooding, air pollution, noise and extreme temperature (by regulating microclimates and reducing the urban heat island effect)
- Reduced morbidity
- Improved opportunities for physical activity and exercise. The benefits depend on a range of factors including the distance, ease of access, size of green space, location in relation to connectivity to residential or workplace areas, attractiveness, available facilities (particularly where used by specific sporting clubs) and multi-use (ie including children play areas, gardens, seating, sporting facilities that can be used by a wide range of the community for different purposes)
- Improved mental health and feelings of wellbeing, particularly lower stress levels
- Improve opportunities for social interactions.

Green space areas in urban areas may also present some hazards, such as attracting anti-social behaviours (particularly in isolated areas), providing areas for drug or sexual activity and unintentional injuries from sports or use of playground equipment. It has also been found that individuals from ethnic or minority groups and those with disabilities are less frequent users of green spaces (Health Scotland 2008; Kendal *et al* 2016; Lee & Maheswaran 2011).

There are a number of sporting/recreational facilities and parks in and around the project footprint that include sporting fields, playgrounds, parks and reserves. The project has been designed to minimise impacts on existing recreational facilities. This is of particular note for the Glebe foreshore, the Bay Run and Easton Park.

Following completion of the construction works it is proposed that the Rozelle Rail Yards would be developed as open space that includes a constructed wetland and additional pedestrian and cyclist infrastructure. This improved open space area would provide the community at Rozelle with increased opportunity for active recreation, potentially improving health. This open space would also connect surrounding communities to Rozelle through the extension of green space between Bicentennial Park and Easton Park. Additional opportunities for open space would be created at Rozelle near the Iron Cove Link portals. The development of these areas of open space would be detailed through an urban design and landscape plan (UDLP).

New open space to be created by the project would be designed with consideration of Crime Prevention Through Environmental Design (CPTED) principles, as outlined in **Appendix L** (Technical

[1] https://www.finance.nsw.gov.au/sites/default/files/NSW_Government_Response.pdf

working paper: Urban design) and **Chapter 13** (Urban design and visual amenity). This includes regard for creating safe, well-lit areas, provision of passive surveillance and other measures.

11.6.4 Changes in community

Roads and motorways can divide residential communities and hinder social contact. The presence of busy roads inhibits residents from socialising and children from playing, or accessing nearby recreational areas. Heavy traffic also affects child development (WHO 2000b). Children learn how to make responsible decisions, how to behave in different situations and develop a relationship with their environment and community through independent mobility. Where children have the opportunity to be able to play in local streets or safely access local parks they have been found to have twice as many social contacts as those where such activities are prevented by heavy traffic.

Social connectedness and relationships are important aspects of feeling safe and secure. Streets with heavy traffic have been associated with fewer neighbourhood social support networks and has been linked to adverse health outcomes (WHO 2000b).

Any temporary and permanent changes to the access to social infrastructure, community resources or to other desirable locations (such as employment, study, friends and family) and safety to movement may affect community networks and in turn trigger community severance.

Community severance effects often occur during major transportation projects due to detours in the local road network, changes to active and public transport routes, and connector roads receiving an increase or decrease in traffic movements. The changes to the road networks particularly along City West Link, Victoria Road, The Crescent, Lilyfield Road and Darley Road may contribute to feelings of community severance and disconnection.

Construction of the project would include the removal of two pedestrian bridges across Victoria Road and City West Link which are popular for both recreational and commuter pedestrian and cyclist traffic. The removal of these bridges, despite the temporary alternatives, may reduce community cohesion and sense of access to place. These connections provide important access to Rozelle Bay and through to the Glebe foreshore walkways. The civil site at The Crescent would also temporarily reduce the connection for pedestrian and cyclists to the Glebe foreshore walkways for residents of both Rozelle and Annandale.

However, once completed, the M4-M5 Link project includes a range of changes to the active transport network as previously noted, this would include two new bridges over City West Link connecting the communities of Rozelle, Balmain, Lilyfield, Glebe and Annandale, and an upgraded east-west connection between Lilyfield Road, the Rozelle Rail Yards, The Bays Precinct and Anzac Bridge.

Further detail is provided in **Appendix H** (Technical working paper: Traffic and transport) and **Chapter 8** (Traffic and transport). Improvements to the active transport network, including improvements to transport connections, would have a positive benefit on community health. Where active transport opportunities are improved and offer safe alternatives to driving and public transport, they can encourage more active recreation and commuting activities.

11.6.5 Visual changes

Visual amenity can be described as the pleasantness of the view or outlook of an identified receptor or group of receptors (eg residences, recreational users). Visual amenity is an important part of an area’s identity and offers a wide variety of benefits to the community in terms of quality of life, wellbeing and economic activity. For some individuals, changes in visual amenity can increase levels of stress and anxiety. However, these impacts are typically of short duration as most people adapt to changes in the visual landscape, particularly within an already urbanised area. As a result, changes in visual amenity are not expected to have a significant impact on the health of the community.

During construction, visual amenity in and around the project footprint has the potential to be affected by factors such as the removal of established vegetation, the installation of construction hoardings and/or the visual appearance of construction sites. Further factors may include the alteration of view corridors to heritage, open space, water bodies or the city skyline.

The operational project would include changes to local visual amenity due to the presence of new and amended infrastructure, landscaping (which includes changes to landform and planting of vegetation) and urban design features.

The urban design and landscape works that would be carried out by the project would be documented in a UDLP. A UDLP would be prepared in consultation with stakeholders and the community prior to the commencement of permanent built surface works and/or landscape works and would present an integrated urban design for the project.

A detailed review and finalisation of architectural treatment of the project operational infrastructure, including ventilation facilities, would be undertaken during detailed design. The architectural treatment of these facilities would be guided by ventilation facility performance requirements, the outcomes of community consultation and the urban design principles identified in **Chapter 13** (Urban design and visual assessment).

Landscaping works would be carried out adjacent to disturbed areas, around operational infrastructure (such as ventilation facilities), and in areas of new open space that would be provided at the Rozelle Rail Yards and adjacent to Victoria Road at Rozelle. Areas where permanent operational infrastructure is proposed have been reviewed against the urban design principles developed for the project, which are outlined in **Chapter 13** (Urban design and visual assessment).

11.6.6 Equity

The health effects associated with impacts related to transport projects are not equally distributed across the community. Groups at higher risk, or more sensitive to impacts, include:

- Elderly
- Individuals with pre-existing health problems
- Infants and young children
- Individuals with disabilities
- Individuals who live in areas of higher levels of air or noise pollution.

Often impacts can accumulate in the same areas, which may already have poorer socio-economic and health status, most commonly due to the affordability of housing in areas that are closer to main roads, industry or rail infrastructure. Disadvantaged urban areas are commonly characterised by high traffic volumes, higher levels of air and noise pollution, feelings of insecurity and lower levels of social interactions and physical activity in the community.

To further evaluate potential equity issues associated with the project, the location of impacts identified in relation to air quality, noise and traffic were reviewed individually and in combination, in conjunction with available information on the location of sensitive community groups.

In many urban areas housing prices are lower along main roadways. The median house prices in the study area are variable; however in most areas they are consistent with the Sydney average. Some public housing is located in the study area; however, these properties are mixed in with privately owned property such that there are no specific areas with higher populations of public housing tenants. Hence there are no social equity issues identified in relation to the change in air quality in the local community.

There are no areas identified in the local community where the combined impact from changes in noise and air quality would be different from the conclusions presented for the individual assessment of air quality and noise impacts.

Suburbs in the study area that, based on the 2011 census data, are slightly more disadvantaged (in relation to the Socio-Economic Index for Areas (SEIFA)) include Glebe, Eveleigh and Marrickville, as well as populations in the Canterbury area. There are no project related air quality or noise impacts (including during cumulative scenarios) that are of significance in these areas. Impacts on human health in these areas would be lower than predicted for the maximum impacted individuals.

Residents located adjacent to a number of key surface roads, particularly City West Link, Parramatta Road, Princes Highway, part of Victoria Road at Rozelle, Southern Cross Drive and the M5 Motorway would benefit from reduced traffic volumes, potentially improved traffic and pedestrian safety, and improvements (albeit small and not measurable) in air quality and noise.

11.7 Economic aspects

The construction expenditure of the project would be of significant benefit to the economy. This expenditure would inject economic stimulus benefits into the local, regional and state economies. Ongoing or improved economic vitality is of significant health benefit to the community, as described below.

Employment opportunities would grow in the region through the potential increase in business customers and through the increase in demand for construction workers. The increase in demand for labour may increase wages in the region, particularly for construction workers, who would be in high demand.

The acquisition and relocation of some businesses can result in impacts on local economies. In addition, changes to access during construction may also adversely impact on some local businesses. To minimise these impacts the project would include development of a Business Management Strategy (refer to **Appendix P** (Technical working paper: Social and economic) for a detailed description of what this would entail).

Freight and commercial vehicle movements are an important component of the economy. Numerous industries are dependent upon efficient transport to service operational requirements. Transport for NSW estimated that freight and logistics contributed $58 billion to NSW State Gross Product (GSP) in 2011. This represented 13.8 per cent of NSW GSP at the time.

An objective of the M4-M5 Link project is to encourage heavy and commercial vehicle movements into the tunnel, increasing efficiencies and reducing *‘freight costs through increased travel speeds and reliability and reducing the distances travelled by freight vehicles’.*

The transport and traffic modelling conducted for the project highlighted that there could potentially be substantial benefits for freight and commercial vehicle movements during the operation of the M4-M5 Link. The subsequent effects of the operation of the M4-M5 Link on business productivity include:

- Reduced cost of commercial and freight movements
- Increased productivity from reduced congestion and travel times for commercial and freight movements
- Increased economic output as a result of increased efficiency in freight and commercial vehicle movements.

The modelling determined that a significant number of freight vehicles diverted from surface roads into the project tunnels with an expectation of travel time savings. This in turn would improve travel times on existing major arterial surface roads such as Victoria Road, Parramatta Road and the Princes Highway for commuters and light commercial vehicles.

11.7.1 Road tolling

The social and economic impacts associated with a new toll road are diverse and far ranging, with the level of the effect being related to which road users are targeted and the amount charged.

The implementation of road tolls can have direct impacts on travel times, reduced emissions and traffic accidents, as well as other less direct impacts on social inequality, company movements, and effects on the regional/national economy which are more difficult to quantify and are generally documented qualitatively.

A potential impact of tolling is the increase in congestion volumes on surrounding roads as a result of toll avoidance (ie ‘rat-running’). The use of a toll road can also increase the cost of living and can exacerbate social inequality. Specifically, the impact of toll roads on households can be assessed as a function of household income, urban spatial structure, and available mobility choices. Depending on the travel routes of individuals, and the individual economic situation, there may be a proportion of the population that would avoid the use of tollways due to affordability.

Funding of WestConnex, as proposed in the *WestConnex Updated Strategic Business Case* (Sydney Motorway Corporation 2015), assumes a distance based toll would be implemented on operation of each component project. Distance based tolling means that motorists would only pay tolls for the sections of the motorway they use. The proceeds of the toll on each component project once operational would be applied to fund the construction of other components of the WestConnex program of works. A maximum toll for the use of the M4-M5 Link would be $6.50 (2017 dollars).Tolls for the entire WestConnex motorway would be capped at a maximum amount of $8.60 (2017 dollars) for cars and light commercial vehicles and a distance of around 40 kilometres. This would provide significant time and cost savings for motorists. Cars and light commercial vehicles would pay one third of the toll for heavy commercial vehicles. Tolls would escalate up to a maximum of four per cent or the consumer price index (CPI) per year (whichever is greater) until 2040. After that, CPI would apply.

The project would enhance the benefits of the WestConnex program of works for travel between western Sydney and the Sydney CBD. For example, a person driving a car in 2017 from Penrith to the Sydney CBD currently has the option of travelling along the M4 Motorway, which ends at Concord, and then would need to travel on the congested surface road network to the Sydney CBD. An alternative route between Penrith and the CBD using the M4 Motorway, WestLink M7, the Hills M2 Motorway, Lane Cove Tunnel and the Sydney Harbour Bridge or the Sydney Harbour Tunnel would cost around $22.00 in tolls ($2017) and is a distance of around 55 kilometres. After opening in 2023, the project would provide a journey using the M4 Motorway straight through to Anzac Bridge, via the M4-M5 Link, for a toll capped at $8.60 (2017 dollars) and a distance of around 40 kilometres. This would provide significant time and cost savings for motorists.

The magnitude of tolls proposed for the project, including consideration of toll avoidance, has been factored into the traffic modelling, and subsequent air quality and noise modelling, and hence impacts on the health of the community have been considered.

11.8 Construction fatigue

Construction fatigue relates to receptors that experience construction impacts from a variety of projects over an extended period of time with few or no breaks between construction periods. Construction fatigue typically relates to traffic and access disruptions, noise and vibration, air quality, visual amenity and social impacts from projects that have overlapping construction phases or are back to back.

For the key areas, where construction fatigue may be of concern, the following was identified:

- Haberfield/Ashfield: construction activities associated with the M4 East project as well as the M4-M5 Link within the construction ancillary facilities in Haberfield would result in surrounding communities being exposed to construction noise, traffic and dust for longer periods of time. Areas potentially affected (depending on which construction ancillary facilities are utilised during the construction of the M4-M5 Link project) are located:
  - Adjacent to the Northcote Street civil site
  - Adjacent to the Wattle Street civil and tunnel site
  - Adjacent to the Haberfield civil and tunnel site/Haberfield civil site
  - Adjacent to the Parramatta Road East civil site and Parramatta Road West civil and tunnel site

  In these areas, additional mitigation measures are identified, specifically an increase in the height of hoarding around the construction sites and at-receptor noise mitigation (where required), to address these longer duration noise impacts
- Rozelle: construction activities associated with the project and other infrastructure projects, namely the CBD and South East Light Rail Rozelle maintenance depot, the proposed future Western Harbour Tunnel and Beaches Link and site management works may result in construction noise for longer periods of time. Areas that may be affected are located:
  - Adjoining Lilyfield Road between Justin Street and Ryan Street
  - Adjoining Brenan Street between Starling Street and White Street

In these areas additional mitigation measures were identified, specifically an increase in the height of hoarding around the construction sites, and upgrading of the acoustic shed performance and at-receptor noise mitigation (where required), to address these longer duration noise impacts. Under this scenario there are a number (345 receptors) that may be impacted by vibration at levels that exceed the human comfort criteria. These impacts will require monitoring and management

- St Peters: construction activities associated with the New M5 and the M4-M5 Link would result in exposure to construction noise for longer periods of time. Areas affected are:
  - Adjacent to Campbell Road.

In these areas, additional mitigation measures are recommended that include optimising the design of acoustic sheds, noise barriers/hoarding and management measures and at-receptor noise mitigation (where required), to address these longer duration noise impacts.

11.9 Stress and anxiety issues

A number of changes within the community have the potential to affect levels of stress and anxiety. Some changes may result in a lowering of feelings of stress and anxiety while there are others that may result in higher levels within the community or individuals, depending on personal circumstances. In addition, construction fatigue from overlapping and consecutive infrastructure projects and ongoing urban developments may result in elevated levels of stress and anxiety for extended periods of time. This is discussed in more detail in **Appendix K** (Technical working paper: Human health risk assessment) and in **Chapter 26** (Cumulative impacts).

Chronic and persistent negative stress, or distress, can lead to many adverse health problems including physical illness and mental, emotional and social problems. Response to stress would vary between individuals with genetic inheritance and personal/environmental experiences of importance (Schneiderman, Ironson & Siegel 2005).

An acute stressful event results in changes to the nervous, cardiovascular, endocrine and immune systems, more commonly known as the ‘fight or flight’ response (Schneiderman, Ironson & Siegel 2005). Unless there is an accident or other significant event, such acute stress events are not expected to be associated with construction or operation of the project.

For shorter-term events, stress causes the immune system to release hormones that trigger the production of white blood cells that fight infection and other disease-fighting elements. This response is important for fighting injuries and acute illness. However, this activity within the body is not beneficial if it occurs for a long period of time. Hormones released during extended or chronic stress can inhibit the production of cytokines (the messengers that allow cells to talk to each other to fight infection), lowering the body’s ability to fight infections. This makes some individuals more susceptible to infections, and they may also experience more severe infections. It can also trigger a flare up of pre-existing autoimmune diseases (which are a range of diseases where the immune system gets confused and starts attacking healthy cells) (Mills, Reiss & Dombeck 2008; Schneiderman, Ironson & Siegel 2005).

Other physiological effects associated with chronic stress include (Brosschot, Gerin & Thayer 2006; McEwen, Bruce S. 2008; McEwen, B. S. & Stellar 1993; Mills, Reiss & Dombeck 2008; Moreno-Villanueva & Bürkle 2015):

- Digestive disorders, with hormones released in response to stress causing a number of people to experience stomach ache or diarrhoea, with appetite also affected in some individuals (resulting in under-eating or over-eating)
- Chronic activation of stress hormones can raise an individual’s heart rate, cause chest pain and/or heart palpitations and increase blood pressure and blood lipid (fat) levels. Sustained high levels of cholesterol and other fatty substances can lead to atherosclerosis and other cardiovascular disease and sometimes a heart attack (Pimple et al. 2015; Seldenrijk et al. 2015)
- Cortisol levels, released at higher levels with stress, play a role in the accumulation of abdominal fat, which has been linked to a range of other health conditions

- Stress can cause muscles to contract or tighten, causing tension aches and pains (Ortego et al. 2016).

Some individuals respond to elevated levels of stress by taking up or continuing unhealthy stress coping strategies such as smoking, drinking or overeating, all of which are associated with significant health risks.

Chronic levels of stress have also been found to cause or exacerbate existing mental health issues, including mood disorders such as depression and anxiety, cognitive problems, personality changes and problem behaviours. It can also affect individuals with pre-existing bipolar disorders.

More generally, it must be noted that urbanisation, or increased urbanisation, regardless of specific projects has been found to affect levels of stress and mental health (Srivastava 2009). These impacts are greater where there is urbanisation without improvements in infrastructure to improve equitable access to employment and social areas/communities (Srivastava 2009). The role of either acute or long-term environmental stress on the health of any community, in general and for specific project(s), including the WestConnex projects, cannot be quantified.

There are a wide range of complex factors that influence health and wellbeing, specifically mental health. It is not possible to determine any specific outcomes that may occur as a result of a specific project, or number of projects. However, it is noted that within any urban environment there would be a wide range of stressors present from infrastructure projects as well as other urban developments that may or may not contribute to the health effects outlined above.

The project, along with the other approved WestConnex projects, aims to improve infrastructure and access within the urban environment. Hence on a broader scale these long-term projects, while they require management of construction impacts, may assist in reducing stress and associated physiological and mental health impacts within the urban environment.

11.10 Management of impacts

Management measures to minimise impacts on human health during construction and operation of the project are provided in the following chapters:

- Transport and travel management measures – **Chapter 8** (Traffic and transport)
- Air quality management measures – **Chapter 9** (Air quality)
- Noise and vibration management measures – **Chapter 10** (Noise and vibration)
- Property acquisition and relocation services – **Chapter 12** (Land use and property)
- Social impact management measures – **Chapter 14** (Social and economic).

12 Land use and property

This chapter considers the potential land use and property implications of constructing and operating the M4-M5 Link project (the project) and expands on the strategic context and justification for the project presented in **Chapter 3** (Strategic context and project need). It describes the framework for integrated land use and transport planning, and provides an assessment of the potential impact on land use and property as a result of the concept design for the project as described in **Chapter 5** (Project description).

The concept design would continue to be refined, where relevant, to improve road network and safety performance, minimise impacts on sensitive receptors and the environment, and in response to feedback from stakeholders and the community.

Potential impacts of the project on utilities, including relocation or adjustment of utilities during construction of the project, as well as measures to protect utilities, are identified in the Utilities Management Strategy that has been prepared for the project and included in **Appendix F** (Utilities Management Strategy). The Utilities Management Strategy identifies, and provides for the management of, potential land use and property impacts associated with the relocation, adjustment and protection of utilities.

The Secretary of the NSW Department of Planning and Environment (DP&E) has issued environmental assessment requirements for the project. These are referred to as Secretary's Environmental Assessment Requirements (SEARs). **Table 12-1** sets out the SEARs and the associated desired performance outcomes that relate to land use and property, and identifies where they have been addressed in this environmental impact statement (EIS).

Table 12-1 SEARs – land use and property

Desired performance outcomes	SEARs	Where addressed in the EIS
3. Assessment of key issues Key issue impacts are assessed objectively and thoroughly to provide confidence that the project will be constructed and operated within acceptable levels of impact.	2. For each key issue, the Proponent must: (b) describe the legislative and policy context, as far as it is relevant to the issue	The relevant legislative and policy context for land use and property is described in in **section 12.1.2**. The legislative policy context for other key issues is described in the relevant sections of the key issues chapters (**Chapters 8** to **Chapter 25**).
3. Health and safety The project avoids, to the greatest extent possible, risk to public safety.	2. The assessment must: Assess the likely risks of the project to public safety, paying particular attention to:	
	• pedestrian safety	Pedestrian safety during construction and operation is addressed in **Chapter 8** (Traffic and transport).
	• subsidence risks	Subsidence risks are addressed in **section 12.3.4** and in **Chapter 19** (Groundwater).
	• bushfire risks	Bushfire risks are addressed in **Chapter 25** (Hazard and risk).
	• the handling and use of dangerous goods.	The handling and use of dangerous goods are addressed in **Chapter 25** (Hazard and risk).

Desired performance outcomes	SEARs	Where addressed in the EIS
9. Socio-economic, land use and property The project minimises adverse social and economic impacts and capitalises on opportunities potentially available to affected communities. The project minimises impacts on property and business and achieves appropriate integration with adjoining land uses, including maintenance of appropriate access to properties and community facilities, and minimisation of displacement of existing land use activities, dwellings and infrastructure.	2. The Proponent must assess impacts from construction and operation on potentially affected property (including Crown lands), businesses, recreational users and land and water users, including property acquisitions/adjustments, access amenity, relevant statutory rights, and community severance and barrier impacts resulting from the project.	Impacts on potentially affected properties are addressed in **section 12.3**. Impacts from construction and operation on Crown lands are assessed in **section 12.3.2**. An assessment of potential overshadowing from buildings and structures associated with the project is provided in **section 12.4.13**. Shadow diagrams indicating the extent of overshadowing on properties that is currently expected as a result of permanent operational infrastructure are provided in **Appendix M** (Shadow diagrams and overshadowing). There may be changes to overshadowing as the detailed design progresses. Access amenity and relevant statutory rights are addressed in **section 12.4.8** and in **Chapter 8** (Traffic and transport). Impacts on businesses are addressed in **section 12.3**, **section 12.3.4** and in **Chapter 14** (Social and economic). Impacts on recreational users have been assessed in **section 12.3.4** and in **Chapter 14** (Social and economic). Impacts on water users are described in **section 12.4.9**. Community severance and barrier impacts are assessed in **section 12.3.4**, and in **Chapter 8** (Traffic and transport) and **Chapter 14** (Social and economic).
	3. The Proponent must identify opportunities for local centre street revitalisation improvements, pedestrian and cyclist access and connectivity and provision of community and social facilities.	The project would deliver new areas of open space around Rozelle and Iron Cove including new and upgraded pedestrian and cyclist connections. A concept plan has been prepared for these locations and is presented in **Chapter 13** (Urban design and visual amenity). This concept plan identifies the ways that the project could deliver and/or facilitate local centre street revitalisation improvements and new community and social facilities. Further discussion is also included in **Chapter 3** (Strategic context and project

Desired performance outcomes	SEARs	Where addressed in the EIS
		need) and **Chapter 14** (Social and economic). Pedestrian and cyclist facilities that would be provided by the project are described in **Chapter 5** (Project description). Impacts on pedestrian and cyclist facilities are assessed in **Chapter 8** (Traffic and transport). Potential opportunities for pedestrian and cyclist connections are also described in **Appendix N** (Technical working paper: Active transport strategy).
	4. The design and siting of project elements should be located in such a way that functional, contiguous areas of residual land are maximised. The design and siting must consider appropriate land use interfaces (ie White Bay) and the social and economic impacts of proposed land uses against alternate land uses.	The design and siting of project elements as described in **Chapter 5** (Project description) have had regard to maximising remaining project land opportunities, particularly around Rozelle and Iron Cove. The potential future uses for remaining project land at these locations are described in the concept plans in **Chapter 13** (Urban design and visual amenity) and **Appendix L** (Technical working paper: Urban design). The development of alternatives and options for project elements are described in **Chapter 4** (Project development and alternatives). Interfacing land uses have been considered in the design and siting of project elements as described in **Chapter 5** (Project description). An assessment of the land use impacts on interfacing projects is included in **section 12.3.4** and in in **Chapter 3** (Strategic context and project need). The social and economic impacts of proposed land uses is assessed in **Chapter 14** (Social and economic).
	5. Where air quality allows, residual land must be designed to positively contribute to additional community uses, public recreation uses and/or affordable or social housing. Passively landscaped areas should not be the default use for residual land.	The potential future uses for land that would be subject to urban design and landscaping and remaining project land are described in **section 12.3** and in **Chapter 13** (Urban design and visual amenity) and **Appendix L** (Technical working paper: Urban

Desired performance outcomes	SEARs	Where addressed in the EIS
		design). The project would deliver new open space that could contain a variety of community and public recreation uses. These potential future uses would be determined through ongoing consultation with relevant councils, the community and other key stakeholders and would be documented in the Residual Land Management Plan and/or Urban Design and Landscape Plan that would be prepared for the project.
	6. The Proponent must assess potential impacts on utilities (including communications, electricity, gas, and water and sewerage) and the relocation of these utilities.	Potential impacts of the project on utilities are assessed in **Appendix F** (Utilities Management Strategy).
	7. Where the project is predicted to affect trunk utilities, the Proponent must undertake a utilities management strategy. The strategy must identify proposed management strategies, including relocations or adjustment of the utilities, and their estimated timing and duration. This strategy must be developed in consultation with the relevant utility owners or providers.	A utilities management strategy has been prepared for the project and is included in **Appendix F** (Utilities Management Strategy).

12.1 Assessment methodology

12.1.1 Overview

The assessment of impacts from the concept design of the project on land use and property has been carried out by undertaking the following key tasks:

- Providing an overview of the existing land use and zoning in the vicinity of the project (see **section 12.2**)
- Reviewing relevant strategic planning documents (see **section 12.1.2**)
- Identifying the existing properties and land uses that would be impacted by the project (see **section 12.3** (property impacts) and **section 12.3.4** (land use impacts))
- Identifying the potential future uses of land required for construction but not required for permanent operational infrastructure, including:
  - New open space, active transport connections and community or social infrastructure
  - Remaining project land that would be retained for future (separate) road infrastructure projects
  - Remaining project land that would be retained for future (separate) road infrastructure projects or considered for separate future development or use, both of which would be subject to the Residual Land Management Plan that would be prepared for the project

- Identifying planned future development that may impact on or be impacted by the project, including a review of recent development applications granted by City of Sydney Council, Inner West Council and DP&E in the vicinity of the project
- Identifying the extent of overshadowing on properties that is potentially expected as a result of permanent operational infrastructure (see **section 12.4.13**)
- Identifying mitigation measures (general and specific) that would assist in reducing land use and property impacts (see **section 12.5**).

12.1.2 Strategic land use and planning context

Relevant plans, policies and strategies

The project aims to be consistent with and support the goals and objectives of NSW strategic planning and transport infrastructure policies, including:

- *NSW Long Term Transport Master Plan* (Transport for NSW 2012b)
- *Sydney's Rail Future: Modernising Sydney's Trains* (Transport for NSW 2012a)
- *Sydney City Centre Access Strategy* (Transport for NSW 2013)
- State and Premier priorities (NSW Government 2015)
- *A Plan for Growing Sydney* (NSW Government 2014a)
- *Rebuilding NSW: State Infrastructure Strategy 2014* (NSW Government 2014b)
- *The Bays Precinct Transformation Plan* (UrbanGrowth NSW 2015)
- *Parramatta Road Corridor Urban Transformation Strategy* (UrbanGrowth NSW 2016)
- *Draft Central District Plan* (Greater Sydney Commission 2016).

These strategic plans and policies provide goals and objectives for land use planning within the Sydney metropolitan area, including consideration of the role of transport infrastructure in accommodating the future housing, transport, employment and amenity needs of Sydney's growing population. Local plans and policies have also been considered in the development of the project. Further detail on relevant plans, policies and strategies and their interaction with the project is provided in **section 12.2.1** and in **Chapter 3** (Strategic context and project need).

The project presents opportunities to support Sydney's integrated land use and transport planning objectives by:

- Together with other WestConnex projects, creating motorway connections between key employment hubs and local communities, and providing links to population growth centres at Parramatta and western Sydney
- Providing a new underground motorway link between the M4 East at Haberfield and the New M5 at St Peters to assist in easing congestion on parts of existing north–south and east–west surface roads
- Providing connections between the extended M4 and M5 motorways and supporting connections to the proposed future Sydney Gateway project (via the St Peters interchange), ultimately improving access to Sydney's international gateways at Sydney Airport and Port Botany
- Facilitating future urban renewal in precincts adjoining the project, including along Parramatta Road (east of Haberfield) and Victoria Road (between Iron Cove Bridge and The Crescent). The urban design and landscaping works to be implemented as part of the project within the Rozelle Rail Yards and the Iron Cove Link surface works (as described in **Chapter 5** (Project description)) would assist in creating opportunities for improved connectivity to these possible future urban renewal projects, including improved connectivity and permeability for pedestrians and cyclists to locations such as The Bays Precinct
- Reducing travel times and improving reliability for bus services as well as, business, personal and freight journeys

- Improving local traffic movements, in particular north–south movements across the Parramatta Road corridor between Haberfield and Camperdown and north–south movements across Victoria Road and The Bays Precinct at Rozelle. These improvements to local traffic movements could facilitate the delivery of future public transport improvements, particularly along Parramatta Road and Victoria Road
- Upgrading and improving facilities for pedestrians and cyclists including the delivery of active transport links around permanent operational infrastructure. This would include two new bridges over City West Link connecting the communities of Rozelle, Balmain, Lilyfield, Glebe and Annandale, and an upgraded east–west connection between Lilyfield Road, the Rozelle Rail Yards, The Bays Precinct and Anzac Bridge
- Providing connections to the proposed future Western Harbour Tunnel and Beaches Link project to the north (via the Rozelle interchange) and to the proposed future Sydney Gateway project at St Peters (via the St Peters interchange) to assist in improving connectivity in Sydney's transport network. These proposed future projects would be subject to separate assessment and approval.

12.2 Existing environment

12.2.1 Regional context

The project is generally located in the inner west region of Sydney within the Inner West and City of Sydney local government areas (LGAs). The project traverses the suburbs of Ashfield, Haberfield, Leichhardt, Lilyfield, Rozelle, Annandale, Stanmore, Camperdown, Newtown and St Peters. A detailed overview of the project is provided in **Chapter 5** (Project description).

Existing land use and development within and around the project contains a mix of residential, commercial, industrial and open space uses including:

- Primarily low and medium density, with limited areas of high density residential land uses around Haberfield, Rozelle, Annandale, St Peters and areas close to public transport
- Open space as well as active and passive recreational uses, located around the project footprint. This includes areas of open space such as Reg Coady Reserve, Algie Park, Blackmore Park, Pioneers Memorial Park, Easton Park, Whites Creek Valley Park, the Bay Run around Iron Cove at Rozelle, King George Park, Callan Park, Camperdown Park, O'Dea Reserve, Bicentennial Park and Sydney Park. Continuous open space corridors, consisting of a series of smaller open spaces, are located along Whites Creek, Johnstons Creek and the Hawthorne Canal
- Industrial and commercial land concentrated in the suburbs of Ashfield, Rozelle, Leichhardt, Camperdown and St Peters. Commercial uses are typically concentrated along arterial roads (such as Victoria Road, Parramatta Road, Pyrmont Bridge Road, King Street, and the Princes Highway), some non-arterial roads (Darley Road and Lilyfield Road), at railway stations, and around medium and density residential areas
- Community facilities such as churches, schools, medical and veterinary centres, child care centres and aged persons homes surrounding the project footprint. These include Haberfield Public School, Rozelle Public School, Lilyfield Early Learning Centre, the University of Sydney Camperdown Campus and the Royal Prince Alfred Hospital and supporting educational and medical facilities at Camperdown.

There are several major transport corridors and other infrastructure located in or adjacent to the project footprint, including Victoria Road, City West Link, Parramatta Road, the Princes Highway, Sydney Trains' suburban railway network, and the Inner West Light Rail line corridor.

Several waterways and creeks are located adjacent or nearby to the project footprint including the Dobroyd Canal (Iron Cove Creek) at Haberfield, Hawthorne Canal at Leichhardt, Whites Creek and Johnstons Creek at Annandale and Lilyfield, Rozelle Bay and Iron Cove at Rozelle, and Alexandra Canal at St Peters.

Land use zonings within and around the project footprint are set by the following environmental planning instruments:

- Ashfield Local Environmental Plan 2013 (Ashfield LEP 2013)

- Leichhardt Local Environmental Plan 2013 (Leichhardt LEP 2013)
- Marrickville Local Environmental Plan 2011 (Marrickville LEP 2011)
- Sydney Local Environmental Plan 2012 (Sydney LEP 2012)
- Sydney Regional Environmental Plan No. 26 – City West (SREP 26).

The regional land use zoning context of the project is shown in **Figure 12-1** and described in **section 12.2.2**. Detailed figures showing the project elements are also included in **Chapter 5** (Project description).

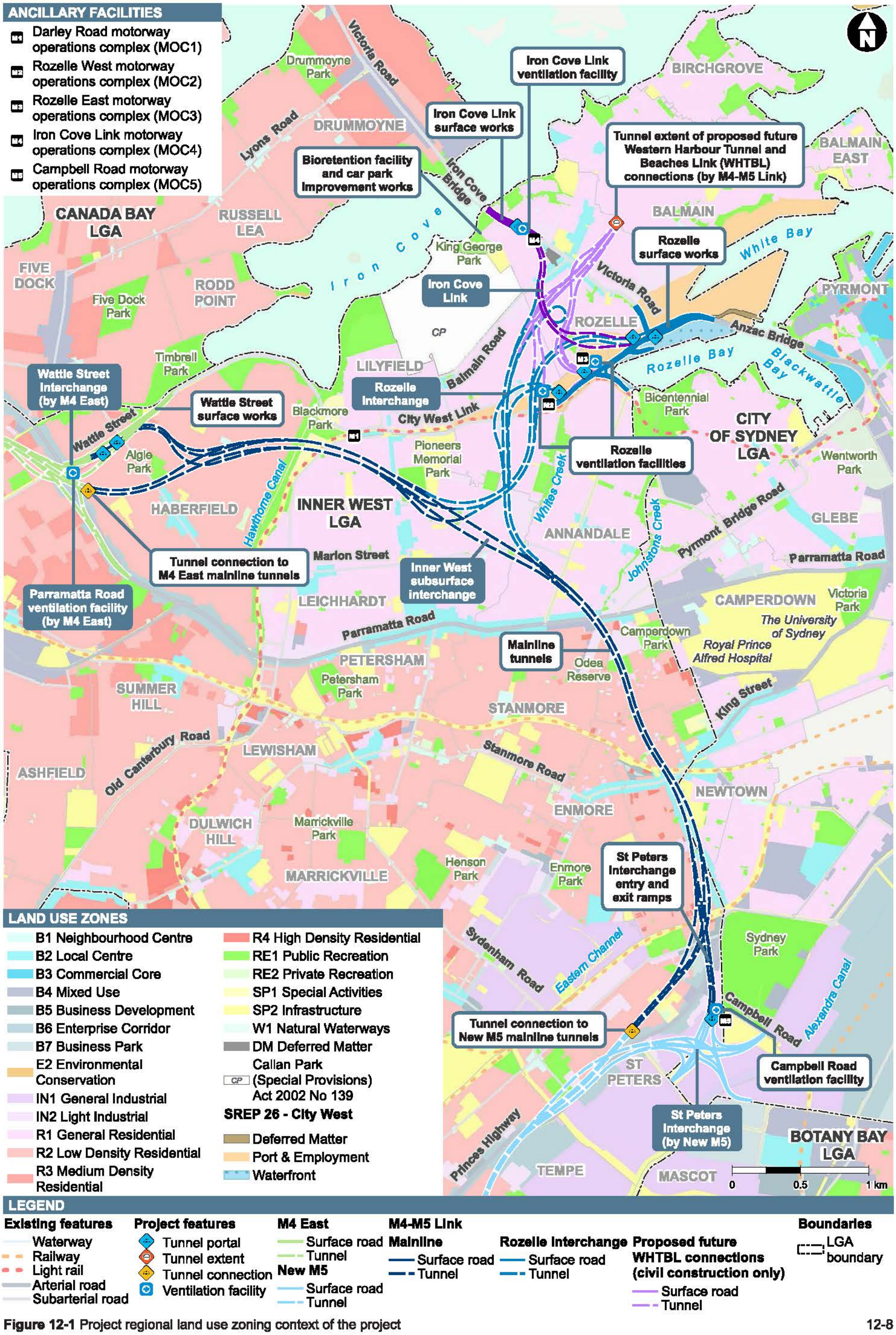


Figure 12-1 Project regional land use zoning context of the project

Local and regional planning and development proposals

The following local and regional planning initiatives and development proposals that could affect or be affected by the project are proposed or underway within and around the project footprint, including:

- The Green Grid – Creating Sydney's Open Space Network (NSW Government Architects Office 2015)
- Cooks River to Iron Cove GreenWay Master Plan and Coordination Strategy (Marrickville Council 2009)
- Lilyfield Road regional bike route separated cycleway (Inner West Council 2016)
- Leichhardt Bike Plan (Leichhardt Council 2016)
- Whites Creek, Johnstons Creek and Dobroyd Canal (Iron Cove Creek) naturalisation works (Creek naturalisations, Sydney Water 2017)
- Easton Park stormwater drain improvements proposed by Sydney Water
- King George Park Plan of Management (Leichhardt Council 2012).

These are described in more detail in the following section. The impacts of the project on these, and of these on the project, are assessed as relevant in **section 12.3.4**.

Sydney's Green Grid is identified in *A Plan for Growing Sydney* (NSW Government 2014) and aims to make Sydney a great place to live, with a connected network of multipurpose green spaces. It also aims to ensure Sydney is a sustainable city that values and protects the natural environment and has a balanced and sustainable approach to land and resource use. The Green Grid project will deliver a connected network of walking trails, bike paths, picnic spots and conservation works to provide high-quality, well-connected greenspace areas for local communities and wildlife. The *Draft Central District Plan* (Greater Sydney Commission 2016) articulates a long term vision for Sydney's Green Grid including a number of priority projects such as the Iron Cove GreenWay and the Cooks River open space corridor.

The Cooks River to Iron Cove GreenWay documented in the *Cooks River to Iron Cove GreenWay Master Plan and Coordination Strategy* (Ashfield Council et al 2009) a five-kilometre-long corridor extending from the Cooks River at Earlwood to Iron Cove, in the Canterbury and Inner West LGAs. The corridor includes sections of the Inner West Light Rail line corridor between Dulwich Hill and Lilyfield.

The Leichhardt Bike Plan is an initiative of the former Leichhardt Council, and aims to guide the future development of the Leichhardt bicycle network and facilities, provide links to other modes of transport and improve the general safety of bike use. No updates or revisions to the Leichhardt Bike Plan have been made available following the formation of the Inner West Council.

Sydney Water is investigating the potential naturalisation of a section of Whites Creek at Annandale. The area being investigated is a 400 metre length of the creek corridor upstream of its outlet to Rozelle Bay. The concrete lined creek channel is in need of repair and the proposal would remove the deteriorated concrete banks and naturalise and rehabilitate the channel. A concept design for the works has been prepared by Sydney Water but at this stage, the design and construction timelines are not known. As part of the project, the section of Whites Creek between The Crescent and Rozelle Bay at Annandale would be naturalised consistent with Sydney Water's plans for the aforementioned upstream section. The design of these naturalisation works would be further developed during detailed design and in consultation with Sydney Water. A description of proposed naturalisation works at Whites Creek at Annandale is provided in **Chapter 5** (Project description).

Similar investigations are also underway by Sydney Water to rehabilitate about 600 metres of the concrete lined Johnstons Creek channel from the outlet at Rozelle Bay at Annandale, and about 200 metres of Dobroyd Canal (Iron Cove Creek) east of Ramsay Street at Haberfield, both of which are in need of repair. Sydney Water is looking to develop naturalising solutions where possible. The early concept design for the naturalisation of Dobroyd Canal (Iron Cove Creek) proposes features like creek banks made of rocks and native plants and some banks turned into salt marsh areas. A similar, final concept design for the Johnstons Creek channel has been prepared. The design and construction timelines for these works are still being investigated by Sydney Water.

Sydney Water is also preparing a proposal to implement drainage upgrades at Easton Park at Rozelle. This would involve diversion of an existing drain to a bioretention basin, designed to treat a portion of stormwater flows. The basin would remove a portion of pollutants generated by the urban catchment and may also provide the potential for re-use as irrigation for the park. The design for the project is understood to be prepared in 2017 with construction scheduled for 2018.

12.2.2 Local context

This section discusses the existing land use and planning controls for each of the proposed surface sites. The project has been designed such that the majority of transport infrastructure would be located underground within tunnels. As a result, surface sites are limited to locations where surface works are required to build temporary construction and permanent operational infrastructure (such as interchanges, surface road upgrades, infrastructure to support the operation of the project, such as ventilation facilities, substations and water treatment plants and temporary construction ancillary facilities).

This section describes the properties, land uses, planning controls and strategic planning context (where appropriate) within and adjacent to the project footprint around the following surface sites:

- The Wattle Street interchange surface works at Haberfield including within and surrounding the Wattle Street civil and tunnel site (C1a), Haberfield civil and tunnel site (C2a)/Haberfield civil site (C2b) and the Northcote Street civil site (C3a) during construction and permanent operational infrastructure
- Surface works within and surrounding the Parramatta Road West civil and tunnel site (C1b) and the Parramatta Road East civil site (C3b) at Ashfield and Haberfield during construction
- The surface works at Darley Road including within and surrounding the Darley Road civil and tunnel site (C4) at Leichhardt during construction and permanent operational infrastructure
- The surface works at Lilyfield, Annandale and Rozelle including within and surrounding the Rozelle civil and tunnel site (C5), The Crescent civil site (C6) and the Victoria Road civil site (C7) during construction and permanent operational infrastructure
- The Iron Cove Link surface works at Rozelle including within and surrounding the Iron Cove Link civil site (C8) during construction and permanent operational infrastructure
- Surface works within and surrounding the Pyrmont Bridge Road tunnel site (C9) at Annandale during construction
- St Peters interchange surface works at St Peters including within and surrounding the Campbell Road civil and tunnel site (C10) during construction and permanent operational infrastructure.

A detailed description of the activities that would occur during construction is provided in **Chapter 6** (Construction work). The permanent operational infrastructure that would be provided as part of the project is described in **Chapter 5** (Project description).

As described in **Chapter 6** (Construction work) the concept design considers two possible combinations for construction ancillary facilities around Haberfield and Ashfield. These are described and assessed in this EIS as Option A and Option B. The construction ancillary facilities that comprise these options have been grouped together and are denoted by the suffix *a* (for Option A) or *b* (for Option B) eg C1a Wattle Street civil and tunnel site.

The construction ancillary facilities that comprise these options have been selected to assist in informing the preferred combination of construction ancillary facilities that would be used to construct the project. The preferred combination would be determined during detailed design and would meet the environmental performance outcomes stated in the EIS and the Submissions and Preferred Infrastructure Report, satisfy criteria that would be identified in any relevant conditions of approval and manage environmental risks.

Wattle Street interchange surface works

Land use

Construction of dive structures, tunnel portals and surface road upgrades and modifications along Wattle Street are being carried out as part of the M4 East project. Substantial changes to land use within this area at Haberfield as a result of property acquisition, construction activities and the introduction of permanent operational infrastructure at the Wattle Street interchange have already been assessed and approved as part of the M4 East project.

Three construction ancillary facilities would be located at Haberfield to support the construction of the project, consisting of:

- Wattle Street civil and tunnel site (C1a)
- Haberfield civil and tunnel site (C2a)/Haberfield civil site (C2b)
- Northcote Street civil site (C3a).

The locations of these are shown in **Figure 12-2**. These construction ancillary facilities would be located on land at the surface and underground currently being used as construction ancillary facilities for the M4 East project and would not require any new temporary or permanent acquisition or leasing. Notwithstanding, potential land use impacts associated with these construction ancillary facilities are assessed in this chapter.

The area around the Wattle Street interchange consists of predominantly residential land uses, comprising attached and detached dwellings and some residential apartments. A mixture of commercial and light industrial land uses front onto Parramatta Road near the Haberfield civil and tunnel site (C2a)/Haberfield civil site (C2b) and Northcote Street civil site (C3a).

A place of worship is located on the western side of Wattle Street near the intersection with Parramatta Road, adjacent to the Northcote Street civil site (C3a). Haberfield Public School is located at Bland Street about 300 metres east of the intersection of Wattle Street and Allum Street. Dobroyd Point Public School is located about 200 metres east of the intersection of Dobroyd Parade and Loudon Avenue. There is a small group of commercial and retail properties on Ramsay Street, at the intersection with Alt Street, including a restaurant. Bunnings Warehouse is located on the corner of Parramatta Road and Frederick Street and The Infants Home (child care centre) is located on Henry Street behind the Bunnings Warehouse. Reg Coady Reserve is located to the north of Wattle Street, west of the intersection with Martin Street.

Planning controls

The Ashfield LEP 2013 defines the land use zoning surrounding the Wattle Street interchange surface works as a mix of the following zones: SP2 Infrastructure, R3 Medium Density Residential, R2 Low Density Residential, B6 Enterprise Corridor, RE1 Public Recreation and B1 Neighbourhood Centre.

The majority of the Wattle Street interchange surface works are on land zoned SP2 Infrastructure and R3 Medium Density Residential. The objective of these zones is to provide for transport infrastructure and related uses and the housing needs of the community within a medium density residential environment respectively.

A portion of the Haberfield civil and tunnel site and the Northcote Street civil site are located on land zoned B6 Enterprise Corridor and R2 Low Density Residential. The objective of these zones is to promote businesses along main roads and provide for the housing needs of the community within a low density residential environment respectively. Land use zoning surrounding the Wattle Street interchange surface works is shown in **Figure 12-3**.

Strategic planning context

Future development is proposed in the vicinity of the site in accordance with the *Parramatta Road Corridor Urban Transformation Strategy* (UrbanGrowth NSW 2016), including maintaining an employment focus along main roads, encouraging appropriately scaled residential development and providing increased connectivity for pedestrians and cyclists. The strategic planning context in the vicinity of the Wattle Street interchange surface works is shown in **Figure 12-3**.

Discussion on the opportunities for future land use and transport integration including opportunities to support the realisation of the *Parramatta Road Corridor Urban Transformation Strategy* is provided in **section 12.3.4**.

Figure 12-2 Wattle Street interchange surface works - existing land use zoning

Figure 12-3 Wattle Street interchange surface works – strategic planning context

Parramatta Road West civil and tunnel site (C1b) and the Parramatta Road East civil site (C3b)

Land use

The Parramatta Road West civil and tunnel site (C1b) and the Parramatta Road East civil site (C3b) would be located on the western and eastern sides of Parramatta Road between around Alt Street and Bland Street at Ashfield and Haberfield. The site is primarily comprised of a car dealership that encompasses land on both sides of Parramatta Road, with several smaller commercial premises on the western side of Parramatta Road near Bland Street.

The area around the Parramatta Road West civil and tunnel site (C1b) and the Parramatta Road East civil site (C3b) consists of predominantly residential land uses, comprising attached and detached dwellings and some residential apartments. A mixture of commercial and light industrial land uses front onto Parramatta Road north of the sites. South of Bland Street, a construction site is present on the western side of Parramatta Road being used to construct the Parramatta Road portals as part of the M4 East project.

Haberfield Public School is located on Bland Street about 100 metres east of the intersection of Parramatta Road and Bland Street. The Yasmar Juvenile Justice training facility is east of Parramatta Road south of Bland Street and the Guardian Early Learning Centre is located further south on the corner of Parramatta Road and Chandos Street. There is a small group of commercial and retail properties on Ramsay Street, at the intersection with Alt Street, including a restaurant. Bunnings Warehouse is located on the corner of Parramatta Road and Frederick Street to the north. The Infants Home (child care centre) is located on Henry Street behind the Bunnings Warehouse. A place of worship is located near the intersection of Wattle Street and Parramatta Road to the north. There is also a place of worship around 300 metres west of Parramatta Road along Alt Street.

Planning controls

The Ashfield LEP 2013 defines the land use zoning surrounding the Parramatta Road West civil and tunnel site (C1b) and the Parramatta Road East civil site (C3b) as a mix of the following zones: B6 Enterprise Corridor, SP2 Infrastructure and R3 Medium Density Residential. The Parramatta Road West civil and tunnel site (C1b) and the Parramatta Road East civil site (C3b) would be on land zoned B6 Enterprise Corridor. The objectives of this zone include to promote businesses along main roads and to provide a range of employment uses. Land use zoning surrounding the Parramatta Road West civil and tunnel site (C1b) and the Parramatta Road East civil site (C3b) is shown in **Figure 12-5**.

Strategic planning context

Future development is proposed in the vicinity of the site in accordance with the *Parramatta Road Corridor Urban Transformation Strategy* (UrbanGrowth NSW 2016) including maintaining an employment focus along main roads, encouraging appropriately scaled residential development and providing increased connectivity for pedestrians and cyclists. The strategic planning context in the vicinity of the Parramatta Road West civil and tunnel site (C1b) and the Parramatta Road East civil site (C3b) are shown in **Figure 12-4**.

Discussion on the opportunities for future land use and transport integration, including opportunities to support the realisation of the *Parramatta Road Corridor Urban Transformation Strategy*, is provided in **section 12.3.4**.

Figure 12-4 Parramatta Road West civil and tunnel site (C1b) and the Parramatta Road East civil site (C3b) - existing land use zoning

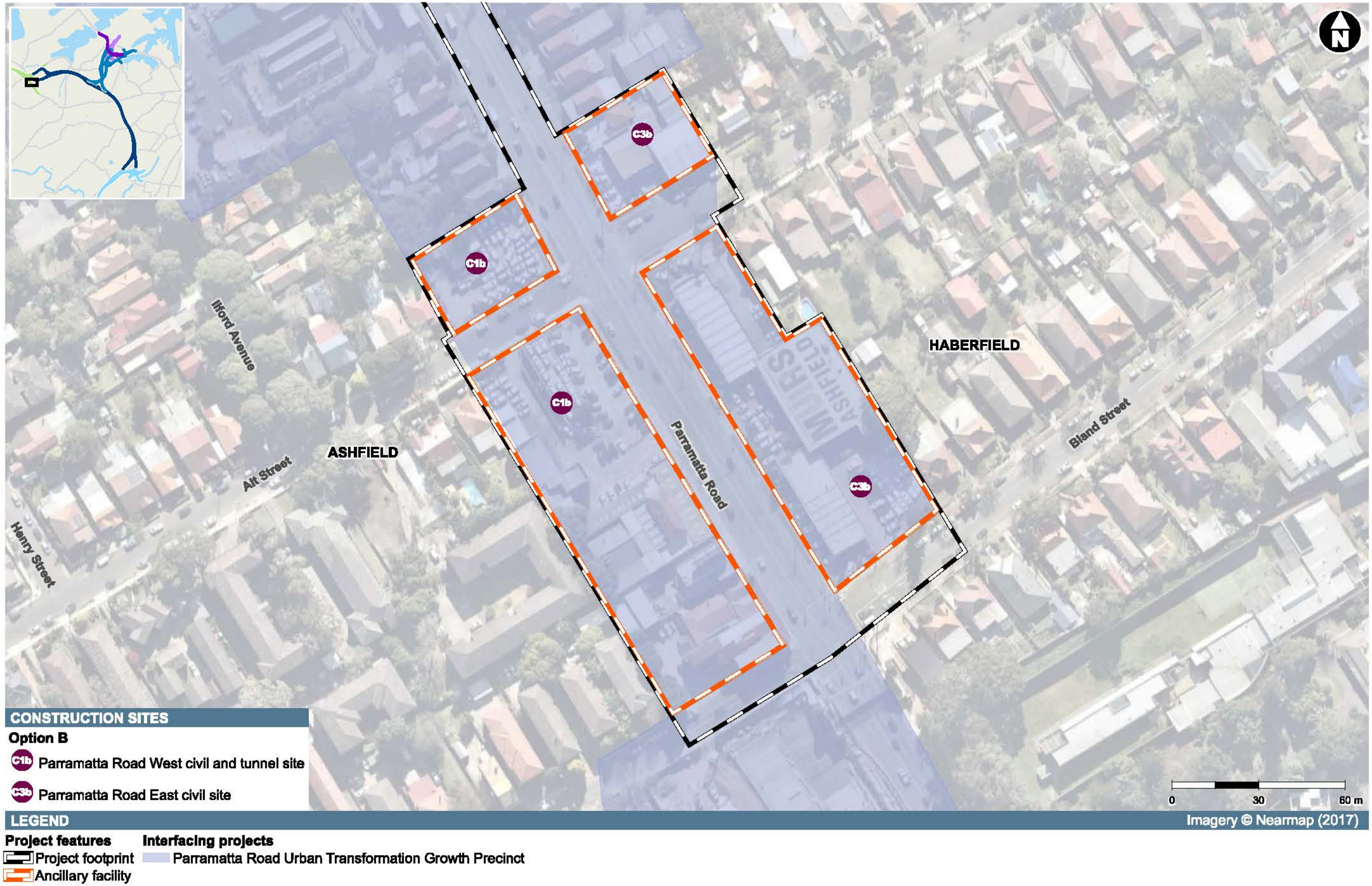


Figure 12-5 Parramatta Road West civil and tunnel site (C1b) and the Parramatta Road East civil site (C3b) – strategic planning context

Darley Road surface works

Land use

The Darley Road surface works would include use of the Darley Road civil and tunnel site (C4) and minor modifications to the surrounding road network to facilitate access during construction and the Darley Road motorway operations complex (MOC1) during operation. The site is currently occupied by a commercial premise on land that is being leased from Transport for NSW. The majority of the works would be carried out on the land currently subject to the commercial premise, next to Leichhardt North light rail stop, between City West Link and Darley Road at Leichhardt.

Land use in the vicinity of the site includes road and light rail infrastructure and residential, recreational areas and local centres. Additional infrastructure related land uses in the vicinity of the Darley Road surface works include the light rail corridor immediately adjacent to the north, City West Link further to the north, the Hawthorne Canal to the west, a stormwater management basin between City West Link and Blackmore Park; and a transport depot near the corner of Balmain Road and City West Link. Other land uses in the vicinity of the site include the 'Canal Road Arts Precinct' (including the Canal Road Film Centre and other creative arts uses) west of the tunnel site, north of City West Link and to the west of Darley Road and medium density residential uses to the south of Darley Road and north of City West Link.

Planning controls

The Leichhardt LEP 2013 defines the land use zoning surrounding the Darley Road surface works as a mix of the following zones: SP2 Infrastructure, B2 Local Centre, R1 General Residential and RE1 Public Recreation.

The Darley Road civil and tunnel site (C4) and the Darley Road motorway operations complex (MOC1) would be located on land zoned B2 Local Centre. The objective of the zone is to provide a range of retail, business, entertainment and community uses that serve the needs of people who live in, work in and visit the local area. Changes to the surface road network during construction would be carried out on land zoned SP2 Infrastructure. The objective of the zone is to provide for transport infrastructure and related uses.

Land use zones in the vicinity of the Darley Road surface works are shown in **Figure 12-6**.

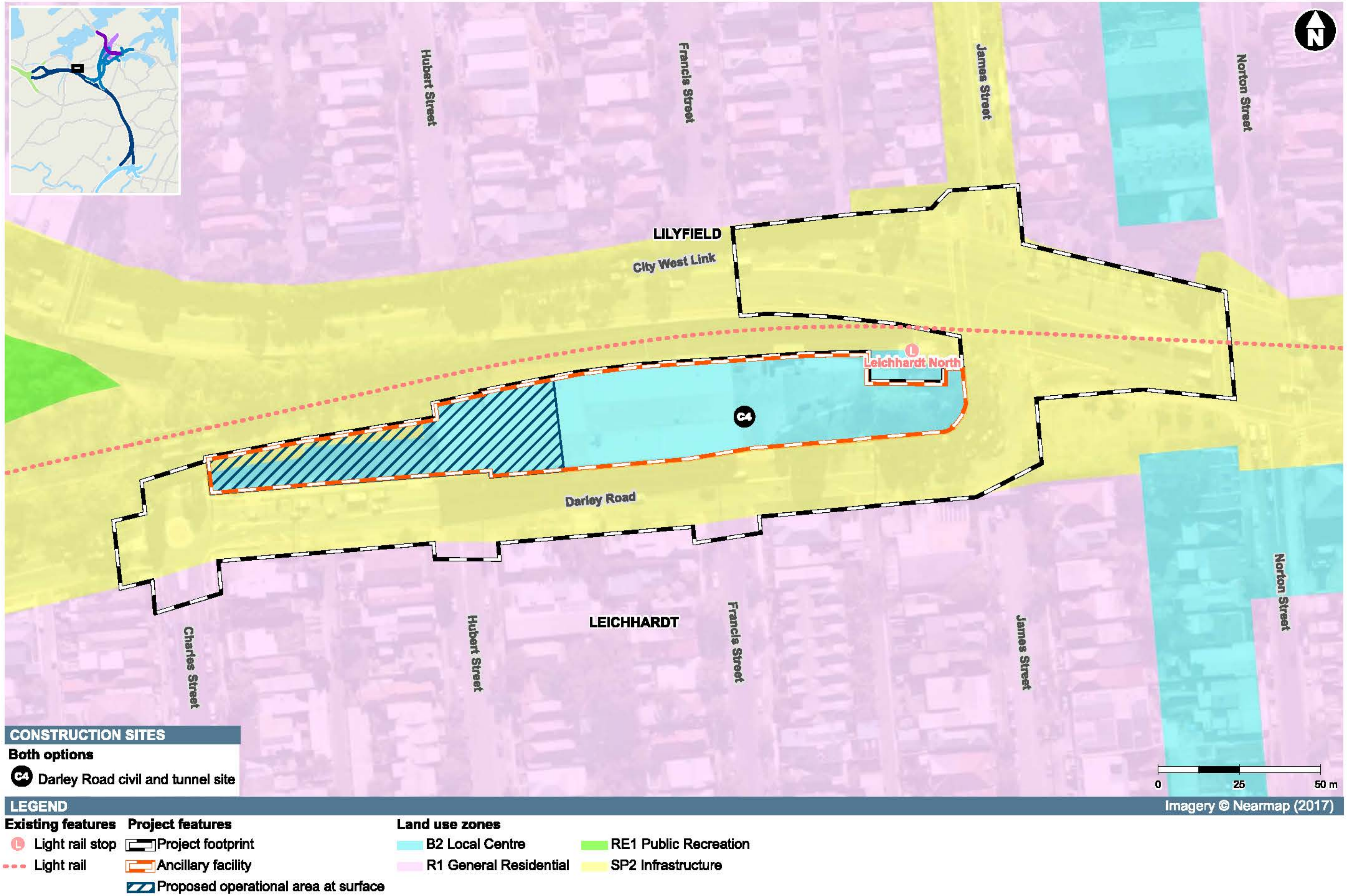


Figure 12-6 Darley Road surface works - existing land use zoning

Rozelle surface works

Land use

The Rozelle surface works would include use of the Rozelle civil and tunnel site (C5), The Crescent civil site (C6) and the Victoria Road civil site (C7) during construction including modifications to the surrounding road network. Permanent operational infrastructure would include new and upgraded transport infrastructure comprising the Rozelle interchange and surface road works, the Rozelle West and Rozelle East motorway operations complexes (MOC2 and MOC3) (including the Rozelle ventilation supply and exhaust facilities), drainage infrastructure, active transport links and new open space. The majority of the Rozelle surface works would be centred on the Rozelle Rail Yards and arterial roads to the south and east. Land use within the Rozelle Rail Yards primarily comprises redundant industrial and transport infrastructure that are being removed as part of the separate site management works project. The central business district (CBD) and South East Light Rail Rozelle maintenance depot is located at the western end of the Rozelle Rail Yards.

Roads and Maritime is carrying out site management works on part of the Rozelle Rail Yards site. The works are needed to manage the existing environmental and safety issues at the site and would also improve access to surface conditions, which would allow for further investigation into the location of utilities and the presence of contamination and waste. Works include removal of vegetation, demolition of buildings, site establishment, utility investigations, and removal of waste and rail infrastructure and site stabilisation. The site management works were subject to a separate environmental assessment. The works were assessed in an REF which was approved by Roads and Maritime under Part 5 of the EP&A Act in April 2017.

The local area is dominated by residential and industrial land uses with associated open spaces, recreational areas, public services and facilities, commercial areas and transport infrastructure. The industrial history of the area is also apparent in some of the maritime-related land use around Rozelle Bay and White Bay, as well as redundant industrial and transport infrastructure within White Bay Power Station.

Key transport infrastructure in proximity to the surface works includes City West Link and the Inner West Light Rail line Corridor to the north, Victoria Road and Anzac Bridge to the east and The Crescent to the south. There are a number of commercial and light industrial developments located on Lilyfield Road and Gordon Street to the north of Rozelle Rail Yards and also on Victoria Road to the east.

Public recreation areas and infrastructure in the vicinity of the Rozelle surface works include:

- Buruwan Park, south of Whites Creek between The Crescent and Bayview Crescent/Railway Parade at Annandale
- Easton Park on Denison Road to the north of the Rozelle interchange
- Whites Creek Valley Park and Cohen Park, which are south of the Rozelle interchange, adjacent to Whites Creek
- Bicentennial Park and Federal Park (about 280 metres and 430 metres south of the Rozelle interchange respectively)
- Several local centres are also close to the Rozelle interchange, particularly along Lilyfield Road and Catherine Street, which are north and south of the Rozelle Rail Yards respectively
- The White Bay Power Station, which is immediately east of Victoria Road
- Several waterways and water bodies are close to the Rozelle interchange, including Rozelle Bay and Whites Creek, which are about 65 metres to the southeast of City West Link, and the Easton Park stormwater canal which runs north–south through the Rozelle Rail Yards.

Planning controls

The SREP 26 and the Leichhardt LEP 2013 define the land use zoning surrounding the Rozelle surface works as a mix of the following zones: Port & Employment and Waterfront Use under the SREP 26, and B2 Local Centre, B7 Business Park, IN2 Light Industrial, R1 General Residential, RE1 Public Recreation and SP2 Infrastructure under the Leichhardt LEP 2013.

The majority of the Rozelle surface works would be located on land zoned Port & Employment under the SREP 26 and land zoned SP2 Infrastructure under the Leichhardt LEP 2013. There are a range of objectives for these zones including providing for ongoing rail, port, road and other related activities.

The Crescent civil site (C6) and works within the project footprint south of City West Link and along James Craig Road would occur on land zoned Waterfront Use under the SREP 26. The objectives of this zone include to provide for development and use of water-based commercial and recreational activities and to provide public access within and across the zone. The Victoria Road civil site (C7) is located on land zoned B2 Local Centre under the Leichhardt LEP 2013. The objective of this zone is to provide a range of retail, business, entertainment and community uses that serve the needs of people who live in, work in and visit the local area.

Works would be carried out within the Interim Metro Corridor (as protected under State Environmental Planning Policy (Infrastructure) 2007 for the CBD Metro. The CBD Metro project was approved in 2010 but did not proceed. Works for the M4-M5 Link project would be carried out in the following areas that are within the Interim Metro Corridor:

- Zone A – Above ground including cut and cover tunnel, including stabling and maintenance depot (at the Rozelle Rail Yards)
- Zone B – Tunnel (generally beneath Victoria Road and towards Anzac Bridge)
- CBD Station Extent (Rozelle and White Bay stations).

Development planned within the Interim Metro Corridor triggers a number of notification and consent requirements, including the requirement to obtain concurrence with Sydney Metro (the relevant rail authority) before development consent can be granted for the project. The project design has given consideration to the future provision of tunnels and stations at Rozelle and White Bay.

Land use zones in the vicinity of the Rozelle surface works are shown in **Figure 12-7**.

Strategic planning context

The land uses and zoning provisions within and in the vicinity of the Rozelle Rail Yards are anticipated to undergo substantial transformation over the coming decades under a number of infrastructure and urban renewal projects, including the future development of The Bays Precinct in consideration of *The Transformation Plan: The Bays Precinct* (UrbanGrowth NSW 2015b) (The Bays Precinct Transformation Plan). The strategic planning context in the vicinity of the Rozelle surface works is shown in **Figure 12-8**.

Discussion on the opportunities for future land use and transport integration including opportunities to support the realisation of The Bays Precinct Transformation Plan is provided in **section 12.3.4**. These potential changes are also discussed in **Chapter 3** (Strategic context and project need).

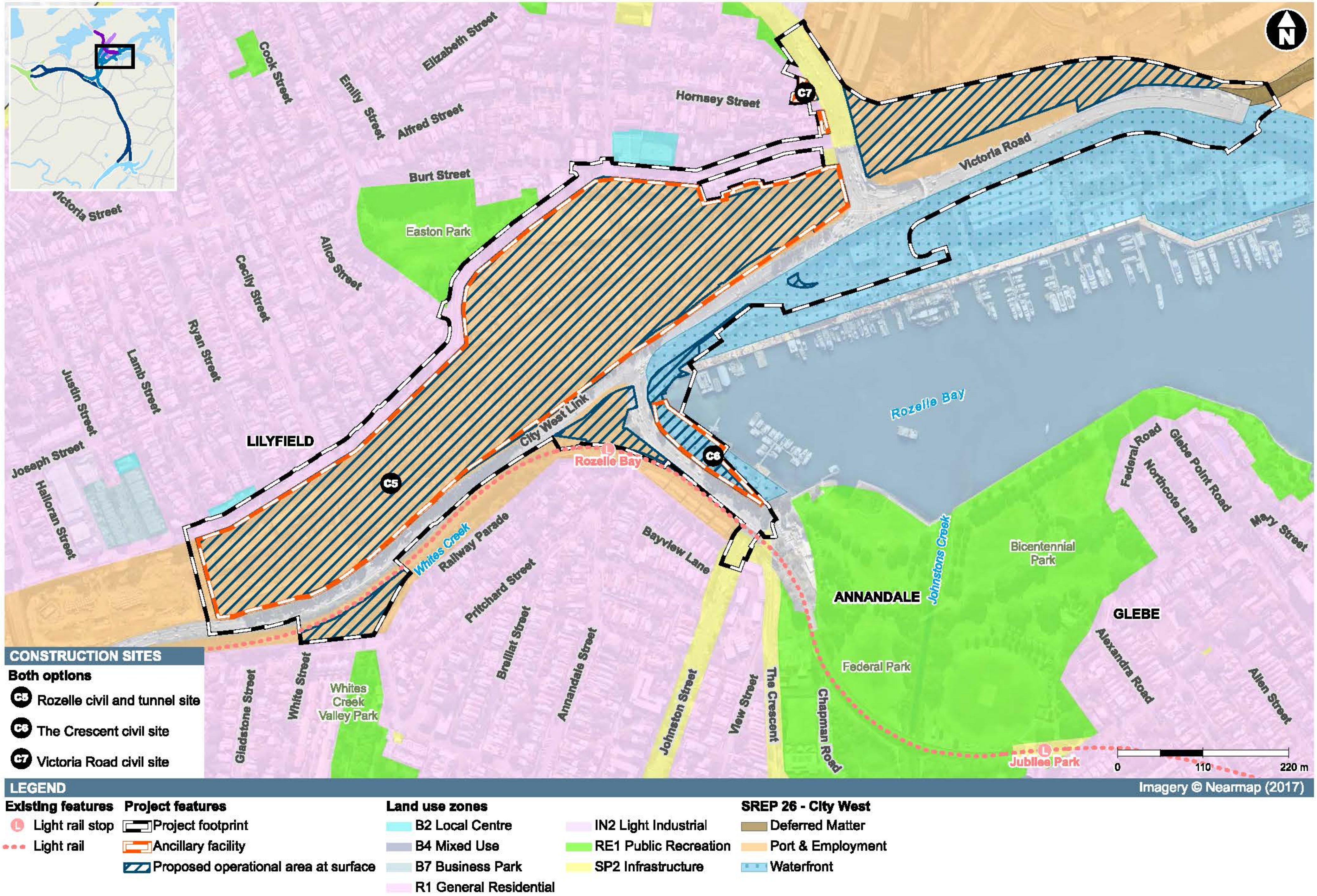
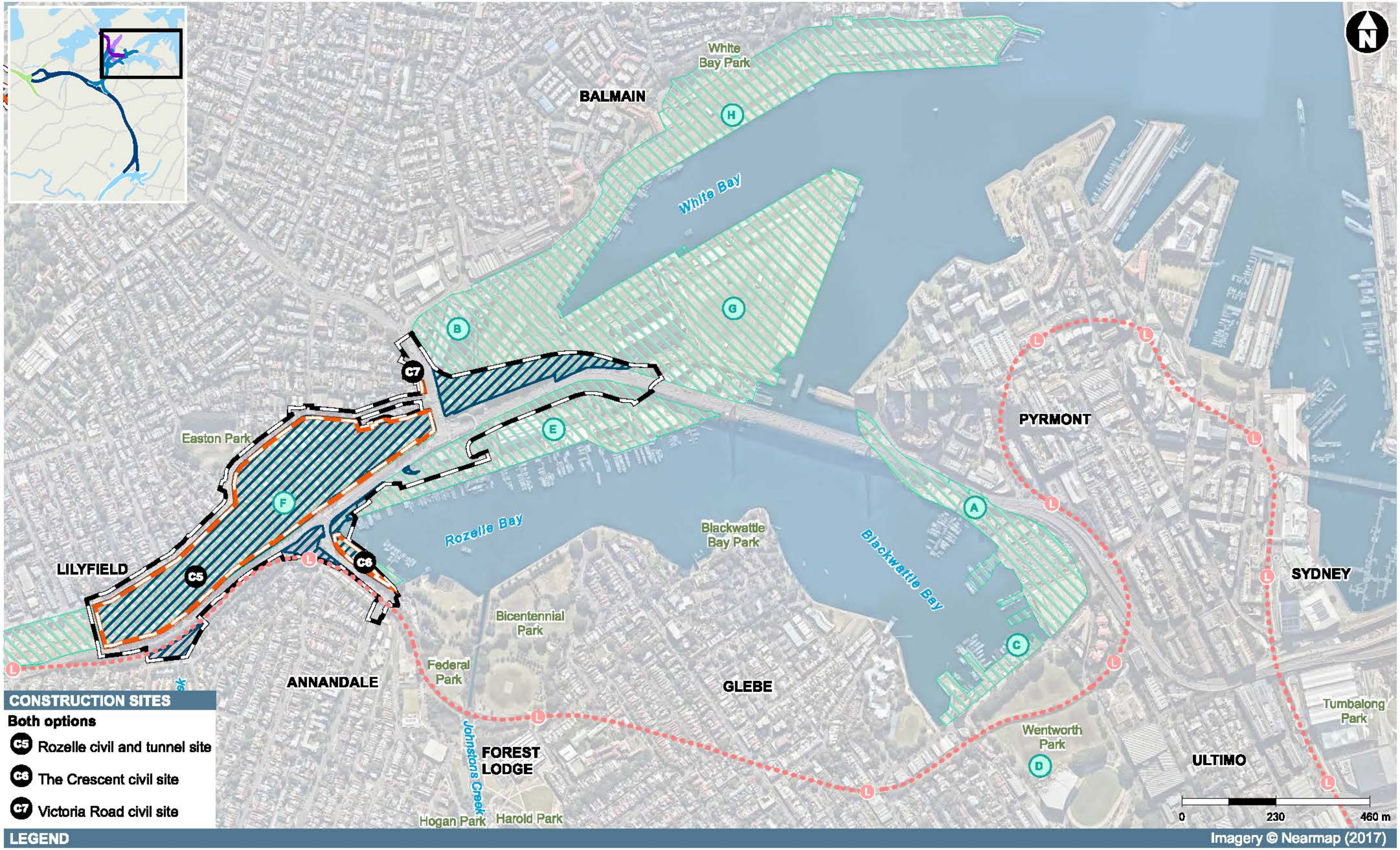


Figure 12-7 Rozelle surface works - existing land use zoning



Existing features
- Light rail
- Light rail stop

Project features
- Project footprint
- Ancillary facility
- Proposed operational area at surface

Interfacing projects
- The Bays Precinct Transformation Plan

The Bays Precinct Destinations
- A Bays Waterfront Promenade
- B White Bay Power Station
- C Bays Market District
- D Wentworth Park
- E Rozelle Bay and Bays Waterways
- F Rozelle Rail Yards
- G Glebe Island
- H White Bay

Figure 12-8 Rozelle surface works – strategic planning context

Iron Cove Link surface works

Land use

The Iron Cove Link surface works would be located along Victoria Road near the eastern abutment of Iron Cove Bridge and within King George Park, adjacent to Manning Street at Rozelle and would include use of the Iron Cove Link civil site (C8) during construction and new and upgraded transport infrastructure, permanent operational infrastructure including the Iron Cove Link motorway operations complex (MOC4) (including the Iron Cove Link ventilation facility), landscaping, and a bioretention facility and improved car parking facilities during operation.

Land use north and south of Victoria Road consists of residential dwellings of varying densities; comprising primarily apartment buildings to the north and detached dwellings to the south. There are also commercial land uses to the south (eg car dealership, liquor store and retail stores) and north (eg car dealership, petrol station and mechanic). Land use south and east includes local centres and infrastructure concentrated around the intersection of Victoria Road with Darling Street and Balmain Road. Land zoned as infrastructure in this area is used for the purposes of education (including the Rozelle Public School), community facilities and a place of worship. There is an additional area zoned SP2 Infrastructure – Electricity Supply located south of Victoria Road associated with the electricity substation on Manning Street.

There is an area of light industrial use located north of Victoria Road, roughly bound by Terry Street and Wellington Street. In addition to existing industrial and commercial uses, medium-density and mixed-use redevelopment in this area is occurring. Areas of public recreation and open space are located on the southern bank of Iron Cove, including King George Park south of Iron Cove Bridge, and Bridgewater Park north of Iron Cove Bridge. North of Victoria Road, Rozelle Public School and St Thomas Child Care Centre are located on Darling Street and the Balmain Cove Early Learning Centre is located on Terry Street.

Planning controls

The Leichhardt LEP 2013 defines the land use zoning surrounding the Iron Cove Link surface works as a mix of the following zones: SP2 Infrastructure, B2 Local Centre, IN2 Light Industrial, R1 General Residential, RE1 Public Recreation and SP2 Electricity Supply.

The majority of the Iron Cove Link surface works would be on land zoned as SP2 Infrastructure, R1 Residential and B2 Local Centre under the Leichhardt LEP 2013. The objective of these zones is to provide for transport infrastructure and related uses, the housing needs of the community and to provide a range of retail, business, entertainment and community uses that serve the needs of people who live in, work in and visit the local area, respectively.

Works would be carried out on a section of King George Park adjacent to the westbound carriageway of Victoria Road zoned RE1 Public Recreation under the Leichhardt LEP 2013. The objective of this zone is to provide a range of recreational settings and activities and compatible land uses. The works area for the bioretention facility and car park improvement works is partly zoned R1 General Residential and partly zoned RE1 Public Recreation under the Leichhardt LEP 2013. The objective of these zones is to provide for the housing needs of the community and enable land to be used for public open space or recreational purposes respectively.

Land use zones surrounding the Iron Cove Link surface works at Rozelle are shown in **Figure 12-9**.

Strategic planning context

Land at the Balmain Leagues Club Precinct on Victoria Road between Moodie Street and Darling Street at Rozelle is zoned as a Deferred Matter under the Leichhardt LEP 2013, which means that the Leichhardt Local Environmental Plan 2000 continues to apply. Under the Leichhardt Local Environmental Plan 2000, the land is zoned Business, with additional provisions included for mixed use development. The project would not preclude potential future development of this site from occurring.

CONSTRUCTION SITES

Both options

C8 Iron Cove Link civil site

LEGEND

Imagery © Nearmap (2017)

Project features

- Project footprint
- Ancillary facility
- Proposed operational area at surface

Land use zones

- B1 Neighbourhood Centre
- B2 Local Centre
- R1 General Residential
- IN2 Light Industrial
- RE1 Public Recreation
- SP2 Infrastructure
- DM Deferred Matter
- CP Callan Park (Special Provisions) Act 2002 No 139

Figure 12-9 Iron Cove Link surface works - existing land use zoning

Pyrmont Bridge Road tunnel site (C9)

Land use

The Pyrmont Bridge Road tunnel site (C9) would be located near the intersection of Pyrmont Bridge Road and Parramatta Road, around Gordon Street and Mallett Street. The site is comprised of commercial and light industrial land uses including a storage warehouse, fitness facility, mechanic and retail stores.

Land uses in the surrounding area include a mix of light industrial, local centre, mixed use and special purpose infrastructure (educational) land uses fronting on to Parramatta Road, which predominantly consists of commercial properties and apartment buildings. A small number of terrace houses are immediately adjacent to the east of the site, fronting Pyrmont Bridge Road. A number of mixed density residential dwellings are located to the east on the northern and southern sides of Pyrmont Bridge Road.

The area north of Parramatta Road consists of light industrial land uses in the immediate vicinity of the Pyrmont Bridge Road tunnel site (C9) and extending to the north and northwest. There is an area of mixed use (primarily commercial properties and medium density residential dwellings) located immediately to the east along Parramatta Road and an area of public recreation along Johnstons Creek to the west. There are general residential areas located around 100 metres and 150 metres to the northeast and northwest respectively.

Commercial and residential properties are located on the southern side of Parramatta Road as well as an educational establishment directly south of the Pyrmont Bridge Road tunnel site (C9) (Bridge Road School). Camperdown Park and O'Dea Reserve are located around 100 metres and 300 metres to the south of Parramatta Road respectively. Other land uses south of Parramatta Road are primarily residential and light industrial.

The Royal Prince Alfred Hospital (RPA) and the University of Sydney are located around 700 metres southeast on Missenden Road and Parramatta Road respectively. Land use zoning surrounding the Pyrmont Bridge Road tunnel site is shown in **Figure 12-10**.

Planning controls

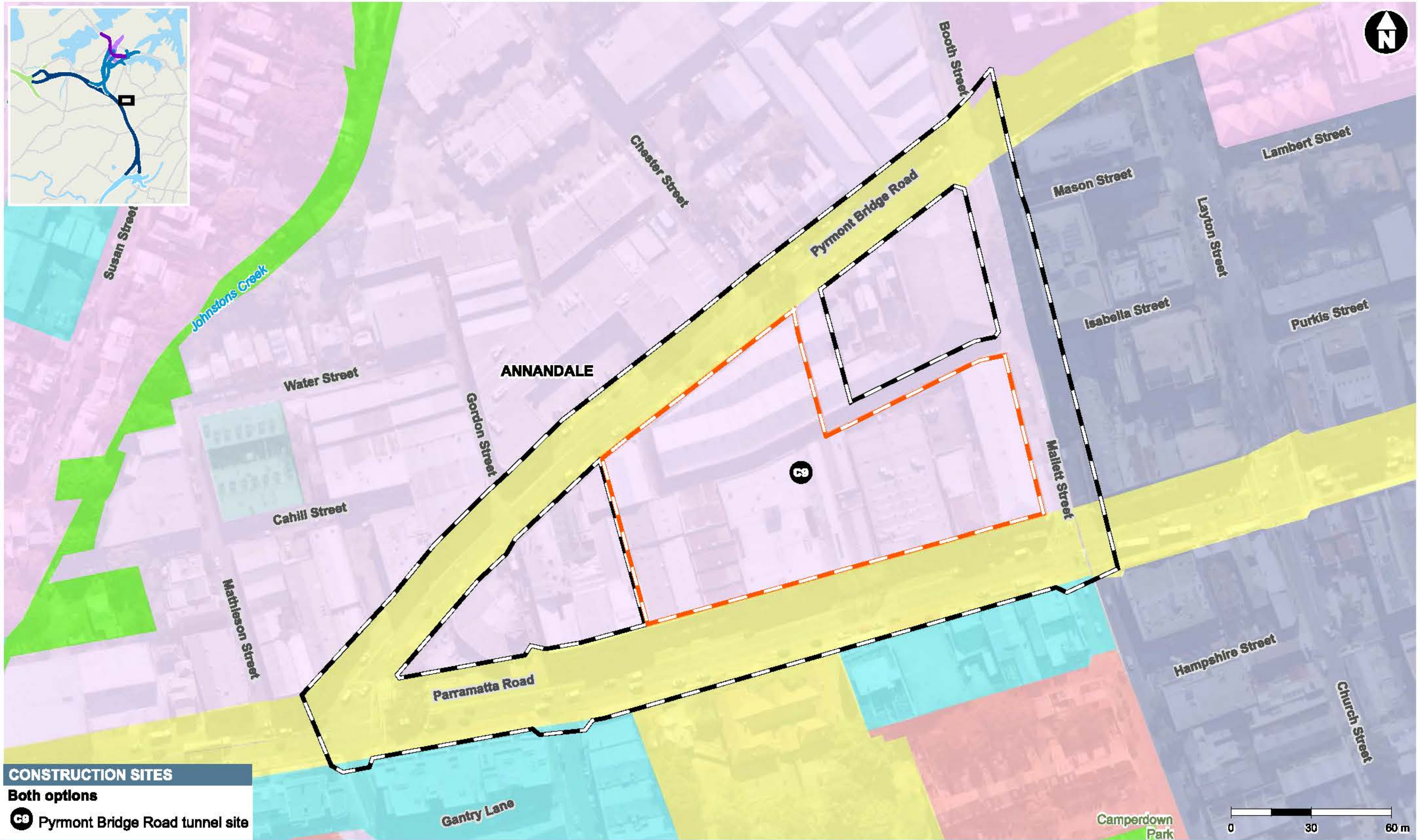
The Leichhardt LEP 2013, the Sydney LEP 2012 and the Marrickville LEP 2011 define the land use zoning surrounding the Pyrmont Bridge Road tunnel site (C9). These comprise:

- Leichhardt LEP 2013: IN2 Light Industrial, SP2 Infrastructure, B7 Business Park and RE1 Public Recreation
- Sydney LEP 2012: B4 Mixed Use, SP2 Infrastructure, R1 General Residential, SP2 Educational Establishment and RE1 Public Recreation
- Marrickville LEP 2011: SP2 Infrastructure, B2 Local Centre, SP2 Educational Establishment, R1 General Residential, R2 Low Density Residential, R4 High Density Residential and B4 Mixed Use.

The Pyrmont Bridge Road tunnel site (C9) is located on land zoned IN2 Light Industrial under the Leichhardt LEP 2013. The objectives of this zone are to provide a wide range of light industrial, warehouse and related land uses.

Strategic planning context

Future development is proposed in the vicinity of the site to be consistent with the *Parramatta Road Corridor Urban Transformation Strategy* including upgrades to pedestrian and cyclist infrastructure along Pyrmont Bridge Road and urban revitalisation along Parramatta Road and Mallett Street. The strategic planning context in the vicinity of the Pyrmont Bridge Road tunnel site is shown in **Figure 12-11**.



CONSTRUCTION SITES

Both options

C9 Pyrmont Bridge Road tunnel site

LEGEND

Imagery © Nearmap (2017)

Project features

Project footprint

Ancillary facility

Land use zones

B4 Mixed Use

B7 Business Park

R1 General Residential

R2 Low Density Residential

B2 Local Centre

IN2 Light Industrial

RE1 Public Recreation

SP2 Infrastructure

Figure 12-10 Pyrmont Bridge Road tunnel site (C9) at Annandale - existing land use zoning

LEGEND

Imagery © Nearmap (2017)

Project features
- Project footprint
- Ancillary facility

Interfacing projects
- Parramatta Road Urban Transformation Growth Precinct

Figure 12-11 Pyrmont Bridge Road tunnel site (C9) – strategic planning context

St Peters interchange surface works

Land use

Integration works to connect the M4–M5 Link with the St Peters interchange would be carried out within the approved New M5 project footprint and would include the Campbell Road civil and tunnel site (C10) during construction, and new transport infrastructure and permanent operational infrastructure, including the Campbell Road motorway operations complex (MOC5) (including the Campbell Road ventilation facility). The existing land use around the St Peters interchange surface works is undergoing change due to the construction of the New M5 project. This is as a result of property acquisition and construction of permanent operational infrastructure including the St Peters interchange and upgrades and modifications to the local road network.

Existing land uses in the immediate vicinity of the St Peters interchange include a commercial enterprise corridor along the Princes Highway, general industrial lands, local and arterial roads, Sydney Park to the north and Alexandra Canal to the east. Surrounding land uses include the residential neighbourhoods of Newtown, Sydenham and St Peters, as well as general residential and industrial areas of Alexandria to the east. There are general residential land uses (primarily apartment buildings) on the north side of Campbell Road adjacent to the east of the works area north of Barwon Park Road.

St Peters Public School and the St Peters Church of England are located around 150 metres to the west of the St Peters interchange. Nearby public recreation areas include Sydney Park north of the St Peters interchange, Simpson Park north of Campbell Street, May Street Reserve on the corner of May Street/Unwins Bridge Road/Campbell Street and Camdenville Park north of Bedwin Road and west of May Street. A commercial enterprise corridor is present along the Princes Highway, immediately west of the St Peters interchange. Other significant areas of commercial activity include those around the Bourke Road/Bourke Street/Gardeners Road intersection, and areas associated with the Sydney Airport.

Land use surrounding the St Peters interchange surface works is shown in **Figure 12-12**.

Planning controls

The Marrickville LEP 2011 and the Sydney LEP 2012 define the land use zoning surrounding the Campbell Road civil and tunnel site (C10) as a mix of the following zones:

- Marrickville LEP 2011: IN1 General Industrial, IN2 Light Industrial, SP2 Infrastructure, R2 Low Density Residential and R1 General Residential
- Sydney LEP 2012: RE1 Public Recreation, R1 General Residential, SP2 Infrastructure and IN1 General Industrial.

The St Peters interchange surface works would be primarily carried out on land zoned IN1 General Industrial, IN2 Light Industrial and SP2 Infrastructure under the Marrickville LEP 2011. The objectives of these zones are to provide for a range of industrial and warehouse land uses, and to provide for infrastructure and related uses. A portion of the works would be carried out on land zoned SP2 Infrastructure under the Sydney LEP 2012. The objective of this zone is to provide for infrastructure and related uses.

Strategic planning context

A range of future developments are proposed for the area surrounding the St Peters interchange surface works including surface operational infrastructure for the New M5 to the west, south and east, and construction ancillary facilities for the Sydney Metro project to the northwest (at Marrickville/Sydenham). Development is also occurring around Mascot and Green Square, south of the Alexandra Canal. These developments include the conversion of previously industrial and commercial land uses to new areas of high and medium density mixed-use development (incorporating areas of residential and commercial development). These developments are changing the way people move, live and work in these areas, and will also influence potential future development and land use behaviours in neighbouring areas such as St Peters.

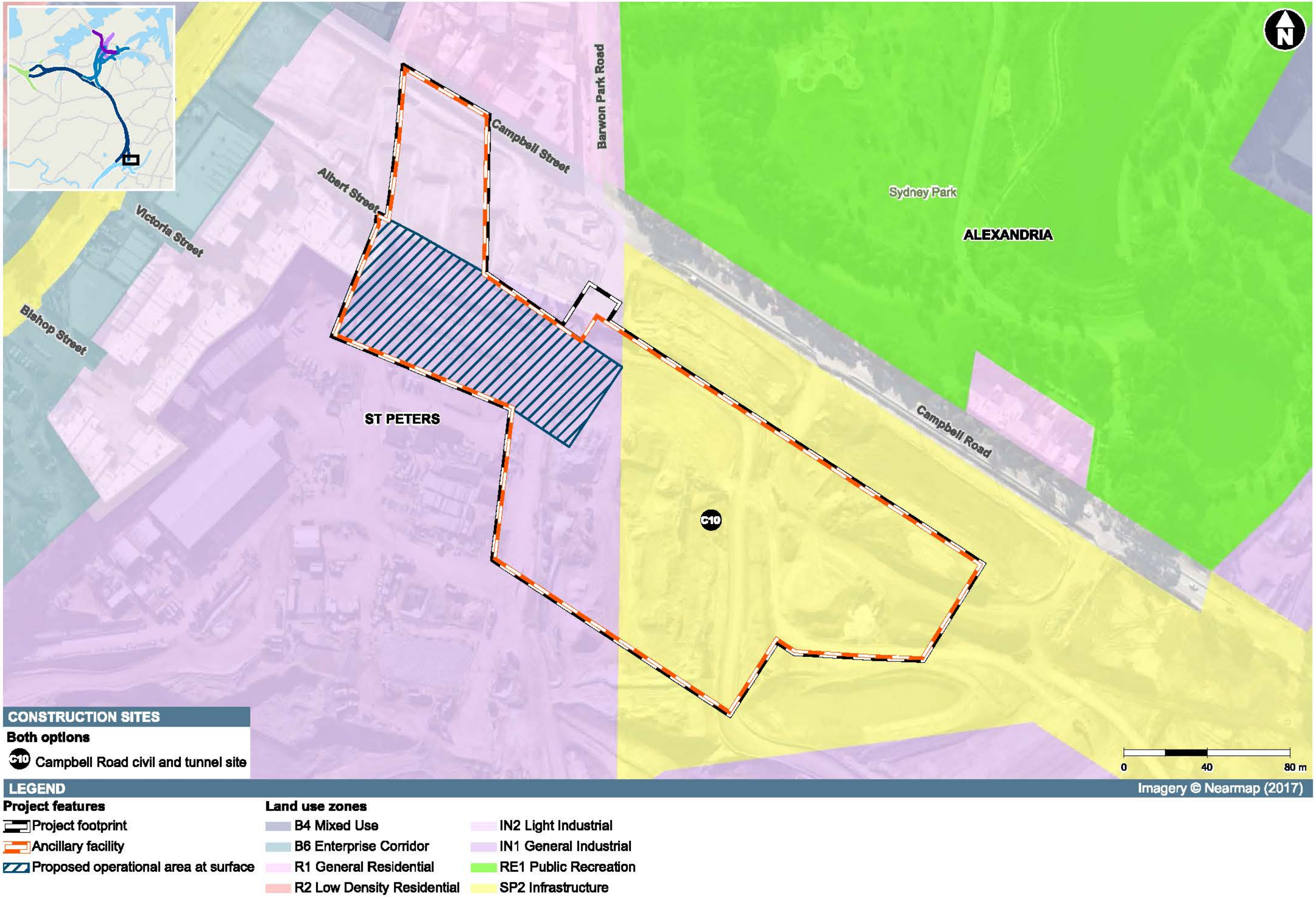


Figure 12-12 St Peters interchange surface works - existing land use zoning

12.3 Potential impacts - property

During construction, the main land use and property impacts would relate to property acquisitions, and demolition of acquired properties, as well as properties that are owned by the NSW Government that are being used for construction and/or operation of the project. Construction stage land use impacts would largely relate to amenity issues (ie visual, noise, air quality, traffic and social and economic impacts) which have been addressed in other chapters of this EIS.

The project has been designed and developed to minimise the need for surface property acquisition and occupation. The need to reduce these impacts has been balanced with maximising opportunities for beneficial re-use of the areas required for construction that would be remaining project land to the operational needs of the project. Notwithstanding this design intent, construction and operation of the project would result in temporary and permanent impacts on property.

Where land required for the construction and/or operation of the project is not currently owned by the NSW Government, discussions are being held with the affected landowners concerning the purchase, lease or licence of the land. As of August 2017, the project would require 51 total surface property acquisitions. These property acquisitions are summarised in **Table 12-2**. Roads and Maritime would also be required to manage a number of leases on land subject to acquisition.

Table 12-2 Property acquisition requirement for the project

Location	Land use (type)	No. of total surface acquisitions[1]
Wattle Street interchange surface works	Acquisitions were carried out at this location as part of the M4 East project	None[2]
Parramatta Road West site (Ashfield)	Mixed use	1
Darley Road surface works	Commercial	1
Rozelle surface works	Commercial/industrial	4
Iron Cove Link surface works	Residential	26
	Commercial/industrial	10
Pyrmont Bridge Road tunnel site	Commercial/industrial	9
St Peters interchange surface works	Acquisitions were carried out at this location as part of the New M5 project	None[3]

Notes:

[1] Multiple strata titles may exist within each parent lot to be acquired

[2] Refer to the M4 East EIS (September 2015) for acquisitions that occurred at this location

[3] Refer to the New M5 EIS (November 2015) for acquisitions that occurred at this location

All compulsory acquisition required for the project would be undertaken in accordance with the *Land Acquisition (Just Terms Compensation) Act 1991* (NSW), the *Land Acquisition Information Guide* (NSW Government 2014) and the land acquisition reforms announced by the NSW Government in 2016 (NSW Government 2016), which can be viewed online at:

https://www.finance.nsw.gov.au/sites/default/files/NSW_Government_Response.pdf

Relocation and some other categories of expenses could be claimable under this Act and related policies.

The project would also use government owned land, including land already owned by Roads and Maritime. Where this land is not already in Roads and Maritime ownership and is required for permanent use, Roads and Maritime would enter into agreements with the relevant government departments – including acquisition or lease arrangements. Where government owned land not owned by Roads and Maritime is required temporarily, this would generally be established through a lease or a Memorandum of Understanding.

In addition to the properties affected by surface activities, land (or interests in land, such as easements) below the surface of the ground would be acquired. This is called subsurface (or substratum) acquisition and is discussed separately in **section 12.3.3**.

Disturbed areas adjacent to operational infrastructure would be landscaped. In addition, concept plans have been prepared for the substantial areas of landscaping around the Rozelle Rail Yards and around Victoria Road at Rozelle (near the eastern abutment of Iron Cove Bridge). These are presented in **Appendix L** (Technical working paper: Urban design) and **Chapter 13** (Urban design and visual amenity) and establish the framework from which detailed landscape plans would be prepared as part of the Urban Design and Landscape Plan (UDLP) for the project.

The UDLP would be the primary mechanism for identifying and describing the public open space uses (including active and passive recreation), community and social infrastructure and or other development that would be delivered as part of the project. Further information about where urban design and landscaping would be carried out as part of the project is provided in **Chapter 5** (Project description) and **Chapter 13** (Urban design and visual amenity).

A flowchart showing the process for identifying the future use of land not required for operational infrastructure is included in **Figure 12-13**. An indicative summary of where urban design and landscaping would be carried out as part of the project is presented in **Table 12-3**.

12.3.1 Remaining project land

Subject to future detailed design and the requirements of the project, parts of the project footprint not required for operational infrastructure and/or landscaping may be contemplated for separate future redevelopment. In some instances, areas of land may also be retained by Roads and Maritime for future (separate) road infrastructure projects. Where this is the case, the land would be rehabilitated and stabilised in preparation for the potential future use. This land is identified as remaining project land.

Remaining project land would be subject to the provisions of a Residual Land Management Plan that would be prepared in consultation with the relevant council and would identify (and consider), but not be limited to:

- Identification and illustration of all remaining project land, including the location, land use characteristics, size and adjacent land uses
- Identification of feasible uses for remaining project land including justification for the selected use
- Timeframes for implementation of the actions in relation to the identified feasible uses.

Future development would be subject to separate development assessment and approval. The project would not rezone or consolidate remaining project land and therefore there would be no changes to land use zoning for future development.

In addition, remaining project land around the Wattle Street interchange at Haberfield and the St Peters interchange at St Peters would be managed to be consistent with the M4 East and New M5 projects' respective Residual Land Management Plans and UDLPs, including the M4 East Legacy Project (as required by the conditions of approval for the M4 East and New M5 projects). The project would not impact on the implementation of these plans, but may impact the timing in which in the plans are carried out.

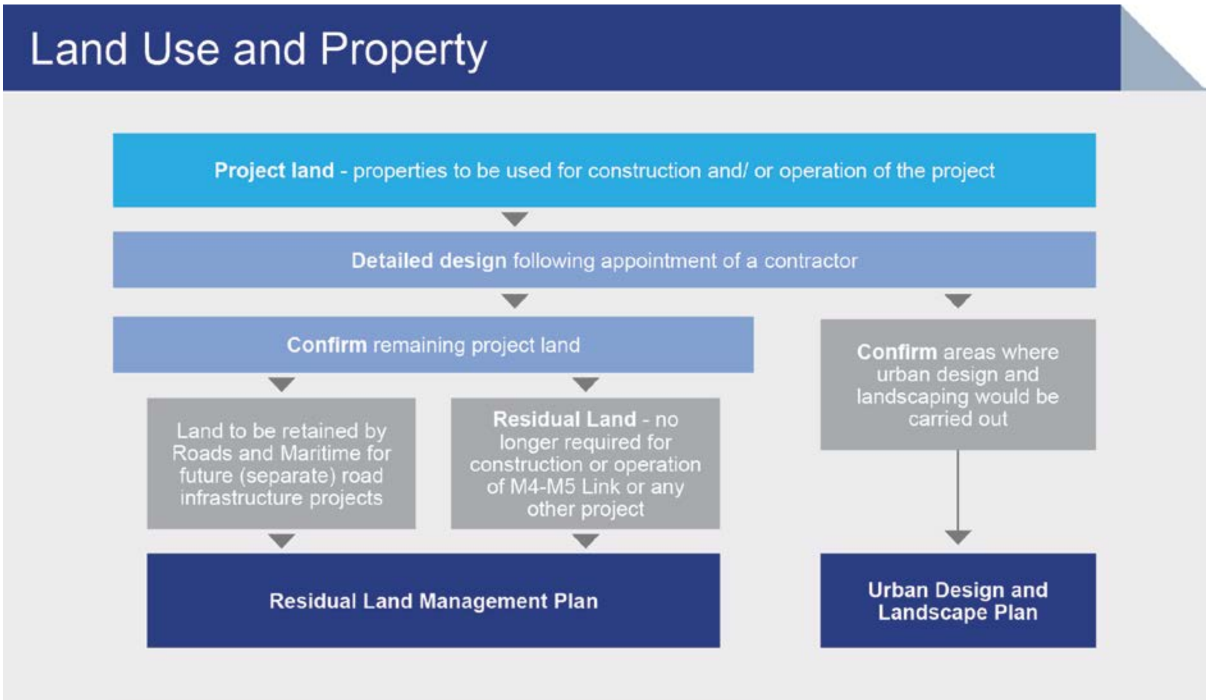


Figure 12-13 Process for identifying the future use of land not required for operational infrastructure

An indicative summary of the locations of remaining project land at the end of construction is presented in **Table 12-3**.

Table 12-3 Indicative summary of land uses at the end of construction

Plan	Urban design and landscaping	Remaining project land (subject to the Residual Land Management Plan)	
Location	(as outlined in UDLPs)	Retained for future road infrastructure projects	Future separate development and/or use
Wattle Street interchange surface works	As identified in the M4 East Urban Design and Landscape Plan, M4 East Residual Land Management Plan and/or the M4 East Legacy Project	Not applicable at this location	As identified in the M4 East Residual Land Management Plan
Parramatta Road West and East civil and tunnel sites	Not applicable at this location	Not applicable at this location	All land following construction
Darley Road surface works	Adjacent to permanent operational infrastructure	Not applicable at this location	Remaining land not required for permanent operational infrastructure
Rozelle surface works	Adjacent to permanent operational infrastructure Provision of new open space within the Rozelle Rail Yards	Adjacent to The Crescent at Annandale	Not applicable at this location

Plan	Urban design and landscaping	Remaining project land (subject to the Residual Land Management Plan)	
Iron Cove Link surface works	Adjacent to permanent operational infrastructure South of Victoria Road, between around Springside Street and Byrnes Street at Rozelle Adjacent to disturbed areas within King George Park	Not applicable at this location	Not applicable at this location
Pyrmont Bridge Road tunnel site	Not applicable at this location	Not applicable at this location	All land following construction
St Peters interchange surface works	Adjacent to permanent operational infrastructure Landscaping on the remaining site would be carried out consistent with the New M5 UDLP and conditions of approval	Not applicable at this location	Not applicable at this location

12.3.2 Potential impacts on Crown land

Two areas of Crown land would potentially be acquired for the project:

- Land required for the construction of the new bioretention facility and upgrades to the existing car park at King George Park at Rozelle, adjacent to Manning Street. This land is currently being used as an informal car park for users of King George Park
- Land within King George Park adjacent to Victoria Road and Byrnes Street at Rozelle for the widening of Victoria Road. This land consists of turf and a landscaped embankment.

These areas of Crown land are currently under the care and control of Inner West Council and fall within the boundary of the Draft Plan of Management for King George Park. It was further noted that the King George Park Draft Plan of Management referred to two 'incomplete land claims' lodged by Metropolitan Local Aboriginal Land Council. These land claims under the *Aboriginal Land Rights Act 1983* (NSW) do not necessarily denote Aboriginal cultural or scientific archaeological values. Land Councils are not required to establish cultural association with lands when making land claims under the *Aboriginal Land Rights Act 1983* (NSW). One of the two land claims referred to has, since preparation of the Draft Plan of Management, been determined by way of refusal. If necessary, the land to which the undetermined incomplete land claim applies would be avoided.

The acquisition and use of this land for the project would reduce the total area of Crown land available for use as community land within King George Park. However, this loss would be a minor impact as the area to be acquired would be minimal, at the margins of the park and adjacent to existing infrastructure. The project would improve a portion of the car park within King George Park adjacent to Manning Street. This would include sealing of a section of the car park surface and landscaping. This would be a benefit to the users of King George Park.

The permanent loss of an area of King George Park for widening of Victoria Road would be offset through the provision of new open space along Victoria Road between Springside Street and Byrnes Street at Rozelle, which would be connected to King George Park via an upgraded pedestrian and cyclist connection. The potential land use impacts associated with the use of this land for the project are assessed in **section 12.4.5**.

12.3.3 Subsurface acquisition

In addition to the properties affected by surface activities, land (or interests in land, such as easements) below the surface of the ground would be acquired to accommodate the tunnels and entry and exit ramps. This is called subsurface (or substratum) acquisition and is illustrated in **Figure 12-14**.

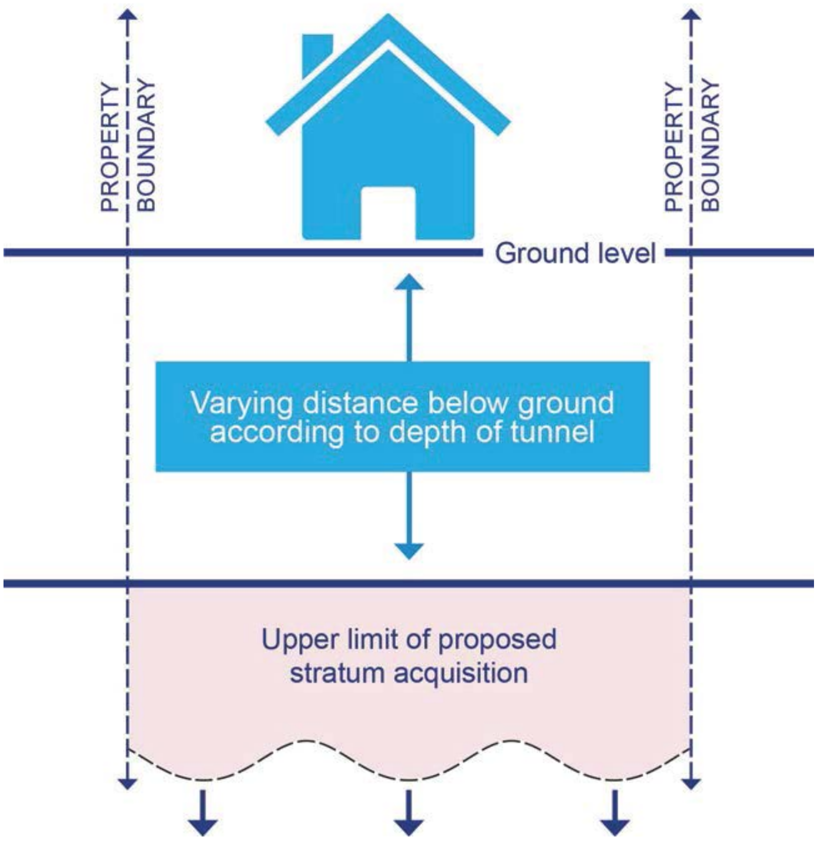


Figure 12-14 Example of subsurface stratum acquisition

The *Land Acquisition (Just Terms Compensation) Act 1991* (NSW) provides that compensation is not payable for the majority of subsurface acquisition of land or easements, unless specific circumstances as detailed in that Act apply. Appendix C of the Roads and Maritime *Land Acquisition Information Guide* (Roads and Maritime 2014) sets out in detail the compensation provisions of the Act relating to subsurface acquisition and the land acquisition reforms announced by the NSW Government in 2016, which can be viewed online at: https://www.finance.nsw.gov.au/sites/default/files/NSW_Government_Response.pdf

This subsurface acquisition would be a stratum acquisition envelope around the tunnels, including any associated ground support that may be required. The introduction of the subsurface stratum, and the tunnel itself, has the potential to limit development above the alignment in some circumstances. The tunnel depth is generally shallowest at tunnel portals. Tunnel portal locations are described in **Chapter 5** (Project description).

In most cases, subsurface acquisition would not affect the future use of property at the surface. Subject to council regulations and approvals, landowners would generally be able to:

- Carry out improvements, such as installing a swimming pool
- Dig deeper foundations for a new building or second storey additions

- Undertake property development.

Where subsurface acquisition is required, Roads and Maritime would contact owners of directly affected properties at the relevant time. If private property is directly affected, Roads and Maritime has the authority to acquire the subsurface land, under the *Roads Act 1993* (NSW), by a compulsory acquisition process. Subsurface acquisition for the project would be confirmed during detailed design.

12.3.4 Ground movement

Background

Ground movement may occur in some areas along the tunnel alignment induced by tunnel excavation. The ground movement anticipated is predominantly settlement, which is downward (also termed subsidence). Upward movement may also occur and is known as heave.

There are two causes of ground movement, which are:

- Tunnel excavation induced ground movement, which is the movement of the soil and rock into the tunnel excavation. This is a short term effect, which happens as soon as the tunnel is excavated and can cause heave and/or settlement
- Soil consolidation (soil shrinkage), which is the dissipation of water from the soil as the groundwater draws down, such as due to inflow into underlying tunnels. This is a longer term effect, which may take some time to occur and causes settlement only.

Tunnel excavation induced ground movement is anticipated to be the prevalent mechanism causing ground movement given that the proposed tunnels are primarily located within competent bedrock beneath thin residual soils that are not typically compressible or water saturated. In the area around the Rozelle Rail Yards where the tunnels intercept saturated alluvial soils, it is assumed that tanked structures are adopted which limit water ingress into the tunnels.

Areas most likely to be affected by settlement are usually where tunnelling is closest to the ground surface (shallowest), around the tunnel portals and entry and exit ramps, and where soils are more likely to be compressible and thus have more voids which can compress. This would include the estuarine and alluvial soils and fill within the palaeochannel underneath the Rozelle Rail Yards.

Induced ground movement due to the tunnel excavation would occur primarily during the construction phase and would typically be in the form of a settlement trough which develops ahead, above and behind the tunnel excavation face. Generally settlement would be greatest in magnitude directly above the tunnel centreline, reducing with increased distance from both the tunnel sides and ahead of the tunnel face. The ground settlement profile generated is typically concave in shape and termed a settlement trough as shown in **Figure 12-15**.

The shape, width and magnitude of the tunnel excavation induced settlement trough is dependent on a number of factors including:

- The depth and size (span) of the tunnel
- The distance between tunnels where multiple tunnels are proposed
- The geotechnical conditions, particularly the stiffness of the rock mass
- The excavation methodology, sequence and allowable advance before the installation of tunnel support
- The tunnel support design and actual performance.

The ground movement associated with a settlement trough can be both vertical and horizontal. Building damage associated with settlement can occur where the building is subjected to tensile strains. Tensile strain can depend on where the building is located with respect to the settlement curve and the shape of the curve itself.

The manner in which a building or structure responds to ground movement also depends on its size, design, materials, foundations and age. For instance a timber or steel framed structure may be flexible, deflecting as the ground moves whereas a masonry building if subject to similar ground movement may behave differently. Other relevant factors may include the overall height (number of storeys) of the building and whether the building has basement levels.

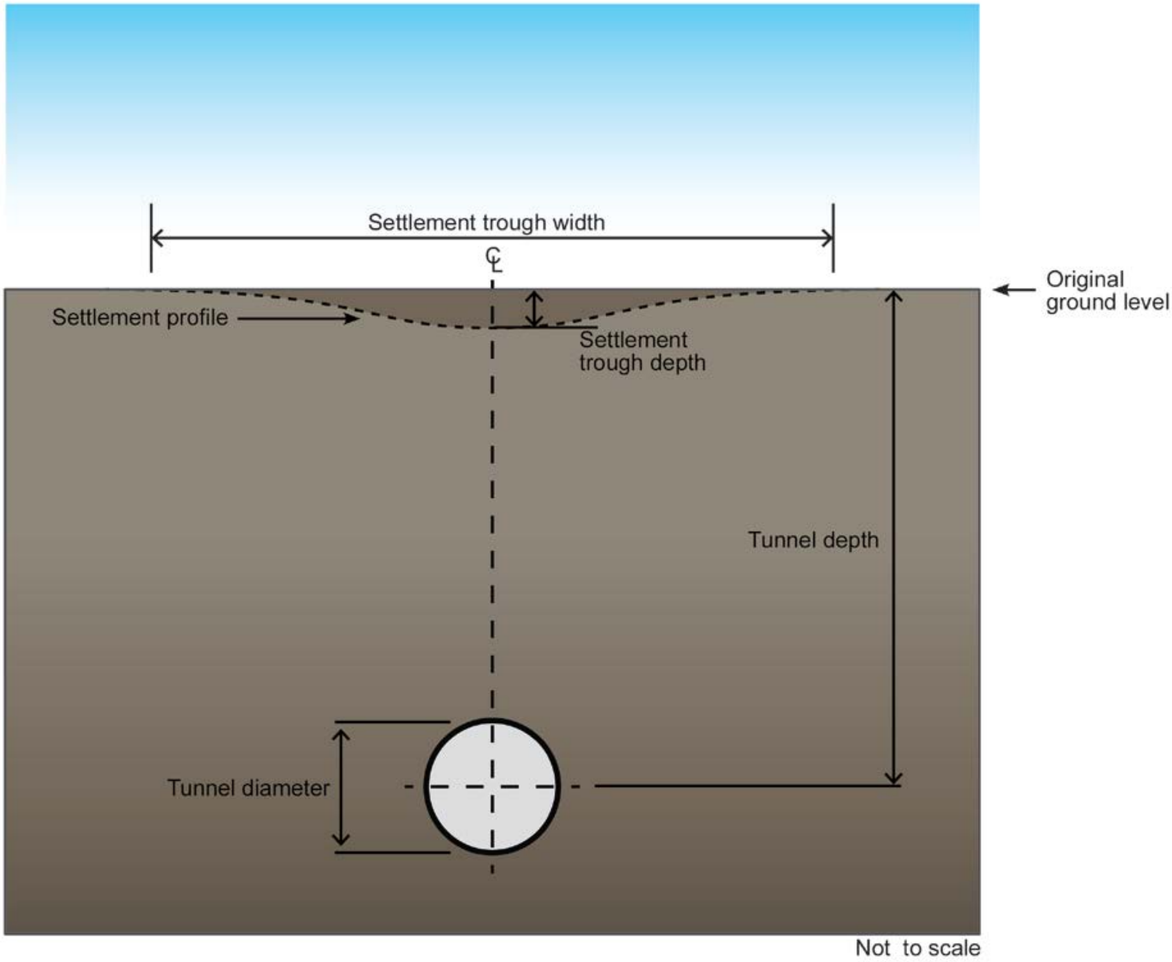


Figure 12-15 Typical settlement profile

Source Technical Manual for Design and Construction of Road Tunnels – Civil Elements

Note - CL in Figure 12-15 refers to centre line

Relevant criteria

Settlement criteria have been specified in the conditions of approval for recent tunnelling projects in Sydney including the WestConnex M4 East and New M5 projects and the NorthConnex project. These criteria are summarised in **Table 12-4** and it is expected that they would be adopted for this project. The additional criterion of tensile strain is included, which addresses the cause of potential building damage.

Table 12-4 Settlement criteria

Beneath structure/facility	Maximum settlement	Maximum angular distortion	Limiting tensile strain (per cent)
Buildings – Low or non-sensitive properties (ie less than or equal to two levels and carparks)	30 mm	1 in 350	0.1
Buildings – High or sensitive properties (ie greater than or equal to 3 levels and carparks)	20 mm	1 in 500	0.1

Beneath structure/facility	Maximum settlement	Maximum angular distortion	Limiting tensile strain (per cent)
Roads and parking areas	40 mm	1 in 250	N/A
Parks	50 mm	1 in 250	N/A

Settlement criteria for individual utilities and infrastructure are determined in consultation with the relevant authorities prior to the commencement of any construction potentially affecting the individual utilities or infrastructure.

Existing environment

A description of the geotechnical conditions within the project footprint is included in **Chapter 15** (Soil and water quality) and **Chapter 19** (Groundwater). Geological long-sections of the mainline tunnels, the Rozelle interchange and the Iron Cove Link are included in **Appendix E** (Geological long-sections).

The project footprint is located within the Sydney Basin and is predominantly underlain by the Triassic rock formations, Ashfield Shale and Hawkesbury Sandstone which outcrop in topographically higher areas. In lower lying areas such as around Rozelle Bay, White Bay, Hawthorne Canal and Johnstons Creek the bedrock is overlain by fill and alluvium. The thickness of the alluvium is variable and may be up to 20 metres deep within the palaeochannels, such as beneath Rozelle Rail Yards and Hawthorne Canal.

The project footprint is located across established inner urban areas of Sydney. The tunnels are located below:

- Residential, commercial and industrial areas
- Watercourses including Hawthorne Canal, Whites Creek and Johnstons Creek
- Open space areas including Easton Park, Pioneers Memorial Park and O'Dea Reserve
- Major public transport infrastructure including the Inner West Light Rail line, the T2 Inner West and South railway line at Newtown, the T3 Bankstown railway line at St Peters, and the proposed Sydney Metro City and South West line at Newtown
- Major road infrastructure including Parramatta Road, City West Link, Victoria Road, King Street and Princes Highway and a number of other roads
- Major utility infrastructure including the Sydney Water Pressure Tunnel at Newtown and the Sydney Water City Tunnel at Newtown
- Listed heritage items and heritage conservation areas.

Refinements of the project design

Geotechnical and groundwater investigations have been carried out to inform the development of the concept design which has been assessed in the EIS and the assessment of potential settlement impacts. These investigations have included:

- Review of regional geology, topography and geotechnical information contained in historic investigations
- Geotechnical investigations carried out for the project including drilling boreholes, testing of soils and rock samples and televiewer imaging of rock stratigraphy within boreholes
- Installation of groundwater monitoring wells and regular measurement of groundwater levels and monitoring of groundwater quality to characterise the groundwater conditions.

As a result of these investigations, a number of refinements to the project design have been made to minimise potential ground movement and groundwater impacts. These include (but are not limited to):

- Altering the horizontal and vertical alignment of the tunnels so that they are located in competent bedrock and dive beneath the palaeochannels where feasible. Examples of where this has occurred include:

- The tunnels diving beneath the palaeochannels in the vicinity of Hawthorne Canal and Johnstons Creek to intercept competent bedrock (Hawkesbury Sandstone)
- Redesigning the Rozelle interchange so that it is predominantly located underground and in the competent bedrock (Hawkesbury Sandstone) located to the north and north west of the Rozelle Rail Yards

- Designing a range of different tunnel and tunnel portal cross sections having regard to the various ground conditions likely to be encountered. The indicative tunnel and tunnel portal cross sections are shown in **Chapter 5** (Project description)
- Reducing the extent of tunnelling within the estuarine and alluvial soils and fill, such as the within the palaeochannel underneath the Rozelle Rail Yards
- Designing some localised sections of tunnel to be tanked to avoid groundwater ingress where the alignment intercepts alluvial soils and poor quality rock around the Rozelle Rail Yards. The localised sections of tunnel which are assumed to be tanked to avoid groundwater ingress are shown in **Appendix T** (Technical working paper: Groundwater)
- Providing excavation support (retention systems), which act as barriers to groundwater ingress, in areas of fill, soft clay or water saturated soils. Options for retention systems include sheet pile walls, diaphragm walls and secant pile walls. Excavation support has been assumed for construction of cut and cover sections of tunnels within the estuarine and alluvial soils and fill at the Rozelle Rail Yards as shown in **Appendix T** (Technical working paper: Groundwater).

Potential impacts on buildings and open space

For the majority of the proposed alignment the tunnels are located at depths of greater than 35 metres below ground level and in competent bedrock. As a result the risk of ground movement is limited. However, at a number of locations where the tunnels are rising to meet the surface roads the tunnelling is shallower at depths of less than 20 metres below ground level. These shallower areas of tunnelling are generally located in the vicinity of:

- The entry and exit ramps to and from the Wattle Street interchange at Haberfield
- The three sets of tunnel portals for the Rozelle interchange at Rozelle and Lilyfield
- The tunnel portals for the Iron Cove Link at Rozelle
- The entry and exit ramps to and from the St Peters interchange.

A preliminary assessment has been carried out to assess the potential for ground movement and angular distortion as a result of the project. The method adopted to predict ground movement is the volume loss approach as described by Mair, Taylor and Burland 1996. The results of this preliminary assessment are presented as ground movement contours and angular distortion contours and are shown in **Figure 12-16** to **Figure 12-30**.

Ground movement

The preliminary assessment shows that over the majority of the tunnel alignment predicted ground movement is less than 20 millimetres which would be consistent with the criteria. There are a number of discrete areas to the north and northwest of the Rozelle Rail Yards, to the north of Campbell Road at St Peters and in the vicinity of Lord Street in Newtown where ground movement above 20 millimetres is predicted. These discrete areas generally coincide with areas of shallower tunnelling and/or where multiple tunnels are located close to each other. They include:

- To the north of Lilyfield Road at Rozelle in the vicinity of Denison Street in an established residential area and Easton Park (open space area) where multiple tunnels are located and settlement in the range 20 to 35 millimetres is predicted
- To the south of Balmain Road at Leichhardt in the vicinity of Cook Street in an established residential area where multiple tunnels are located and settlement in the range 20 to 30 millimetres is predicted.
- To the north of Lilyfield Road at Rozelle in the vicinity of the City West Link to New M5 entry and exit ramps in an established residential area where settlement in the range 20 to 30 millimetres is predicted

- To the north of Campbell Road at St Peters in an established residential area where settlement in the range 20 to 50 millimetres is predicted
- In the area of Lord Street at Newtown in an established residential area close to St Peters railway station where settlement in the range 20 to 35 millimetres is predicted.

For low buildings of two storeys in height or less a settlement criterion of 30 millimetres is applicable. For high buildings of three storeys or more a settlement criterion of 20 millimetres is applicable. For roads a settlement criterion of 40 millimetres is applicable and for open space areas a settlement criterion of 50 millimetres is applicable.

A range of options are available to minimise settlement in areas where ground movement in excess of the relevant settlement limits are predicted. These are discussed below and in **section 12.5**.

There is also an area within Rozelle Rail Yards to the south of Lilyfield in the vicinity of the proposed M4 East/Iron Cove Link to Anzac Bridge entry and exit ramps where settlement of up to 40 millimetres is predicted. This area is located within the project footprint. Engineering design measures would be developed during detailed design for the project infrastructure that would be located in this area of the Rozelle Rail Yards site to address potential settlement impacts.

Angular distortion

Preliminary assessment of angular distortion has not identified any areas within the project footprint where the angular distortion is steeper than one in 500. The areas with the highest predicted angular distortion occur in the vicinity of the Wattle Street interchange ramps at Haberfield and the St Peters interchange ramps within Campbell Road at St Peters but in both locations the relevant criteria would be met.

Groundwater drawdown and cumulative impacts

The preliminary assessment does not include prediction of settlement as a result of groundwater drawdown (consolidation settlement). In contrast to predicting tunnel excavation-induced ground movement, which has a well-documented and accepted methodology, prediction of consolidation settlement relies on the prediction of induced groundwater drawdown, which is complex and subject to significant uncertainties.

Settlement that occurs due to groundwater drawdown is gradual and generally occurs at a slower rate (possibly over years). It can sometimes also be difficult to distinguish from settlement due to groundwater drawdown that may be naturally occurring; or occurring due to another influence; or occurring as a result of seasonal variations which can cause swelling or shrinkage of the soil. The extent of groundwater drawdown often occurs over a wider area beyond the location of the tunnels and results in a wider and shallower settlement trough which is less likely to result in tensile strain on buildings and building damage.

Cumulative settlement impacts include the combined impacts of settlement from tunnel excavation induced ground movement and groundwater drawdown. Tunnel excavation induced ground movement is anticipated to be the prevalent mechanism causing ground movement given that the proposed tunnels are primarily located within competent bedrock (Hawkesbury Sandstone and Ashfield Shale). Residual soil profiles developed on the weathered sandstone and shale bedrock are typically relatively thin, stiff and of low compressibility and as such would be less susceptible to ground settlement.

The risks associated with groundwater drawdown and induced settlement within the Ashfield Shale and Hawkesbury Sandstone is considered low because of the geotechnical properties of the rock. As water is removed from these rock types the structural integrity and strength of the rock remains due to its competent nature. As a result, cumulative settlement impacts are not anticipated to be an issue for tunnels excavated in the Hawkesbury Sandstone or Ashfield Shale.

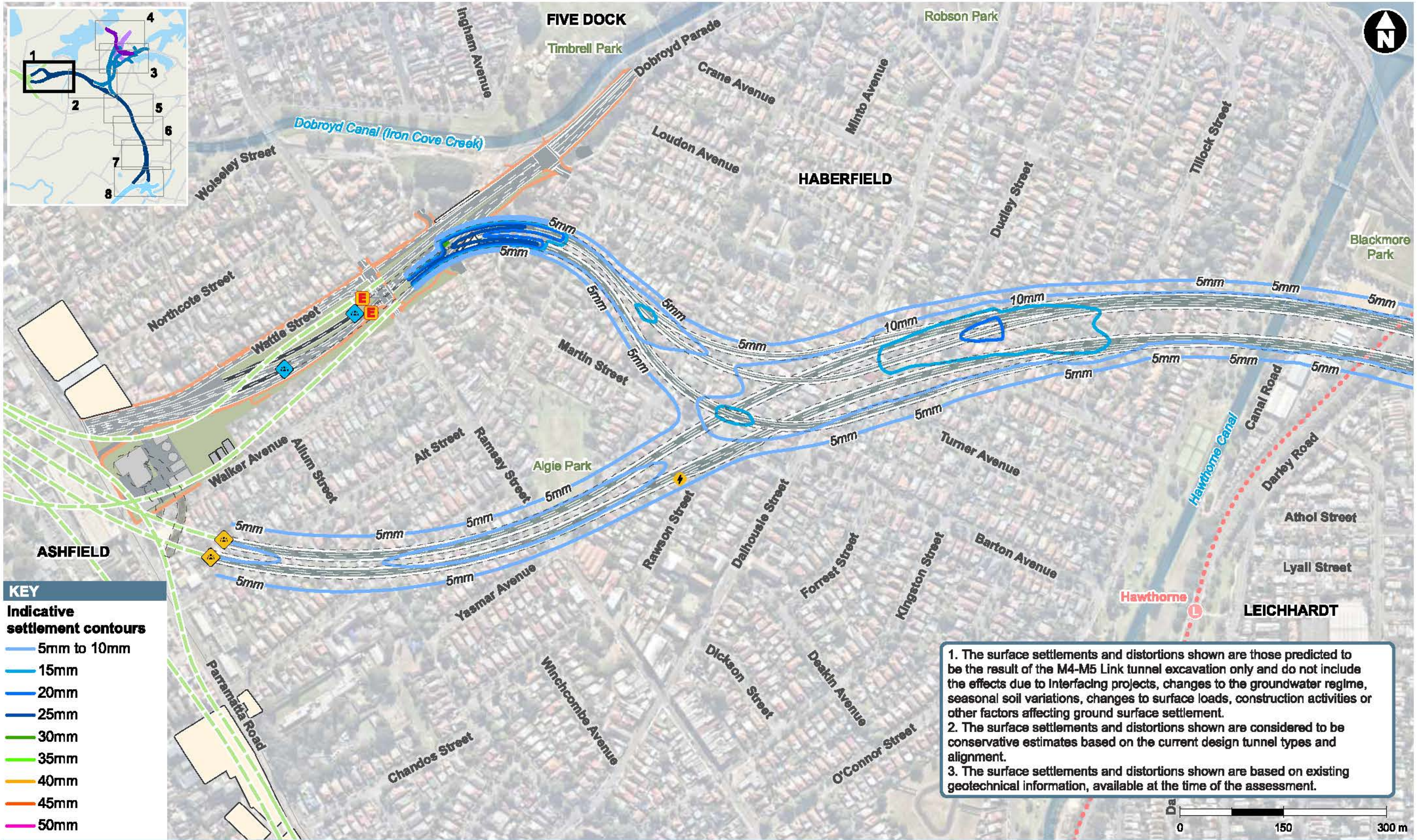
In contrast, as groundwater drawdown occurs within the alluvium the structural integrity of the unconsolidated sediment is compromised resulting in more settlement than would be expected from the sandstone and shale. Cumulative settlement impacts in the alluvium would be minimised by including tanked tunnel sections through the alluvium or by aligning the tunnels beneath the palaeochannels thereby minimising groundwater leakage.

Detailed design phase

Further assessment including hydrogeological modelling would be undertaken during detailed design to determine the level of predicted settlement impacts. A range of options are available to minimise settlement in areas where ground movement in excess of the relevant settlement limits are predicted including:

- Review of the proposed tunnel design including:
  - The depth and alignment of tunnels
  - The proximity of multiple tunnels to each other
  - The proposed tunnel support system
  - The tunnel lining to manage groundwater inflows
- Rationalising the layout of the proposed ventilation tunnels particularly at the Rozelle interchange
- Review of the construction methodology such as the rate of tunnel advance and the tunnel support
- Consideration of ground improvement options.

It is anticipated that a combination of the abovementioned options would be sufficient to ensure that ground movement associated with the project is less than the relevant settlement criteria.



LEGEND

Imagery © Nearmap (2017)

Existing features
- Light rail
- Light rail stop

M4 East
- Surface road
- Tunnel
- Surface roads
- Shared path
- Land subject to M4 East UDLP
- Land subject to M4 East RLMP
- Ventilation facility

M4-M5 Link tunnels
- Mainline tunnel
- Temporary access tunnel

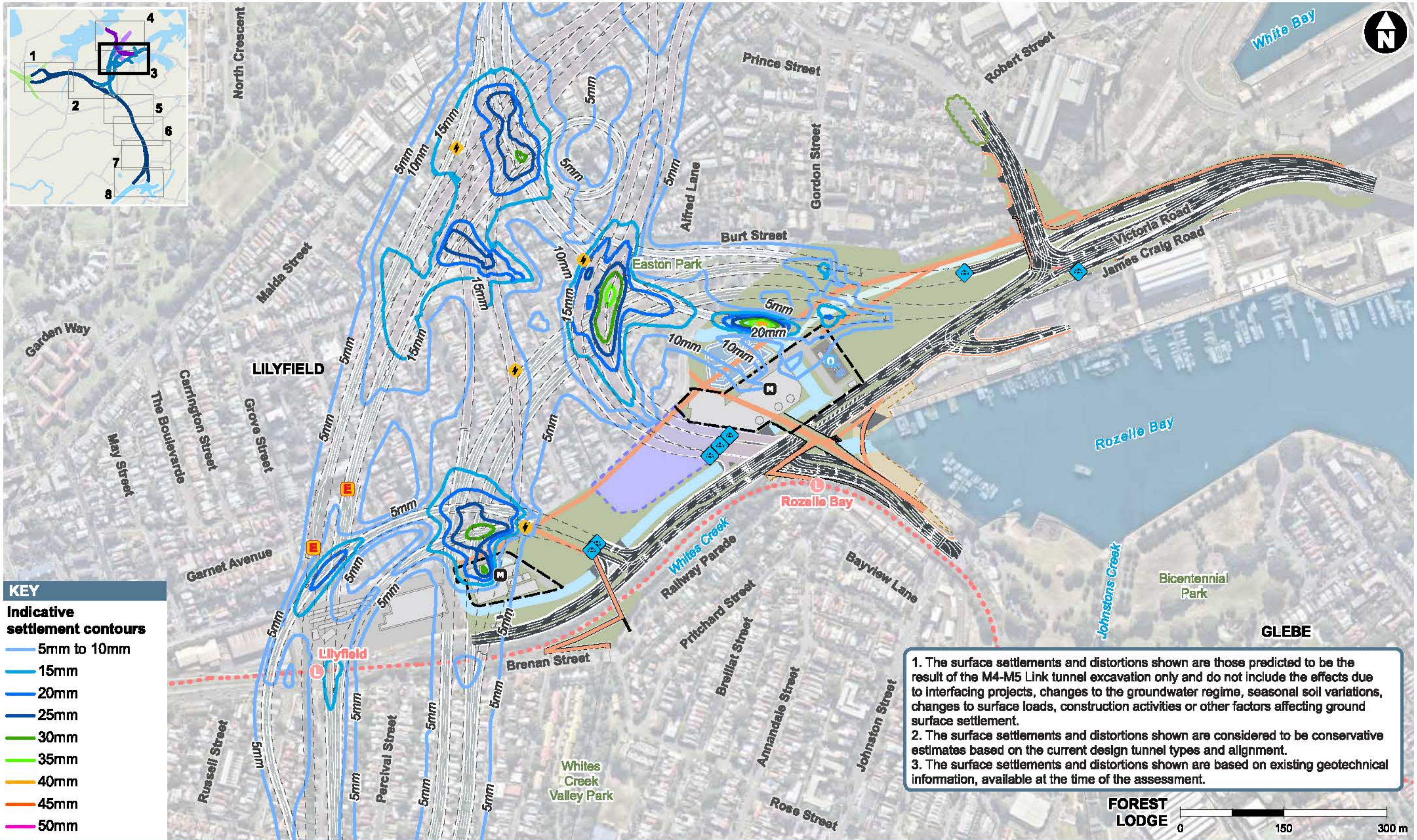
M4-M5 Link surface works
- Surface road (civil finishing works)

Project features
- Indicative toll location
- Tunnel portal
- Tunnel connection

Ancillary facility
- Underground substation

Figure 12-16 Preliminary settlement analysis (settlement contours) - Map 1

Figure 12-17 Preliminary settlement analysis (settlement contours) - Map 2



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Existing features
- Light rail
- Light rail stop

M4-M5 Link tunnels
- Rozelle interchange tunnel
- Iron Cove Link tunnel
- Proposed future WHTBL connections (civil construction only)

M4-M5 Link surface works
- Surface road
- Operational facilities
- Remaining project land
- Land subject to UDLP
- Bioswale
- Drainage channel
- Constructed wetland
- Bus lane
- Shared path
- Proposed future WHTBL connections construction area

Project features
- Indicative toll location
- Tunnel portal

Ancillary facility
- Water treatment facility
- Underground substation
- Motorway operations complex

Figure 12-18 Preliminary settlement analysis (settlement contours) - Map 3

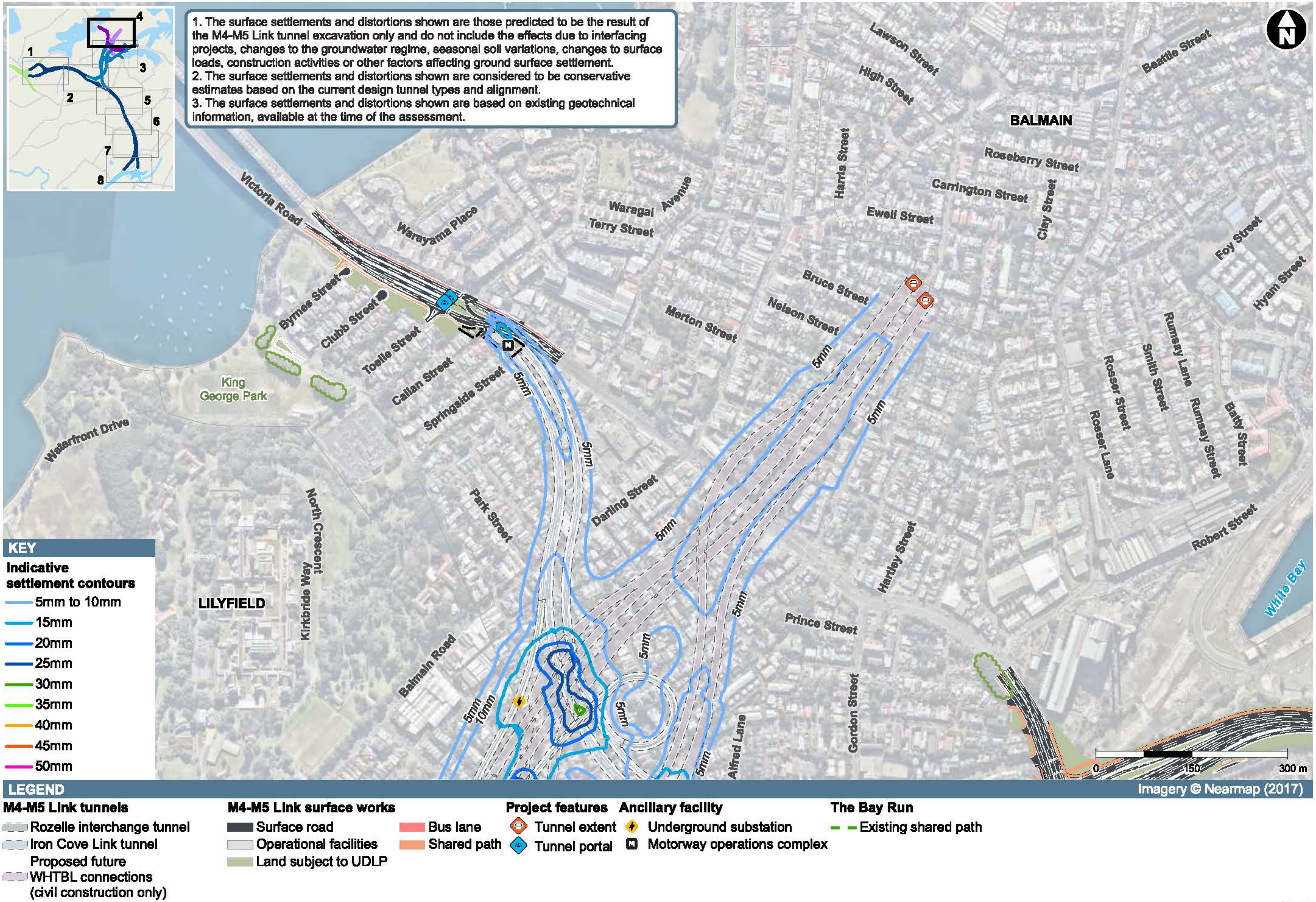
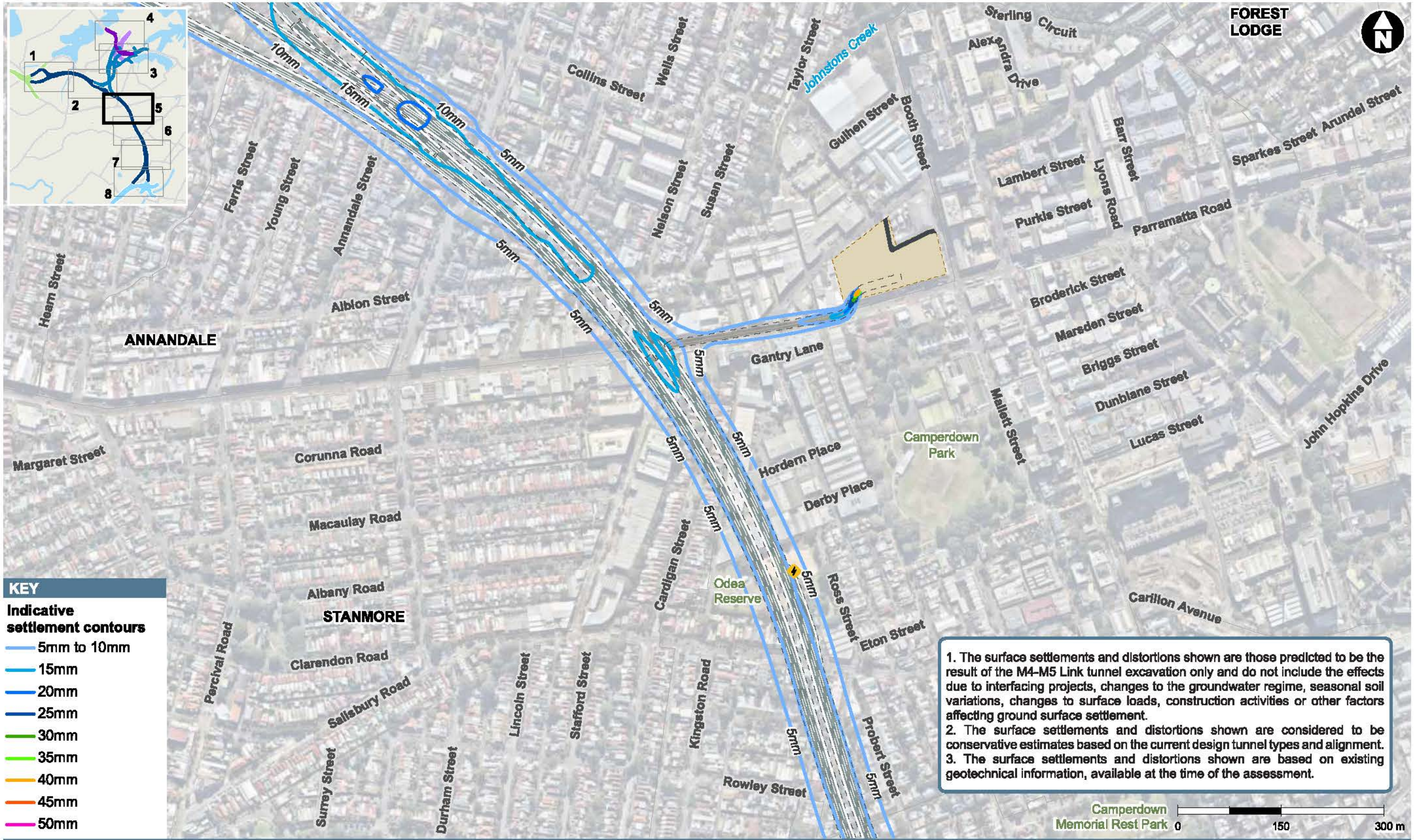


Figure 12-19 Preliminary settlement analysis (settlement contours) - Map 4



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M4-M5 Link tunnels
- Mainline tunnel
- Rozelle interchange tunnel
- Temporary access tunnel

M4-M5 Link surface works
- Remaining project land

Ancillary facility
- Underground substation

Figure 12-20 Preliminary settlement analysis (settlement contours) - Map 5

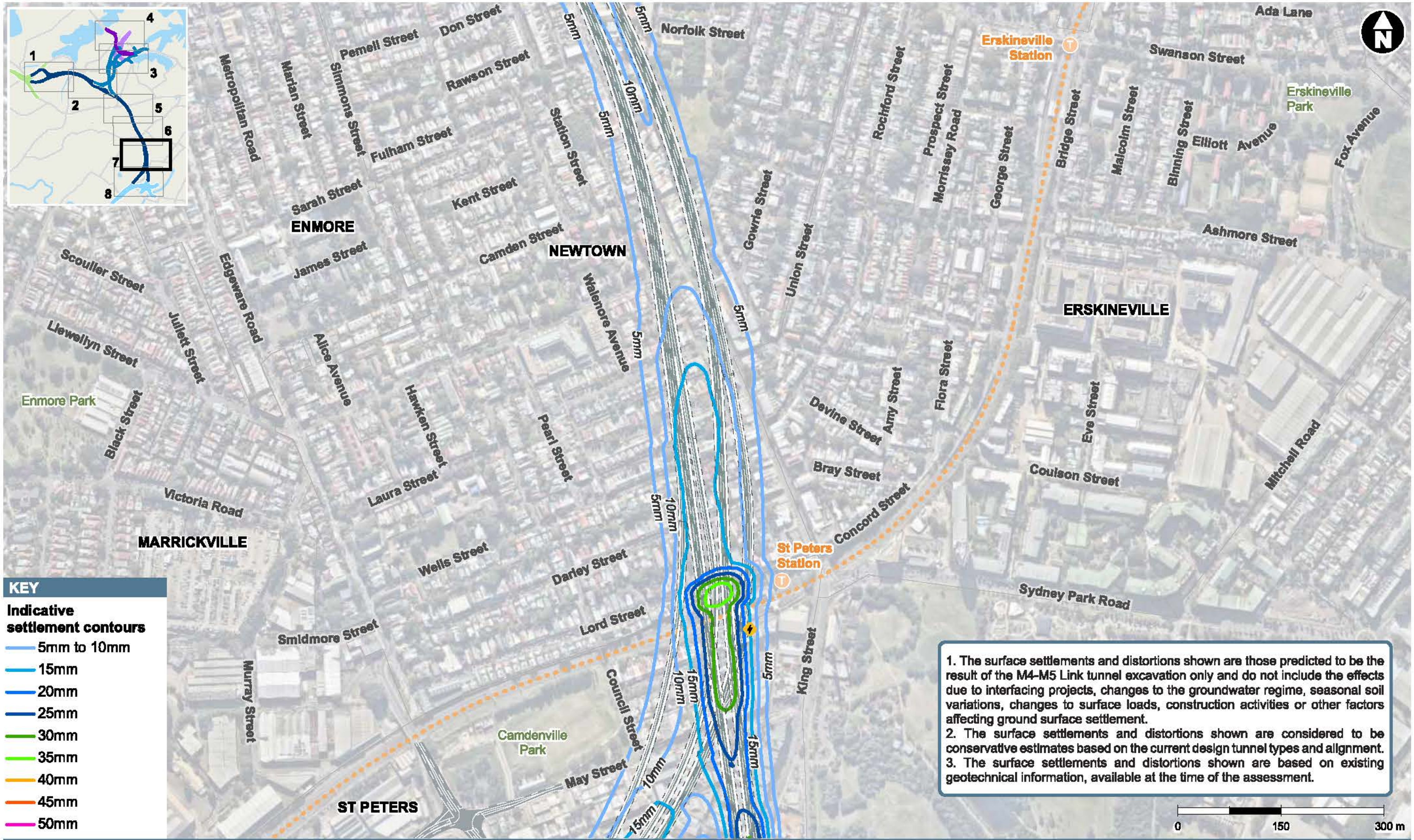
LEGEND Imagery © Nearmap (2017)

Existing features
- Railway
- Railway station

M4-M5 Link tunnels
- Mainline tunnel

Ancillary facility
- Underground substation

Figure 12-21 Preliminary settlement analysis (settlement contours) - Map 6



1. The surface settlements and distortions shown are those predicted to be the result of the M4-M5 Link tunnel excavation only and do not include the effects due to interfacing projects, changes to the groundwater regime, seasonal soil variations, changes to surface loads, construction activities or other factors affecting ground surface settlement.
2. The surface settlements and distortions shown are considered to be conservative estimates based on the current design tunnel types and alignment.
3. The surface settlements and distortions shown are based on existing geotechnical information, available at the time of the assessment.

LEGEND

Imagery © Nearmap (2017)

Existing features — Railway; Railway station

New M5 — Surface road

M4-M5 Link tunnels — Mainline tunnel

Ancillary facility — Underground substation

Figure 12-22 Preliminary settlement analysis (settlement contours) - Map 7

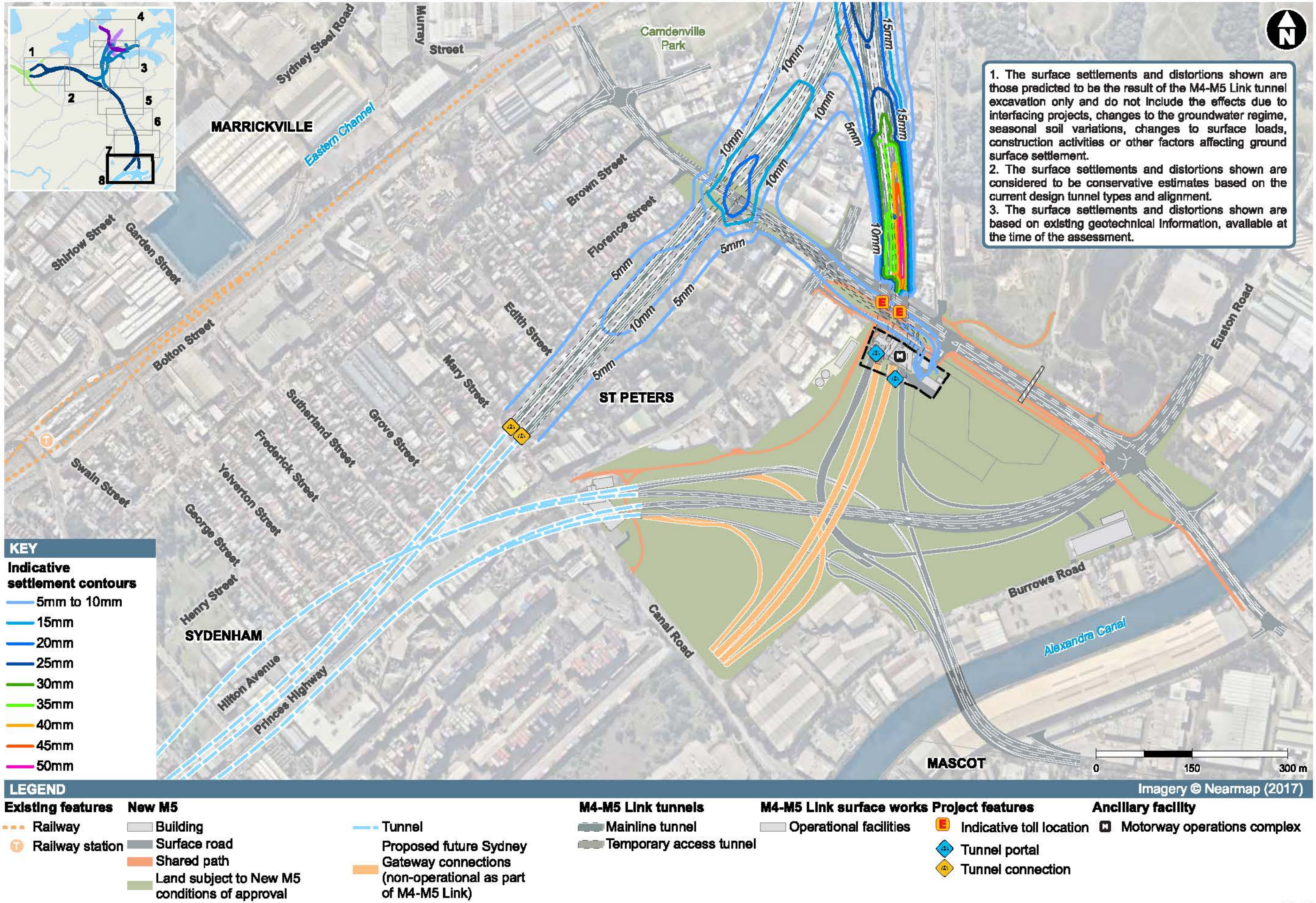


Figure 12-23 Preliminary settlement analysis (settlement contours) - Map 8

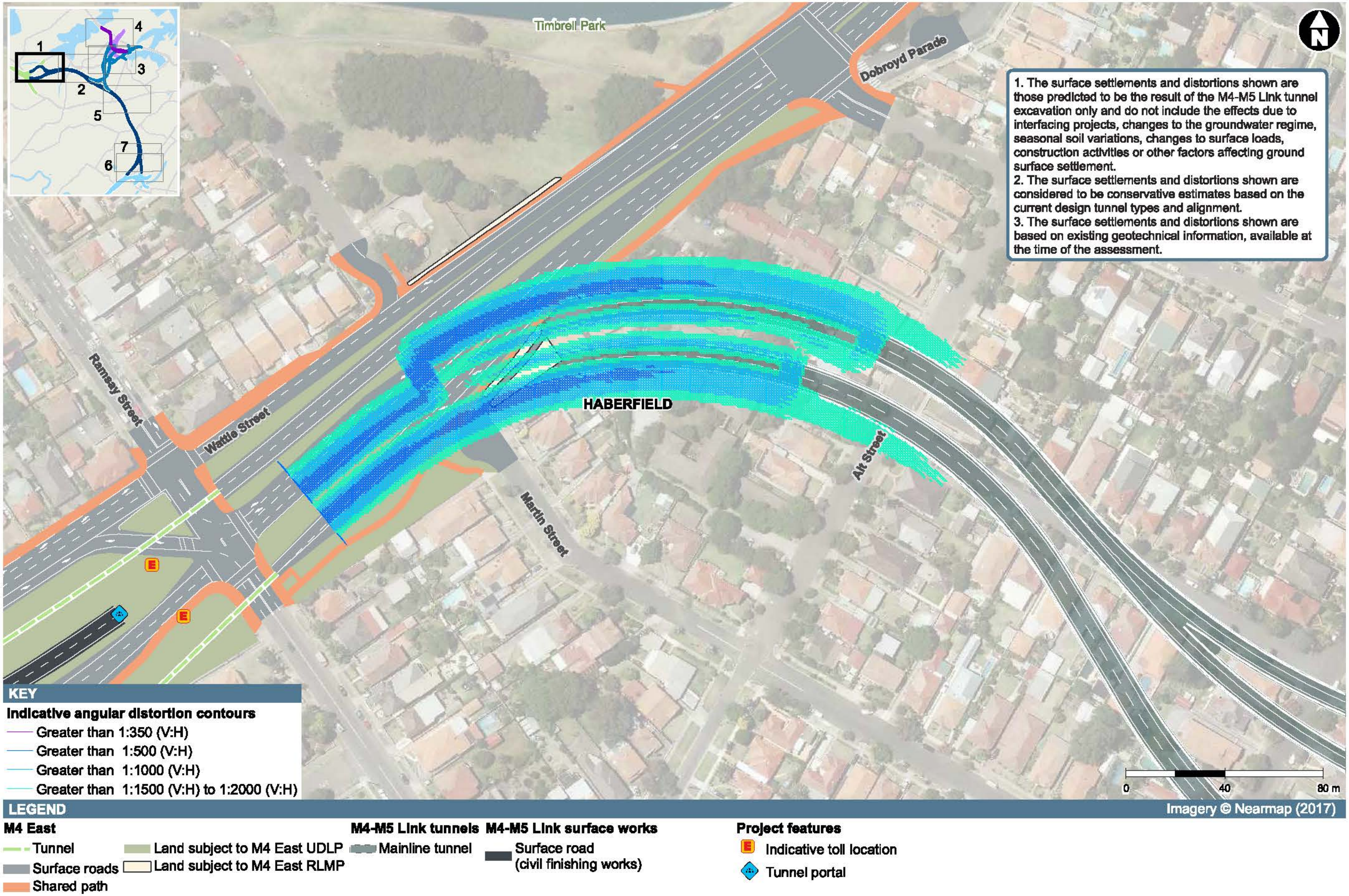


Figure 12-24 Preliminary settlement analysis (angular distortion contours) - Map 1

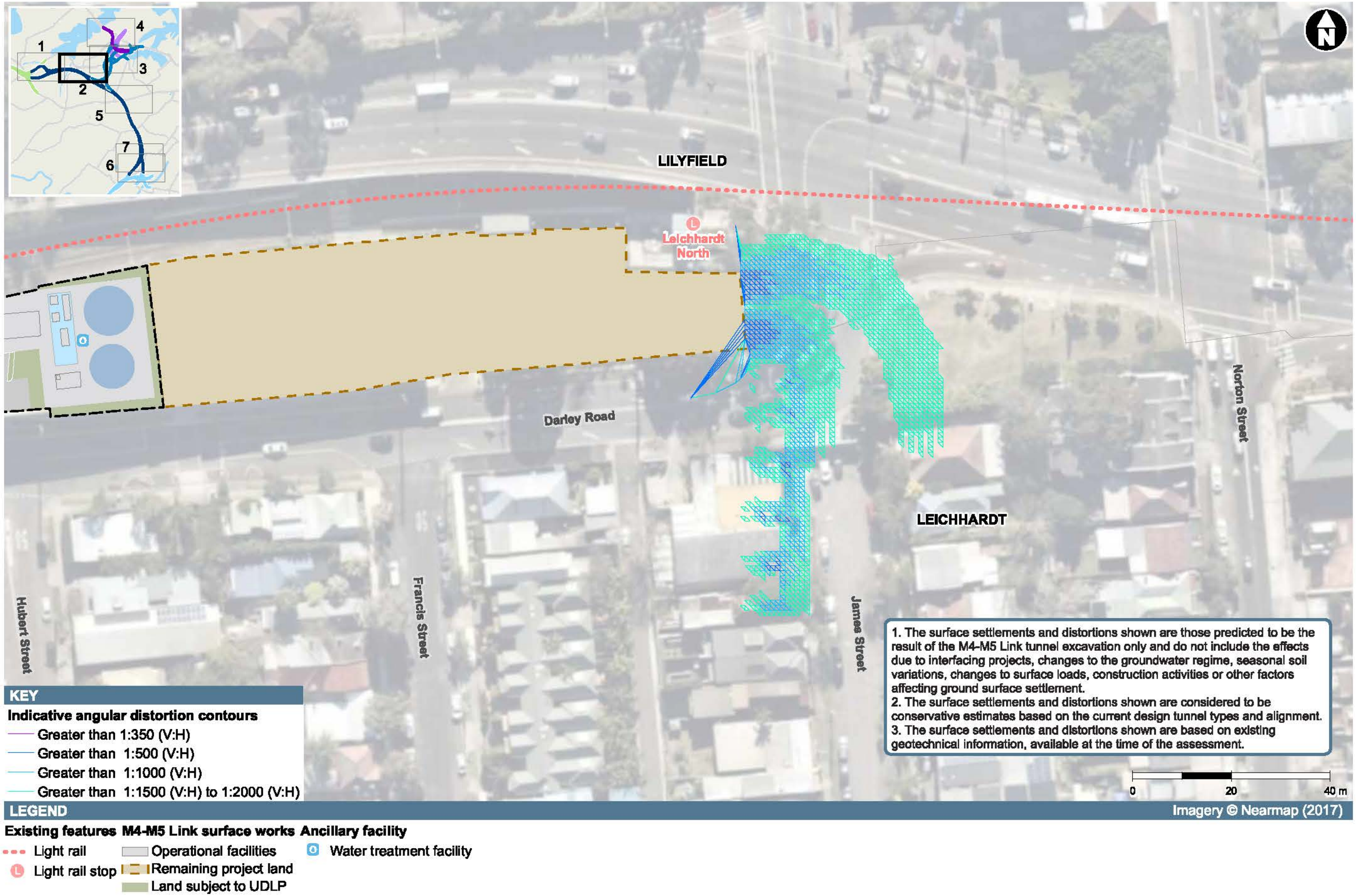


Figure 12-25 Preliminary settlement analysis (angular distortion contours) - Map 2

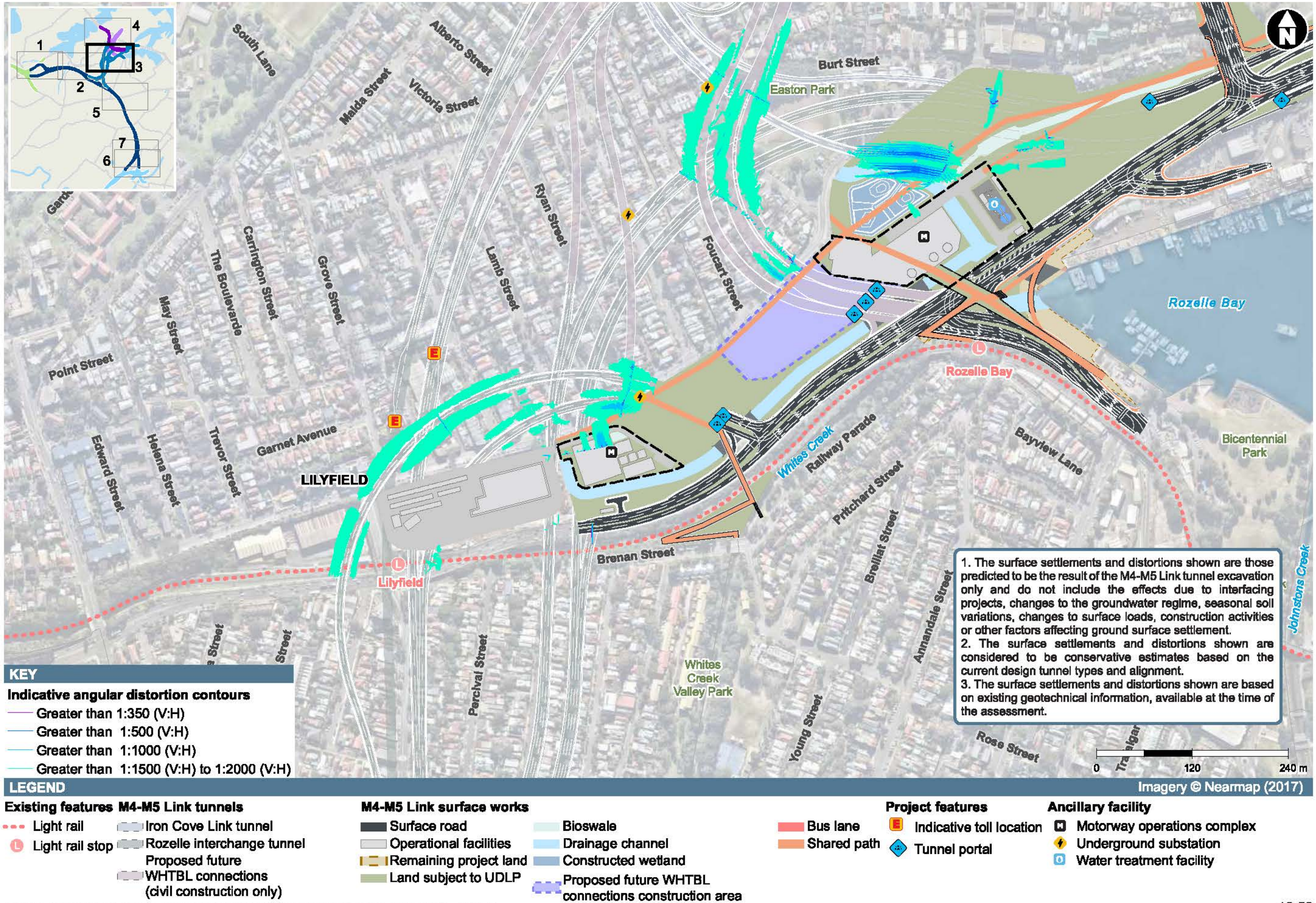
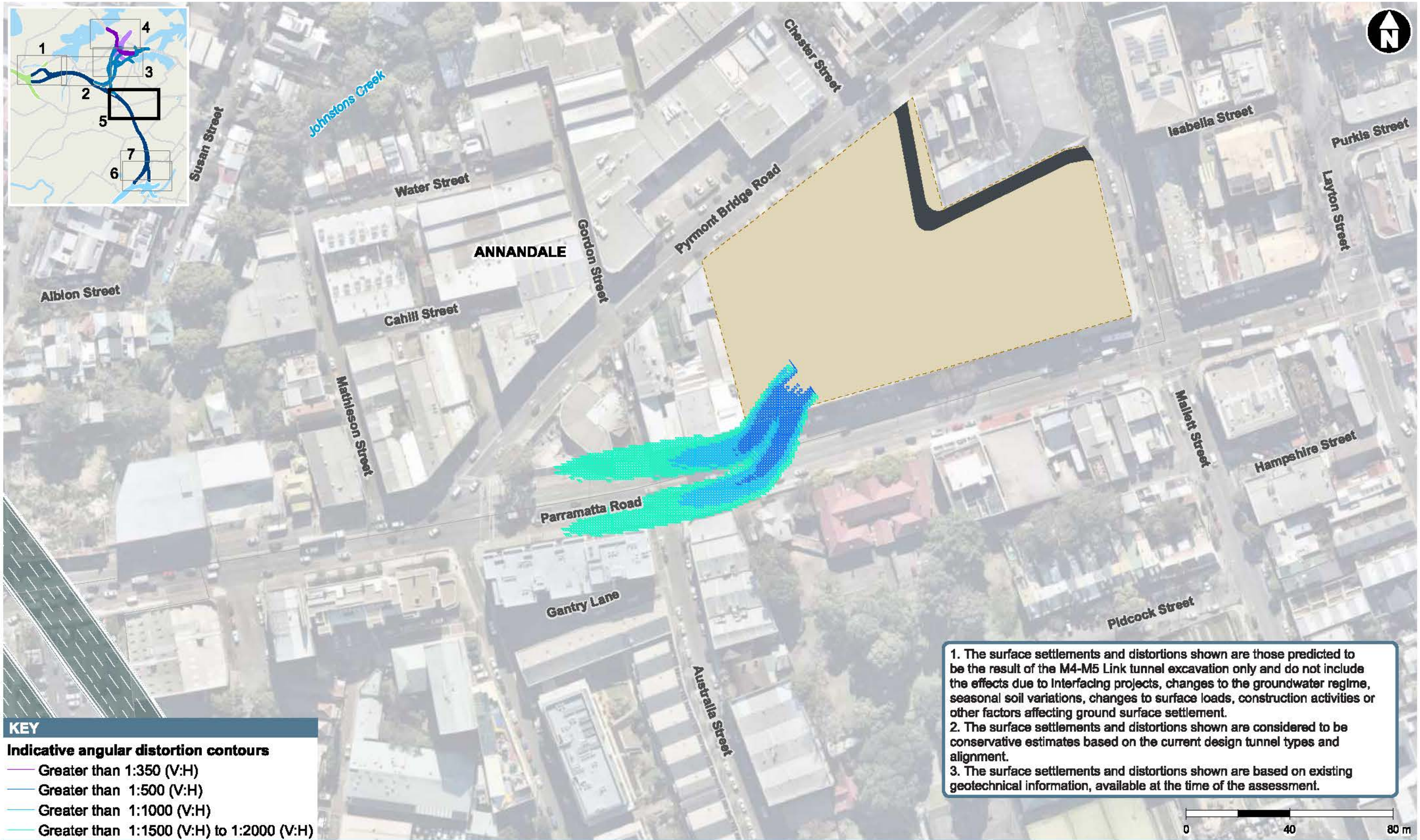


Figure 12-26 Preliminary settlement analysis (angular distortion contours) - Map 3

Figure 12-27 Preliminary settlement analysis (angular distortion contours) - Map 4



KEY

Indicative angular distortion contours

- Greater than 1:350 (V:H)
- Greater than 1:500 (V:H)
- Greater than 1:1000 (V:H)
- Greater than 1:1500 (V:H) to 1:2000 (V:H)

LEGEND

Imagery © Nearmap (2017)

M4-M5 Link tunnels **M4-M5 Link surface works**

Mainline tunnel   Remaining project land

Figure 12-28 Preliminary settlement analysis (angular distortion contours) - Map 5

LEGEND Imagery © Nearmap (2017)

Existing features
- Railway
- Railway station

New M5
- Surface road
- Land subject to New M5 conditions of approval

M4-M5 Link tunnels
- Mainline tunnel

Ancillary facility
- Underground substation

Figure 12-29 Preliminary settlement analysis (angular distortion contours) - Map 6

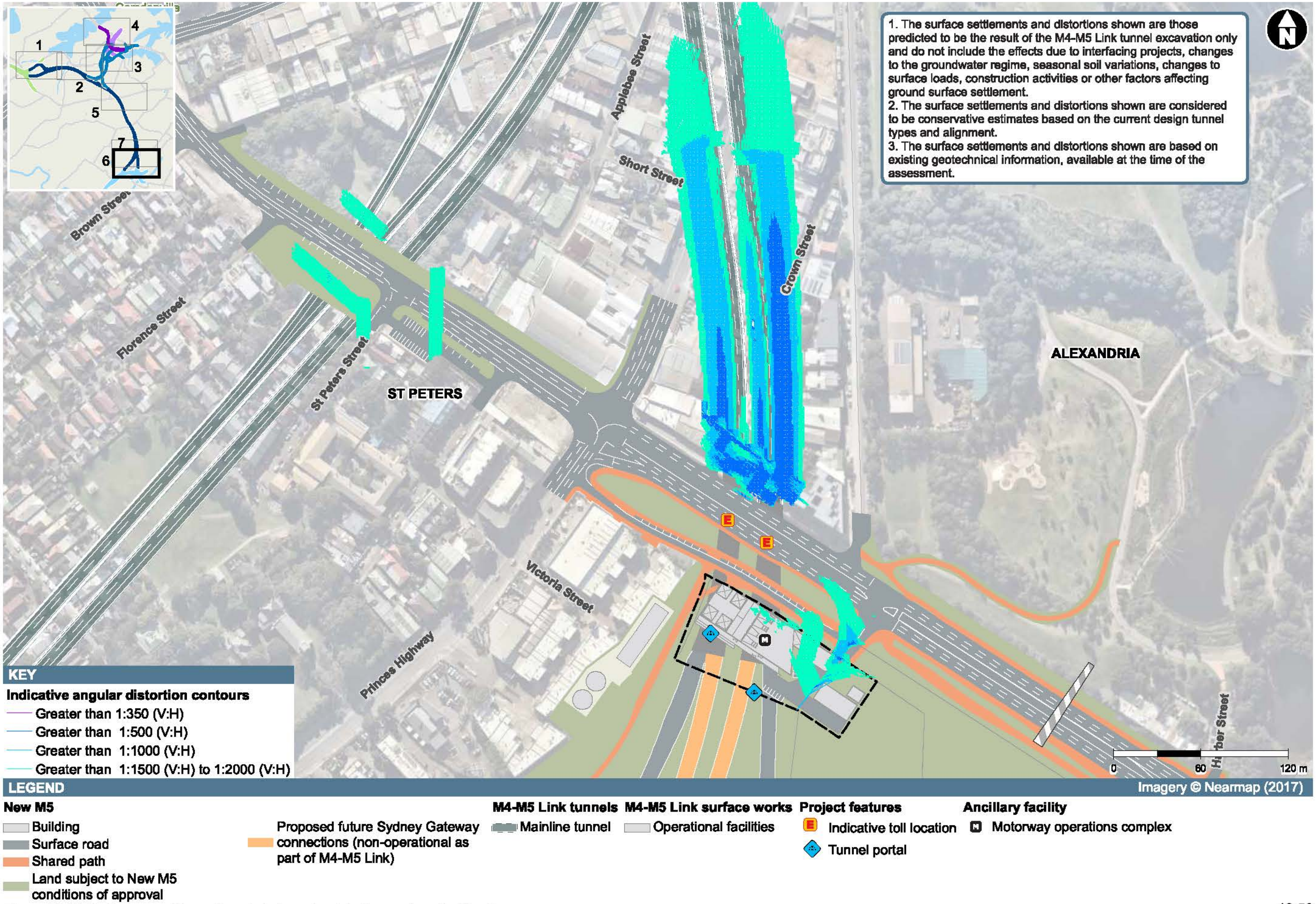


Figure 12-30 Preliminary settlement analysis (angular distortion contours) - Map 7

Potential impacts on infrastructure

Sydney Water Tunnels

The mainline tunnels alignment crosses key Sydney Water utility services including the Pressure Tunnel and the City Tunnel. These tunnels supply water to residents of Sydney's eastern and southern suburbs and run from Potts Hill to Waterloo. The Pressure Tunnel is listed on the State Heritage Register and on Sydney Water's Heritage and Conservation Register under section 170 of the *Heritage Act 1977* (NSW) and is of State heritage significance. The City Tunnel is listed on the Sydney Water's Heritage and Conservation Register and is of local heritage significance.

The Pressure Tunnel was constructed circa 1930 and is described as having an excavated diameter of 3,800 millimetres and an internal steel lining of 2,480 millimetres diameter and is located at an approximate invert level of Reduced Level (RL) -35 metres Australian Height Datum (AHD). The M4-M5 Link mainline tunnel alignment passes above the Sydney Water Pressure Tunnel in the vicinity of Enmore Road and King Street at Newtown. This interface is shown in **Figure 12-31**. In this location, the base of the M4-M5 Link mainline tunnels are located about 12 metres above the obvert level for the Pressure Tunnel. The closest construction/access shaft for the Pressure Tunnel (shaft 14) is around 45 metres from the M4-M5 Link mainline tunnels.

The City Tunnel was constructed circa 1960 and is described as having an excavated diameter of 3,000 millimetres with cement lined steel pipe of 2,100 millimetres diameter and is located at an approximate invert level of RL-15 metres AHD. The M4-M5 Link mainline tunnel alignment passes below the Sydney Water City Tunnel in the vicinity of Princes Highway and Alice Street in Newtown. This interface is shown in **Figure 12-31**. In this location, the top of the M4-M5 Link mainline tunnels are located about 11 metres below the invert level for the City Tunnel.

In the unlikely event that settlement was to impact on a section of either of these water tunnels then this could result in water leaking through tunnel seals or joints and travelling through the geological profile to reach the surface, in turn impacting on property, buildings and infrastructure. Alternatively the leaking water could travel through the geological profile to intercept the motorway tunnels resulting in additional water inflows to the tunnels. Water leaks could result in a range of potential impacts including:

- Impact on customer service due to reduced water pressure
- Physical damage to property, buildings and infrastructure
- Physical damage to motorway tunnels
- Long delays to complete the necessary repairs to the water tunnels impacting on customer service
- Costs to repair the water tunnels and any properties, buildings and infrastructure impacted.

Due to the clearance achieved by the M4-M5 Link alignment relative to the Sydney Water tunnels, and the geological conditions in the areas where these cross over points occur, it is expected the Sydney Water assets would not be adversely impacted. Preliminary settlement assessments have predicted that both of the Sydney Water tunnels would experience minimal movement:

- Around two to five millimetres (upward heave) and maximum angular distortion of one in 3,000 for the Pressure Tunnel
- Around 10 to 16 millimetres (settlement) and maximum angular distortion of one in 2,000 for the City Tunnel.

The assessment was based on assumptions about the strength and stiffness of the water tunnels given that limited information about the design and condition of these assets was available.

Detailed surveys should be undertaken to verify the levels and condition of these Sydney Water assets. A detailed assessment would be carried out in consultation with Sydney Water to demonstrate that construction of the M4-M5 Link tunnels would have negligible adverse settlement or vibration impacts on these tunnels. A settlement monitoring program would also be implemented during construction to validate or reassess the predictions should it be required.

Sydney Metro City and Southwest rail tunnels

The M4-M5 Link mainline tunnel alignment passes beneath the approved Sydney Metro City and Southwest rail tunnels in the vicinity of Lord Street at Newtown. This interface is shown in **Figure 12-32**.

At this location it is understood that the Sydney Metro tunnels are located at a depth of around 20 metres below existing ground level. The Sydney Metro tunnels will be excavated by Tunnel Boring Machine and the two tunnels will each have a diameter of seven metres and a 13.9 metre centre to centre spacing. An eight metre exclusion zone applies around the proposed Sydney Metro tunnels (above, below and to each side of the tunnels). It is understood that the Sydney Metro tunnels are likely to be constructed prior to the M4-M5 Link tunnels although it is likely that they would not be in operation by the time the M4-M5 Link tunnel excavation was complete.

In this location, the M4-M5 Link tunnels (the mainline tunnels connecting to the New M5 and the ramp tunnels connecting to St Peters interchange) are at a depth varying between around 35 and 45 metres below ground level. On this basis, it is considered that there is adequate separation distance provided between the M4-M5 Link mainline tunnels and the Sydney Metro tunnels and the eight metre exclusion zone would not be impacted.

In the unlikely event that settlement was to impact on the Sydney Metro tunnels, it could result in structural damage to the tunnel linings potentially leading to delays in the construction program, costs to repair the damage and impacts on commuters if the opening of rail services is delayed. The preliminary assessment has predicted that construction of the M4-M5 Link mainline tunnels would cause maximum settlement of about 10 millimetres and maximum angular distortion of 1:1,700 to the Sydney Metro tunnels. It is not expected that this magnitude of settlement would adversely impact on the Sydney Metro tunnels.

During detailed design, an assessment would be carried out in consultation with Transport for NSW to establish appropriate technical criteria in relation to settlement and vibration and demonstrate that construction of the M4-M5 Link tunnels would have no adverse impacts on the Sydney Metro tunnels. A settlement monitoring program would also be implemented during construction to validate or reassess the predictions should it be required.

Inner West Light Rail line

The Inner West Light Rail line is a 12.7 kilometre route connecting Central Station and Dulwich Hill via 23 light rail stops, including stops at Rozelle Bay and Lilyfield in the vicinity of the proposed Rozelle interchange. The light rail line transports more than 9.7 million customers each year. It is assumed that the maximum speed on the light rail line is between 40 and 60 kilometres per hour.

The proposed M4-M5 Link tunnels cross below the existing light rail line in two locations in the vicinity of City West Link and Lilyfield Station. At the eastern location the preliminary assessment shows predicted settlement in the range five millimetres to 10 millimetres. At the western location the predicted settlement is in the range 10 millimetres to 15 millimetres and the angular distortion is greater than one in 2,000 (vertical to horizontal (V:H)).

The tunnels also cross below the CSELR maintenance depot which is currently being constructed in the area between the light rail line and Lilyfield Road. It is understood that the maintenance depot will commence operation in 2019. In this location, the predicted settlement is in the range of five to 10 millimetres and the angular distortion is in the range one in 1,500 to one in 2,000 (H:V). The assessment indicates that with appropriate engineering support in place, ground movement is not likely to be a significant issue for the light rail line or the maintenance depot in this area.

In the unlikely event that settlement was to impact on a section of the light rail line this could lead to safety issues for vehicles using the impacted section of track and short term closures of the line to allow for the necessary repairs. This in turn would potentially impact on the level of service for commuters. There would also be additional costs to repair any impacted section of track.

Discussions would be undertaken with RailCorp to establish appropriate technical criteria in relation to settlement and vibration and to determine the requirements for monitoring. A settlement monitoring program would also be implemented during construction to validate or reassess the predictions should it be required.

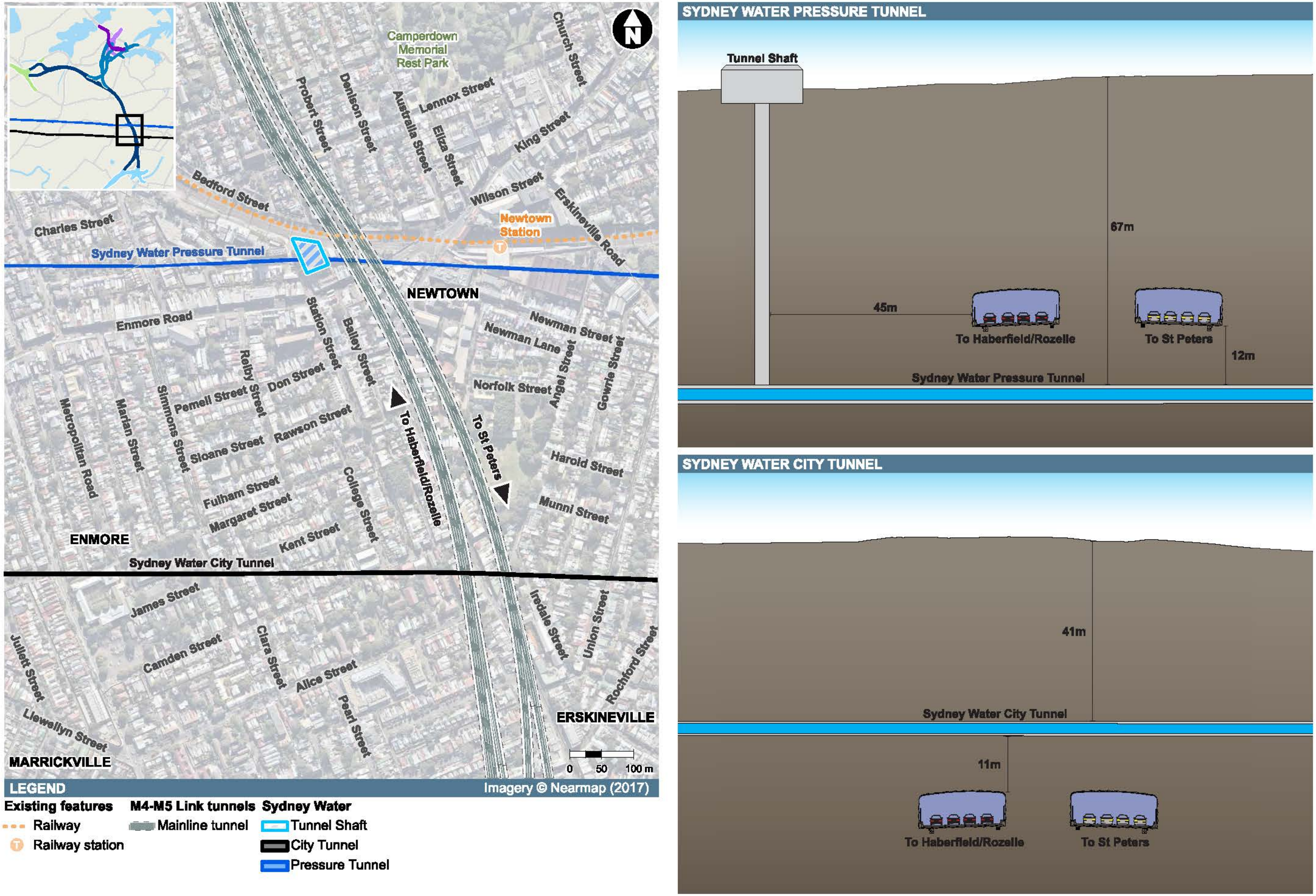


Figure 12-31 Interface with Sydney Water Pressure Tunnel and Sydney Water City Tunnel

Sydney Metro West rail tunnels

Sydney Metro West would provide a direct connection between the CBDs of Parramatta and Sydney and would work with the existing T1 Western Line, effectively doubling rail capacity from Parramatta to the CBD. It is understood that the final number of stations and the alignment of the line will be finalised through community and industry consultation. Four key precincts to be serviced have been identified including Parramatta, Sydney Olympic Park, The Bays Precinct and Sydney CBD. The project is expected to be built largely underground and be operational in the second half of the 2020s.

Insufficient public information is available at this time regarding the alignment of the proposed Sydney West Metro rail tunnels to determine whether there is a direct interface with the M4-M5 Link project. Consultation will be undertaken with Transport for NSW regarding the potential interface of the two projects as the preliminary design for the Sydney West Metro project is developed and, if required, adjustments to horizontal and vertical alignments of the tunnels can be made during the detailed design phase.

Utilities

Utility services in areas within the M4-M5 Link project footprint, particularly where works are proposed close to the surface, should be managed to prevent adverse impacts. The Utilities Management Strategy (**Appendix F**) identifies the significant utility services within the project footprint that would either be:

- Avoided
- Retained and protected (if required)
- Relocated
- Removed.

Where necessary, consultation would occur with the relevant utility service provider regarding the utility works which are proposed. This would include establishing appropriate settlement and vibration criteria, carrying out further assessments of potential impacts and monitoring of impacts if required.

Interface agreements

Interface agreements would be agreed with the owners of infrastructure and utility services likely to be impacted by construction of the project. These agreements may typically include: establishing appropriate settlement and vibration criteria; carrying out further detailed assessments of potential impacts; and monitoring of settlement and vibration impacts if required.

Management of potential impacts

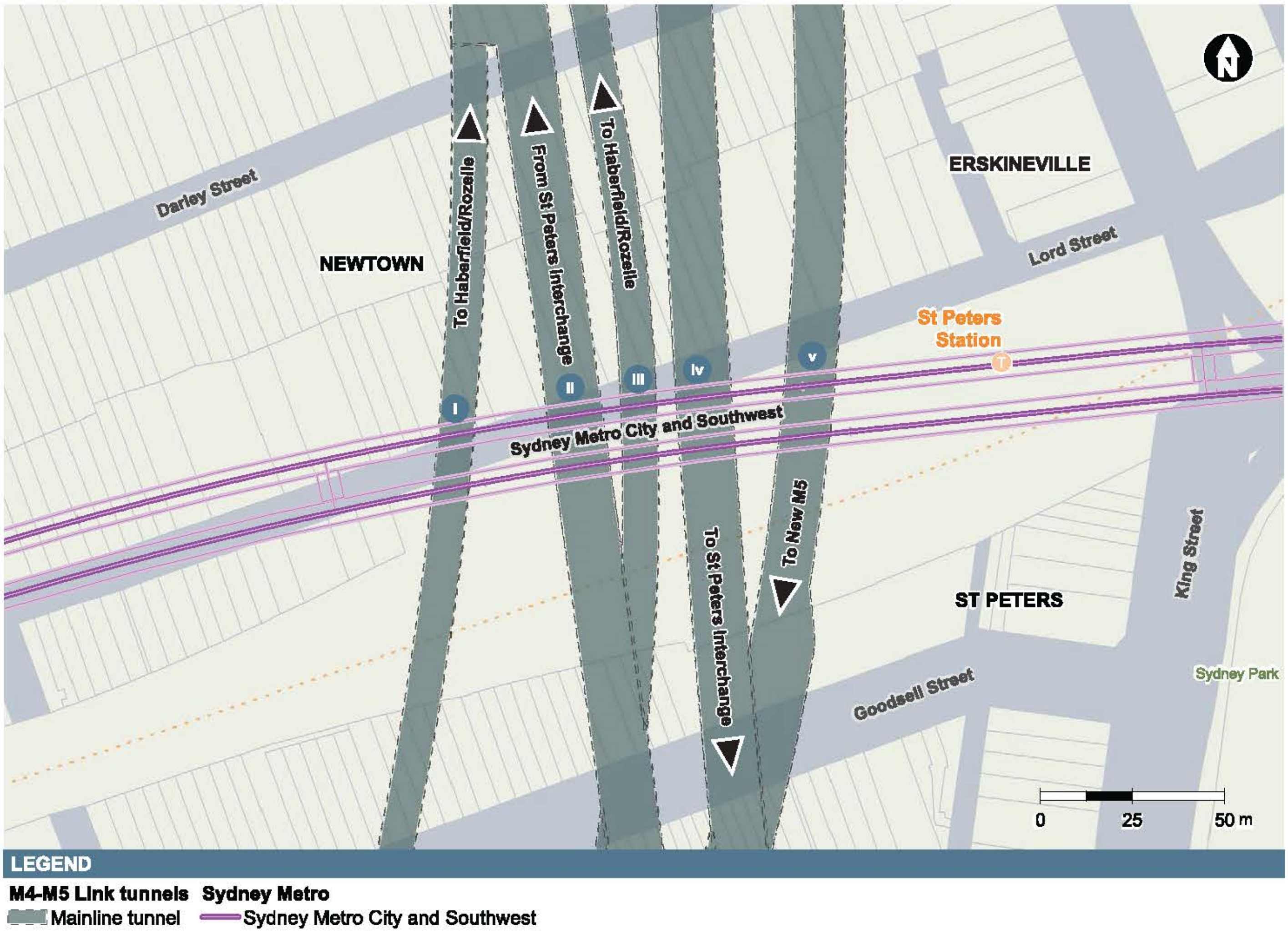
Prior to and during construction a range of management measures would be implemented to ensure that ground movement impacts are managed including:

- Ground settlement will be managed to comply with the accepted settlement, angular distortion and limiting tensile strain criteria
- Development of detailed predictive settlement models to guide tunnel design and construction methodology, including the selection of options to minimise settlement where required
- Preparation of building condition surveys for properties within the zone of influence of tunnel settlement (50 metres from the outer edge of the tunnels and within 50 metres of surface works)
- Preparation and implementation of a Settlement Monitoring Plan
- Where construction of the project is deemed the cause of cracking or property damage, the damage would be repaired at no cost to the owner
- An Independent Property Impact Assessment Panel, comprising of geotechnical and engineering experts, will be established prior to the commencement of works to independently verify building condition survey reports, resolve any property damage disputes and establish ongoing settlement monitoring requirements

- Preparation of agreements with utility owners and infrastructure owners identifying acceptable limits of settlement, settlement monitoring and actions in the event that settlement limits are exceeded.

These management measures are discussed further in **section 12.5**. Similar management measures have been successfully implemented to manage potential settlement impacts on a number of recent road and rail tunnelling projects in the Sydney metropolitan region.

Further details regarding ground borne noise and vibration including anticipated damage categories for reference buildings are provided in **Chapter 10** (Noise and vibration). Further details regarding predicted groundwater drawdown and associated settlement impacts are provided in **Chapter 19** (Groundwater). Further details regarding potential impacts of the project on utilities are provided in **Appendix F** (Utilities Management Strategy).



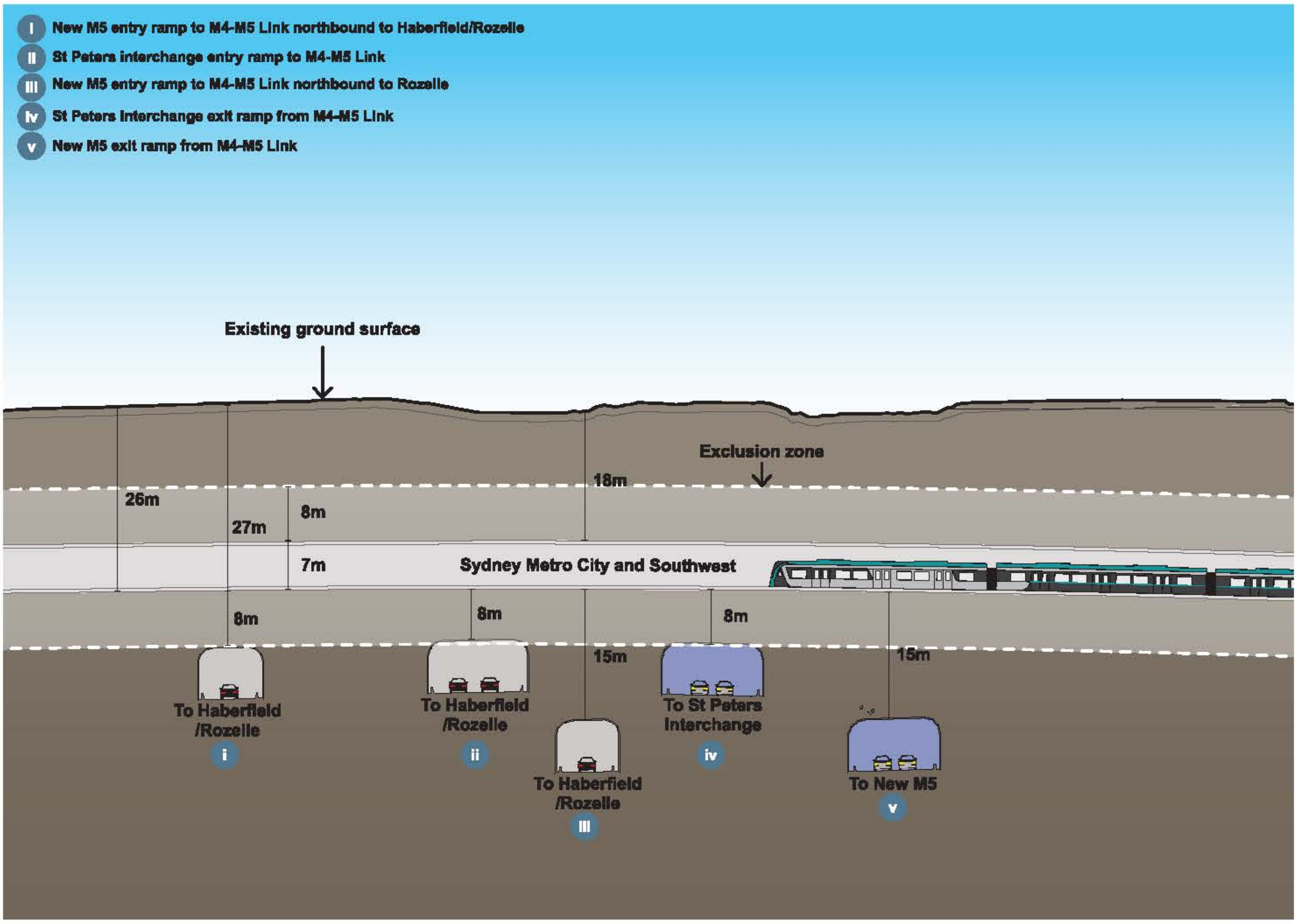


Figure 12-32 Interface with Sydney Metro City and Southwest Tunnels

12.4 Potential impacts – land use

Land use changes as a result of the project would occur largely in response to the introduction of new construction and/or transport infrastructure at Haberfield, Ashfield, Leichhardt, Lilyfield, Rozelle, Annandale and St Peters. The project would not impact on land subject to development applications.

The following sections summarise the potential implication of the proposed transport infrastructure, landscaping, construction ancillary facilities and construction activities on existing land uses, land use zonings and the development potential of land. This section also describes potential impacts on water users and land use impacts associated with utility works. An overshadowing assessment of permanent buildings and structures which have the potential to result in overshadowing on neighbouring residential properties is also included in this section. Shadow diagrams indicating the extent of overshadowing on properties that is currently expected as a result of permanent operational infrastructure are provided in **Appendix M** (Shadow diagrams and overshadowing).

Potential indirect impacts as a result of changes to land use would predominantly relate to social and economic values. **Chapter 14** (Social and economic) and **Appendix P** (Technical working paper: Social and economic) provide details relating to these potential impacts. In addition, potential settlement impacts are discussed in this section and in **Chapter 10** (Noise and vibration) and **Chapter 19** (Groundwater).

12.4.1 Wattle Street interchange surface works

Direct land use impacts

The Wattle Street interchange surface works would be temporary and carried out within the existing road reserve (Wattle Street) or on land being used as construction ancillary facilities for the M4 East project. These construction works would be consistent with the current and future use of the land as transport infrastructure, and would not adversely impact on land use or development potential. However, the use of this land for construction would extend the total period of time to which adjacent land users may be subject to potential impacts. Cumulative impacts, including impacts relating to extended construction durations are anticipated to be primarily related to issues of amenity such as construction noise and dust, access and changes to the road network and associated socio-economic impacts. These are assessed in **Chapter 26** (Cumulative impacts).

At the conclusion of construction, the site would be used for transport infrastructure (Wattle Street interchange). Remaining land on the site not used for transport infrastructure would be rehabilitated and landscaped consistently with the M4 East Residual Land Management Plan, the M4 East UDLP and/or the M4 East Legacy Project. These plans are being prepared and implemented as part of the M4 East project, in accordance with the relevant conditions of approval.

12.4.2 Parramatta Road West civil and tunnel site (C1b) and the Parramatta Road East civil site (C3b)

Direct impacts on existing land use

The use of this land during construction as construction ancillary facilities would change the land use temporarily from commercial to construction infrastructure. This would temporarily increase the total amount of land being used for construction in this area, as land south of Bland Street at Ashfield is also being used to support construction of the M4 East project until 2019.

The use of this site during construction would temporarily remove the potential for redevelopment of the site for commercial purposes (that may otherwise have been possible given its B6 Enterprise Corridor land use zoning) which, coupled with the use of land for construction of the M4 East project adjacent and to the south of Bland Street, would have a moderate impact on local land use. However, given the length of the Parramatta Road corridor and the number of similar potential commercial redevelopment sites, the project would have a minor, temporary impact on regional land use.

Following construction, the site would be rehabilitated to generally the existing ground level or as otherwise agreed with Roads and Maritime. Future development would be determined by Roads and Maritime, and would be subject to separate development assessment and approval and the restrictions of the relevant consent authority. The project would not rezone or consolidate remaining project land and therefore there would be no permanent changes to land use zoning for future development. Further details on the potential development and/or use of remaining project land at this location would be outlined in the Residual Land Management Plan that would be prepared for the project.

Land uses of adjoining properties would not be directly impacted by the use of this land during construction. Potential indirect amenity impacts during construction to adjoining land uses are assessed separately including in **Chapter 8** (Traffic and transport), **Chapter 9** (Air quality), **Chapter 10** (Noise and vibration) and **Chapter 14** (Social and economic).

Land use/transport integration and opportunities

As the site is directly adjacent to Parramatta Road, there is potential for the construction of the project to have a short term impact on the realisation of projects that are associated with the *Parramatta Road Corridor Urban Transformation Strategy* (UrbanGrowth NSW 2016). However, given the temporary nature of the construction works, it is not anticipated this would have a long term or significant impact on future development potential of the site. When considering potential reuse opportunities for this land, Roads and Maritime would have regard to the objectives of the *Parramatta Road Corridor Urban Transformation Strategy.*

The project would act as a catalyst for the proposed urban transformation along Parramatta Road through a forecast reduction in traffic east of the M4 East entry and exit ramps (as detailed in **Chapter 3** (Strategic context and project need)).

12.4.3 Darley Road surface works

Direct impacts on existing land use

The introduction of a construction ancillary facility at this location would result in a temporary change in land use from commercial to construction infrastructure.

A permanent change in land use would also occur at this location following the completion of construction, with around 0.2 hectares of the site to be used for the Darley Road motorway operations complex (MOC1), with the remainder likely to become remaining project land and therefore be subject to the Residual Land Management Plan that would be prepared for the project. The change in land use related to the use of a portion of the site for operational infrastructure would be inconsistent with the current land use zoning (B2 Local Centre under the Leichhardt LEP 2013). However, this change would be generally consistent and compatible with the land use in the immediate vicinity of the proposed motorway operations complex (transport infrastructure including the Inner West Light Rail line and associated Leichhardt North light rail stop). This change in land use would have a minor to moderate local impact on land use. However, the broader area contains a number of similar commercial premises and this change is therefore considered to be a minor regional impact on land use.

The indicative siting of operational project infrastructure (as shown in **Chapter 5** (Project description)) has been developed in consideration of maximising areas of land that would be available for potential future development (remaining project land). This has primarily been achieved by optimising the design to co-locate facilities, therefore reducing land-take. The siting of the operational project infrastructure at the western end of the site also allows for the remaining project land component to be located nearest to the Leichhardt North light rail stop. Future development would be determined by Roads and Maritime, and would be subject to separate development assessment and approval and the restrictions of the relevant consent authority. The project would not rezone or consolidate remaining project land and therefore there would be no permanent changes to land use zoning for future development. Further details on the potential development and/or use of remaining project land at this location would be outlined in the Residual Land Management Plan that would be prepared for the project.

12.4.4 Rozelle surface works

To assess land use impacts at Lilyfield and Rozelle, the Rozelle surface works have been broken down into three areas:

- Rozelle Rail Yards

- The Crescent and Whites Creek
- Victoria Road and Anzac Bridge approaches.

Rozelle Rail Yards

Direct impacts on existing land use

Construction activities in the Rozelle Rail Yards, including the establishment of a construction ancillary facility would result in a temporary change in land use from redundant industrial and transport infrastructure to construction infrastructure. This change in land use would be lessened due to the site management that would be carried out within the Rozelle Rail Yards in accordance with a separate environmental assessment and approval. A description of these site management works is provided in **Chapter 2** (Assessment process). This change in land use during construction would have a negligible impact on local and regional land use as the majority of the site is currently inaccessible and disused. The construction works along City West Link would not change the existing land use and would therefore have a negligible land use impact.

The urban design and landscaping concept for the Rozelle Rail Yards is described in **Chapter 5** (Project description) and shown in **Appendix L** (Technical working paper: Urban design). The siting of operational project infrastructure such as the ventilation facilities and tunnel portals and entry and exit ramps has been developed in consideration of maximising areas of land that would be available for future landscaping and/or provision of community and social infrastructure. This has included consideration of reservation of adequate space between operational elements of the project to enable separate future delivery of sporting fields and associated elements such as amenities blocks and car parking.

The concept plan for the urban design and landscaping outcome at the Rozelle Rail Yards would be further refined during detailed design and would have regard to identifying opportunities to deliver outcomes that support and connect existing neighbourhoods, complement and stimulate local economies and provide opportunities for growth across existing and future local industries along and around Victoria Road at Rozelle. This could include provision of community and social infrastructure such as sporting fields and other active recreational facilities, and would be determined through consultation with relevant stakeholders and the community. The process for finalising the urban design and landscaping outcome would be detailed in the UDLP that would be prepared for the project.

The Rozelle surface works would be undertaken within the Interim Metro Corridor (see **section 12.2.2**) at the Rozelle Rail Yards. This area was designated for the Rozelle stabling and maintenance depot as part of the CBD Metro project The provision of operational project infrastructure as well as land that would be available for future landscaping and/or provision of community and social infrastructure as part of the M4–M5 Link would conflict with the proposed use of this land for the CBD Metro if the project was to proceed. Consultation will be undertaken with Transport for NSW regarding the potential interface of the two projects.

Land use/transport integration and opportunities

The Bays Precinct Transformation Plan identifies the Rozelle Rail Yards as providing an opportunity for mixed housing as well as public spaces and employment uses. The Bays Precinct Transformation Plan also identifies the potential for opportunities provided by the redevelopment of the Rozelle Rail Yards for integration and connection of communities to the north and south through the creation of public open space and improved connections between Lilyfield and the waterfront.

The NSW Government announced in July 2016 that the project would deliver up to 10 hectares of new open space/parkland and active transport links for the community. Further information on the provision of active transport links and open space is provided in **Chapter 5** (Project description).

While the project is consistent with The Bays Precinct Transformation Plan vision for the creation of new open spaces, provision of new pedestrian and cyclist links, and the acknowledgment of the rail heritage of the area, it is inconsistent with the Plan with respect to the development of the Rozelle Rail Yards for mixed housing. Should the project not proceed, the Rozelle Rail Yards would likely be developed in accordance with The Bays Precinct Transformation Plan, including the provision of public spaces, employment uses and mixed housing.

The Crescent and Whites Creek

Direct impacts on existing land use

The construction site adjacent to The Crescent (The Crescent civil site (C6)) is temporary and would only be required during construction. There would therefore be no permanent change to land use at this location. Following construction, the site's current land use would be retained through rehabilitation of the site to its pre-construction state (and function). Impacts on surrounding land uses would be negligible. Access to the businesses that use the Sydney Multihull Central Marina and associated parking would be protected and maintained during construction. Potential indirect amenity impacts during construction to adjoining land uses are assessed separately including in **Chapter 8** (Traffic and transport), **Chapter 9** (Air quality), **Chapter 10** (Noise and vibration) and **Chapter 14** (Social and economic).

Buruwan Park, which extends between The Crescent and Bayview Crescent/Railway Parade at Annandale, would be permanently acquired for use for road infrastructure, primarily to accommodate the realignment of The Crescent. This would be a direct loss of around 0.3 hectares of public open space at Annandale and would therefore impact directly on recreational users of this area. This change in land use from recreational land to infrastructure would have a moderate to high local impact on land use. Buruwan Park acts as a passive recreational for the community, and a pedestrian walkway that connects Bayview Crescent and The Crescent with the Rozelle Bay light rail stop. However, the provision of new open space within the Rozelle Rail Yards and new pedestrian and cyclist bridges and paths to provide connectivity is considered to be a beneficial outcome for the community, and the loss of Buruwan Park is therefore minor in the regional context.

As described in **Chapter 6** (Construction work) and **Chapter 8** (Traffic and transport), equivalent access would be provided during construction prior to the closure and removal of Buruwan Park. Under the permanent design, connectivity between Bayview Crescent, The Crescent and the Rozelle Rail Yards would be improved through the provision of a pedestrian and cyclist bridge that would span The Crescent and City West, including new pedestrian connections to the Rozelle Bay light rail stop. This new pedestrian and cyclist bridge is described in **Chapter 5** (Project description).

Land use/transport integration and opportunities

The design of new pedestrian and cyclist connections over City West Link linking the Rozelle Rail Yards with Whites Creek/Railway Parade and The Crescent at Annandale would support the realisation of The Bays Precinct Transformation Plan and provide for improved connectivity to the Rozelle Bay light rail stop. The realignment of The Crescent would also enable potential future development of waterfront land between The Crescent and Rozelle Bay by creating a larger contiguous land parcel than the relatively narrow area that is currently available. Potential future development of this land does not form part of the project and would be subject to separate planning processes by others.

Victoria Road and Anzac Bridge approaches

Direct impacts on existing land use

The Victoria Road civil site (C7) and reconstruction of Victoria Road would result in the loss of commercial and residential premises located on the western side of Victoria Road and the potential future redevelopment of this land for commercial and local centre uses in accordance with the land zoning.

This change in land use from commercial to transport infrastructure would have a moderate impact on local land use. However, the broader area surrounding the site on Victoria Road contains commercial uses and proportionately the loss of these commercial premises is minor in a regional context. Remaining project land at the site would be subject to landscaping in accordance with the UDLP to be prepared for the project.

Widening of Victoria Road on the approach to and from Anzac Bridge would extend into the White Bay Power Station Destination as identified in The Bays Precinct Transformation Plan. This would have a minor land use impact on the potential future development of this land for commercial and residential purposes.

Land use/transport integration and opportunities

The design of the new bridge at the Victoria Road/The Crescent intersection has included reservation of space below the bridge for an active transport connection between Anzac Bridge and the Rozelle Rail Yards. This connection would also be designed such that a future connection into the White Bay Power Station Destination and broader The Bays Precinct (being developed by UrbanGrowth NSW separate to this project) could be integrated.

The works proposed on the eastern side of the new bridge to connect motorists travelling from the Rozelle interchange to Anzac Bridge have been designed in consideration of proposed future development at the White Bay Power Station site. This has included optimising the design of the permanent operational infrastructure (including roads, active transport connections and utility works) at this location to minimise encroachment.

12.4.5 Iron Cove Link surface works

To assess land use impacts associated with the Iron Cove Link surface works, the Iron Cove Link surface works have been divided into two areas:

- The area around the Iron Cove Link portals and entry and exit ramps along Victoria Road
- The bioretention facility and car park improvement works within King George Park, adjacent to Manning Street.

Iron Cove Link portals and entry and exit ramps along Victoria Road

Direct impacts on existing land use

The introduction of a construction ancillary facility at this location (the Iron Cove Link civil site (C8)) would result in a temporary change in land use from commercial to construction infrastructure. This change in land use would temporarily remove the development potential of the site for residential purposes given the land's R1 land use zoning under the Leichhardt LEP 2013.

The predominant change in land use at this site would be from residential and commercial to transport infrastructure and open space and/or community facilities. This change is associated with the acquisition of properties south of Victoria Road to accommodate road widening and the Iron Cove Link motorway operations complex (MOC4), including the Iron Cove Link ventilation facility, and the subsequent provision of urban design and landscaping of land not required for transport infrastructure.

The urban design and landscaping concept for the Iron Cove Link portals and entry and exit ramps along Victoria Road is described in **Chapter 5** (Project description) and shown in **Appendix L** (Technical working paper: Urban design). The siting of operational project infrastructure such as the ventilation facilities and tunnel portals and entry and exit ramps has been developed in consideration of maximising areas of land that would be available for future landscaping and/or provision of community and social infrastructure.

This has included siting the ventilation facility and substation at the eastern perimeter of the area that would be disturbed south of Victoria Road. By doing so, a contiguous parcel, albeit interrupted by Callan, Toelle and Clubb streets, would be provided to enable strong connections between Springside Street, King George Park and Iron Cove Bridge, supported by the provision of an improved active transport connection as part of the project. This approach also enables revitalisation of this section of Victoria Road through delivery of the urban design and landscaping outcome, as well as providing a template for potential future replication by others east along Victoria Road.

The concept plan for the urban design and landscaping outcome around the Iron Cove Link portals and entry and exit ramps along Victoria Road would be further refined during detailed design and would have regard to identifying opportunities to deliver outcomes that support and connect existing neighbourhoods, complement and stimulate local economies and provide opportunities for growth across existing and future local industries along and around Victoria Road at Rozelle. This could include provision of community and social infrastructure such as passive recreational facilities, outdoor gyms and/or infill residential and would be determined through consultation with relevant stakeholders and the community. The process for finalising the urban design and landscaping context around the Iron Cove Link portals and entry and exit ramps along Victoria Road would be detailed in the UDLP that would be prepared for the project.

In addition, a small section of land currently used for public recreation within King George Park (immediately south of the eastern Iron Cove Bridge approach) would be used temporarily during construction. A portion of this land would then be permanently occupied for transport infrastructure purposes (including carriageways and pedestrian and cyclist paths) during operation. The remaining project land not required for operation would be rehabilitated and returned for use for public recreation purposes. This change would have a negligible permanent impact on recreational users as the land that would be occupied is at the periphery of the park and comprised predominantly of landscaping and an embankment. In addition, new landscaped areas to be provided on the southern side of Victoria Road to the east of this location would offset this loss.

The Bay Run connection between King George Park and Iron Cove Bridge would be maintained during construction. Diversions around the construction area within King George Park would be provided, including a temporary connection between King George Park and the shared path on Iron Cove Bridge. Following the completion of construction, the connection between the Bay Run and Victoria Road and Iron Cove Bridge would be reinstated in generally the same arrangement as existing.

Bioretention facility and car park improvement works

Direct impacts on existing land use

A bioretention facility and carpark improvement works would be constructed within an existing informal car park within King George Park, adjacent to Manning Street at Rozelle. The land is zoned for public recreation uses. This facility would treat stormwater run-off from Victoria Road to the north. The provision of pipes to convey this water is described in further detail in **Appendix F** (Utilities Management Strategy). Public recreation areas adjacent to the site would remain and would not be affected during construction.

The use of part of this land for car parking would be temporarily restricted during construction for a period of around three months. Around half of the car parking spaces would be retained. A detailed car parking strategy would form part of the Construction Traffic and Access Management Plan and would be developed in consultation with local councils and stakeholders associated with public facilities adjacent to project sites. Further, opportunities such as limiting construction at this location to weekdays and carrying out these works during periods when demand for parking at King George Park is lower would be investigated during detailed design.

At the completion of construction, the existing land use (an informal car park) would be reinstated in an enhanced form through the car park improvement works (to formalise the car park) and associated landscaping. The current zoning and use of King George Park for public recreation limits the potential for development of the site for other permissible uses. The potential for construction of the bioretention facility to significantly affect the development potential of the site would therefore be low.

There is potential for the project to temporarily impede upon plans to improve parking availability and amenity at King George Park as identified in the Draft King George Park Plan of Management (Leichhardt Council, 2012). However, the formalisation of around 30 car parking spaces would result in a beneficial land use outcome for this land. The formalisation of the carpark would improve the safety and efficiency of the carpark through the provision of marked crossing locations and delineated parking spots. This would be consistent with the King George Park Draft Plan of Management, which recognises that improvements to the ease of use, safety and capacity of the carpark are required.

12.4.6 Pyrmont Bridge Road surface works

Direct impacts on existing land use

The Pyrmont Bridge Road tunnel site (C9) would be located between Parramatta Road and Pyrmont Bridge Road at Annandale on land that is currently used by commercial and industrial businesses. These uses would not be possible during construction, and closure of the existing commercial and industrial premises and demolition of the existing buildings would be required.

The use of this site during construction would also temporarily remove the potential for redevelopment of the site for light industrial purposes (that may otherwise have been possible given it is IN2 Light Industrial land use zoning under the Leichhardt LEP 2013). This change would have a moderate permanent impact on land use as it would remove the existing commercial and light industrial uses. However, the wider area contains a number of similar light industrial and commercial premises and this change would have a minor regional impact on land use.

Following construction, the site would be rehabilitated to generally the existing ground level or as otherwise agreed with Roads and Maritime. Future development would be determined by Roads and Maritime, and would be subject to separate development assessment and approval and the restrictions of the relevant consent authority.

The project would not rezone or consolidate remaining project land and therefore there would be no permanent changes to land use zoning for future development. Further details on the potential development and/or use of remaining project land at this location would be outlined in the Residual Land Management Plan that would be prepared for the project.

Land use/transport integration and opportunities

As the site is directly adjacent to Parramatta Road, there is potential for the construction of the project to have a short term impact on the realisation of projects that are associated with the *Parramatta Road Corridor Urban Transformation Strategy*. However, given the temporary nature of the construction works, it is not anticipated this would have a long term or significant impact on future development potential of the site. When considering potential reuse opportunities for this land, Roads and Maritime would have regard to the objectives of the *Parramatta Road Corridor Urban Transformation Strategy.*

The project would act as a catalyst for the proposed urban transformation along Parramatta Road by facilitating a forecast reduction in surface road traffic along Parramatta Road, east of the M4 East entry and exit ramps (as detailed in **Chapter 3** (Strategic context and project need)).

12.4.7 St Peters interchange surface works

Direct impacts on existing land use

The St Peters interchange is being constructed and delivered by the New M5 project. Integration works to connect the M4-M5 Link with the St Peters interchange and construction of the Campbell Road motorway operations complex would occur on the site. As this area is currently being used for the construction of the New M5 project, the ongoing use of this area for the construction of the project would be consistent with the current land use.

The remainder of the site would be landscaped and converted into public open space following the completion of the M4-M5 Link and the New M5 projects. Urban design and landscaping works would be carried out in accordance with the UDLP and consistent with the New M5 Residual Land Management Plan and the New M5 UDLP.

12.4.8 Access impacts

Direct impacts on property access

Access to properties not acquired, leased or otherwise occupied for project purposes would generally be maintained at all times during construction and operation. Where temporary impacts on existing property access are unavoidable as a result of construction activities (eg footpath and pavement works), consultation would be carried out with the landowner and/or tenant to provide equivalent standards of access. Short-term changes to access during construction are described further in **Chapter 6** (Construction work).

Indirect, permanent changes to access resulting from road closures and/or modifications are discussed in the following section. The traffic and transport impacts from these changes are described in **Chapter 8** (Traffic and transport).

Indirect impacts on property access

Rozelle surface works

The Rozelle interchange would require the permanent closure of Gordon Street south of Lilyfield Road. This bi-directional road is a cul-de-sac at the boundary of the Rozelle Rail Yards and is used to access businesses along this short section of the road. The properties using Gordon Street for access would be acquired for the project and as a result, the closure of this road would not have permanent impacts on access to private property. No other local roads around the Rozelle interchange would be permanently impacted by the project.

Iron Cove Link surface works

The project would alter access and connectivity around the Iron Cove Link portals along Victoria Road via the introduction of permanent operational infrastructure and associated upgrades and modifications to the surface road network. Toelle Street and Callan Street would be reopened in the same traffic operational arrangement as existing. Clubb Street would be converted into a permanent cul-de-sac. Residents accessing Clubb Street could use Toelle Street or Callan Street via Manning Street to access from Victoria Road. The Byrnes Street cul de sac would be retained but would be moved a short distance to the southwest.

The closure of Clubb Street would require motorists, who currently use the left-in, left-out intersection with Victoria Road, to use an alternative route to travel between Clubb Street and Victoria Road. This would slightly increase travel times for motorists. However, the creation of a cul-de-sac at the northern terminus of Clubb Street would also provide opportunities for amenity improvements along this street, as through traffic would be reduced. These amenity improvements would be further supported by the integration of pedestrian paths along Clubb Street with the upgraded east–west active transport network that would be provided along Victoria Road.

There would also be permanent impacts on residential and business on-street parking provision. However, most of these parking spaces are adjacent to properties being acquired and so the impact of their loss is reduced. The final numbers would be confirmed during detailed design.

Changes to access and connectivity associated with the Iron Cove Link surface works are further described in **Table 12-5**. Impacts on property access due to changes in the road network are assessed in **Chapter 8** (Traffic and transport) and **Chapter 14** (Social and economic).

Table 12-5 Changes to access and connectivity for the Iron Cove Link surface works

Location	Changes to access and connectivity
Byrnes Street	Modification to existing cul-de-sac to suit Victoria Road widening
Clubb Street	Closure at Victoria Road and creation of a cul-de-sac to suit Victoria Road widening
Toelle Street	Minor adjustments at intersection with Victoria Road to suit new road alignment
Callan Street	Minor adjustments at intersection with Victoria Road to suit new road alignment
Terry Street	Minor adjustments to the right-hand turn from Victoria Road southern (westbound) carriageway into Terry Street
Shared path along southern carriageway of Victoria Road	Provision of upgraded shared path to suit new road alignment including integration with the Bay Run at King George Park
Informal car park within King George Park, adjacent to Manning Street	Provision of formalised car park and bioretention facility. Existing access arrangements at Manning Street would be maintained

Impacts on pedestrian and cyclist access

Temporary changes to pedestrian and cyclist access to facilitate construction of the project would be required. In most cases, footpath access for pedestrians along surface roads where works would be carried out would be maintained on at least one side of the road at all times. Where works would require pedestrians to use an alternative route for a short period of time to ensure the safety of pedestrians and construction workers, these alternate routes would be clearly delineated.

Closure of a section of footpaths on both sides of Northcote Street at Haberfield would be required during construction. This would be a continuation of the current closure of this section of footpaths along Northcote Street to facilitate construction of the M4 East project. Alternative access to Parramatta Road would be provided via Ash Lane and either Wolseley Street or Wattle Street at Haberfield.

The project would also require the removal of two pedestrian and cyclist bridges at Rozelle; the east–west bridge that spans across Victoria Road near Lilyfield Road, and the north–south bridge that extends across Victoria Road, connecting to the southern side of The Crescent. The shared path along the southern side of Victoria Road between around Springside Street and Byrnes Street at Rozelle would also be closed during construction. These changes to existing pedestrian and cyclist infrastructure would require temporary diversions to be established during construction. These are described and assessed in **Chapter 8** (Traffic and transport) and may result in a minor increase in travel times for pedestrians and cyclists. However, these increases in travel times would be temporary and would ensure pedestrian and cyclist safety is maintained during construction.

The pedestrian and cyclist infrastructure that would be removed at Rozelle would be permanently replaced by:

- A new east–west underpass below Victoria Road that would link Anzac Bridge and the future The Bays Precinct with the Rozelle Rail Yards and Lilyfield Road
- Two new north–south connections that would extend across City West Link, linking the Rozelle Rail Yards with The Crescent and Railway Parade at Annandale.

Together with a network of internal pathways in the Rozelle Rail Yards, the pedestrian and cyclist connections that would be provided around the Rozelle and Iron Cove Link surface works would connect:

- Victoria Road and Anzac Bridge
- The future The Bays Precinct
- Lilyfield Road and Easton Park
- The Inner West Light Rail line Rozelle Bay light rail stop
- Federal Park
- Whites Creek Valley Park
- Bicentennial Park.

A detailed description of the pedestrian and cyclist connections that would be provided at the Rozelle interchange is included in **Appendix N** (Technical working paper: Active transport strategy). Impacts on pedestrian and cyclist access due to changes in the road network during construction and operation are discussed in **Chapter 8** (Traffic and transport) and **Chapter 14** (Social and economic).

12.4.9 Impacts on water users

Potential impacts on water users would be limited to Rozelle Bay in proximity to The Crescent civil site (C6). Works at and around the site would involve the realignment of City West Link, the construction of the culvert below City West Link that would convey flows from the Rozelle Rail Yards to Rozelle Bay, upgrades to the Rozelle Bay outfall and flood mitigation works along Whites Creek between the light rail bridge and Rozelle Bay. These works would be likely to require construction equipment access from Rozelle Bay via barge or boat, and the establishment of coffer dams and/or other devices within the immediate vicinity of these construction areas.

Water users at Rozelle Bay in proximity to this construction ancillary facility include a maintenance barge wharf located immediately adjacent to the east of site, a wharf area (associated with a marine construction business) and the Sydney Superyacht Marina between James Craig Road and Rozelle Bay. Recreational water users may also use Rozelle Bay from time to time.

Access to land-based water users including the Sydney Superyacht Marina and maintenance barge wharf would be maintained during the construction and operation of the project. Impacts on water users would be minor and temporary, constrained to the periods of time where barges or boats would need access and to the area of works around the confluence of Whites Creek and Rozelle Bay. These works would likely occur over a period of up to around 24 months, however water craft movements associated with these movements would be minimal. Construction works would be limited to an area of Rozelle Bay not typically used by water users, and minimal boat traffic would be required. The project would therefore have negligible impact on water users.

12.4.10 Utility works

It is likely that utilities and services located within or close to the project footprint, including electricity, gas, telecommunications (including optic fibre cables), and sewer and water mains, would need to be protected, relocated or realigned as part of construction of the project. This is particularly the case around areas of surface or shallow soil disturbance.

A Utilities Management Strategy has been prepared for the project and is included in **Appendix F**. The Utilities Management Strategy provides information in relation to:

- Utility relocations and adjustments which are proposed within the project footprint. These have been assessed as part of the EIS and would be subject to a Utility Relocation Management Plan
- Utility relocations and adjustments which may be required in areas outside of the project footprint. The Utilities Management Strategy provides the framework for how these utility works would be assessed and managed including requirements for stakeholder and community consultation and further environmental assessment.

The utility services which have been considered in the strategy include: communications, gas, electricity, water, sewerage and drainage.

Potential land use and socio-economic impacts as result of the utility works could include:

- Impact on property access (eg driveways), noting that existing property access would be maintained other than for short periods during the works and in consultation with the property owner and/or lessee
- Impact on visibility of existing commercial businesses
- Impact on access to areas of public open space
- Amenity impacts on sensitive land uses such as schools, child care centres and medical facilities
- Amenity impacts on residential land uses adjacent to the work areas
- Temporary disruption to services such as power and water supply during the works
- Generating employment opportunities for workers during the construction phase
- Providing indirect economic benefits for some business during the construction phase.

These impacts can be managed by the proposed management measures identified in the Utilities Management Strategy in **Appendix F**, including preparation of a Communications Plan and providing prior notification to residential, business and other landowners that may be affected.

Potential amenity impacts on surrounding land uses as a result of utility works has been assessed in the relevant parts of this EIS, including **Chapter 8** (Traffic and transport), **Chapter 9** (Air quality, in particular **section 9.6**), **Chapter 10** (Noise and vibration), **Chapter 11** (Human health risk) **Chapter 13** (Urban design and visual amenity) and **Chapter 14** (Social and economic).

The project would also require connection to electricity, water and wastewater/sewer utilities. These connections are also described in detail in **Appendix F** (Utilities Management Strategy). The nature and extent of utility changes would be confirmed during the design development of the project, with appropriate relocation or replacement alternatives identified in accordance with the process identified in the Utilities Management Strategy.

12.4.11 Ground level development

This section describes where in this EIS potential changes in amenity for ground level receptors have been assessed and potential future changes to the nature and scale of development around key project connections over time.

Potential changes in amenity for ground level receptors have been assessed in the relevant parts of this EIS, including **Chapter 8** (Traffic and transport), **Chapter 9** (Air quality, in particular **section 9.6**), **Chapter 10** (Noise and vibration), **Chapter 11** (Human health risk) **Chapter 13** (Urban design and visual amenity) and **Chapter 14** (Social and economic).

In each case, the impacts of the project on local amenity have been demonstrated as manageable within acceptable limits, subject to the application of appropriate mitigation and management measures and this EIS generally. These mitigation and management measures are outlined in each chapter, and summarised in a consolidated form in **Chapter 29** (Summary of environmental management measures).

The ventilation facilities for the project would be located as far from existing residential dwelling as practicable. The locations of these facilities have also been selected to minimise potential impacts (including air quality and visual amenity impacts) to nearby residential receptors and other sensitive receptors, achieve positive urban design outcomes and ensure the efficient operation of these facilities. The operation of the ventilation facilities would not prevent continued use or development of surrounding land in accordance with the existing land use zoning.

The potential air quality impacts and human health impacts associated with the ventilation facilities are discussed **Chapter 9** (Air quality) and **Chapter 11** (Human health risk). Potential visual amenity impacts are discussed in **Chapter 13** (Urban design and visual amenity).

The provision of a new motorway standard connection between Haberfield, Rozelle and St Peters, and the future connection to the proposed future Sydney Gateway and Western Harbour Tunnel and Beaches Link, is likely to change the desirability of residential, commercial and industrial developments, particularly around motorway access points. This improved connectivity may make some areas more desirable for living and working than is currently the case. Changes in desirability are likely to gradually affect the nature and scale of development around key project connection points over time.

12.4.12 Elevated receptor locations

The project has the potential to influence development patterns for existing and future elevated receptor locations (for example, those receptors within multi-storey residential buildings) as a consequence of operation of the project’s ventilation outlets. Elevated receptors have the potential to experience higher air quality impacts because emissions from the ventilation outlets have less time to disperse compared to potential impacts at ground level. **Chapter 9** (Air quality) includes an assessment of potential air quality impacts for ground level and elevated receptor locations.

The future development of land (including re-zonings) in the vicinity of the ventilation facilities that may involve multi-storey buildings would need to consider the air dispersion performance of the ventilation facilities. Roads and Maritime would assist local councils or the DP&E in determining any relevant land use considerations applicable to future development for inclusion in LEPs or development control plans, where required. This would include procedures for identifying the width and height of buildings that are likely to be either affected by the plume from the ventilation outlet or affect the dispersion of the plume from the ventilation outlet.

Potential impacts on elevated receptors are relevant around:

- The Rozelle ventilation facility. Development patterns and height restrictions for developments in this area are regulated under the Leichhardt LEP 2013 and the SREP 26. Land around the Rozelle ventilation facility in the Leichhardt LGA and the SREP 26 is not currently subject to a statutory building height limit
- The Iron Cove Link ventilation facility. Development patterns and height restrictions for developments in this area are regulated under the Leichhardt LEP 2013. Land around the Rozelle

ventilation facility in the Leichhardt LGA and the SREP 26 is not currently subject to a statutory building height limit

- The Campbell Road ventilation facility at St Peters. Development patterns and height restrictions for developments in this area are regulated under the Marrickville Local Environmental Plan 2011 and the Sydney LEP 2012. Current building height controls applying around the Campbell Road ventilation facility are:
  - Development around the ventilation facility and within the Sydney LGA (to the north and east) is generally industrial in nature and subject to an 18 metre building height limit. Some areas along the Alexandra Canal have building height limits up to 22 metres
  - There are no statutory building height limits that apply to Sydney Park
  - Most land immediately around the Campbell Road ventilation facility in the Marrickville LGA is not currently subject to a statutory building height limit. Residential development further to the west, between the Princes Highway and Unwins Bridge Road is limited to a building height of 9.5 metres, which is around two storeys plus a roof structure.

Refer to **Chapter 9** (Air quality) for further information regarding potential impacts on elevated receptors.

12.4.13 Overshadowing

The project includes permanent buildings and structures that have the potential to result in overshadowing on neighbouring residential properties. Shadow diagrams for mid-winter (21 June) have been prepared for these buildings and structures and can be found in **Appendix M** (Shadow diagrams and overshadowing). The shadow diagrams in **Appendix M** (Shadow diagrams and overshadowing) only show the shadows cast by the proposed infrastructure and do not factor in the existing situation (ie any other structures (eg existing buildings and vegetation) that would currently cause overshadowing impacts). The shadow diagrams are therefore considered to be worst case and are not reflective of design work that would be undertaken to ensure that the buildings and structures would be designed to avoid potential impacts.

No assessment has been undertaken of overshadowing from potential noise barriers as no noise barriers are proposed as part of the concept design. However, noise barriers may be investigated as a potential noise mitigation option in some areas of the project (refer to **Chapter 10** (Noise and vibration)). Analysis of overshadowing impacts associated with noise barriers, if they are proposed, would be undertaken during detailed design.

Table 12-6 summaries the potential overshadowing impacts in mid-winter (21 June) expected as a result of permanent operational infrastructure.

Table 12-6 Potential overshadowing impacts of project infrastructure during operation (mid-winter (21 June))

Location	Description of potential impacts
Darley Road motorway operations complex (MOC1) including: • Water treatment facility • Substation	Shadows from the water treatment facility and substation would fall within the site and/or into the adjoining Darley Road road reserve. There would be no impacts on nearby residential properties.

Location	Description of potential impacts
Rozelle West motorway operations complex (MOC2) and pedestrian and cyclist facilities including: • Ventilation supply facility • Intake substation • Fire pump room and tanks • Pedestrian and cyclist bridge	Shadows from the ventilation supply facility, fire pump room/deluge tanks and substation would fall within the Rozelle Rail Yards site. The areas within the site that would be impacted would include the western drainage channel and associated landscape planting areas. There would be no impact on nearby residential properties. Shadows from the pedestrian and cyclist bridge structure would predominantly fall within parts of the adjacent road corridor (City West Link), the Inner West Light Rail line corridor and vegetated areas between the light rail corridor and the north side of Brenan Street at Annandale. There would be no impact on nearby residential properties or areas of public open space.
Rozelle East motorway operations complex (MOC3) and pedestrian and cyclist facilities including: • Ventilation exhaust facility • Three ventilation outlets • Substation • Water treatment facility • Pedestrian and cyclist bridge	Shadows from the three ventilation outlets and ventilation building would fall primarily within the Rozelle Rail Yards and the City West Link road reserve. The areas within the site impacted by overshadowing would include the tunnel portals to/from the proposed future Western Harbour Tunnel and Beaches Link, the western drainage channel and a limited area of the pedestrian and cyclist bridge. Shadows from the water treatment facility would fall within the Rozelle Rail Yards, on a driveway and carpark area associated with the water treatment facility and on the northern drainage channel. Shadows from the pedestrian and cyclist bridge structure would predominantly fall within parts of the adjacent road corridors (City West Link and The Crescent) and would also impact on limited sections of the western drainage channel. There would be no impact on residential properties or proposed public open space.
Iron Cove Link motorway operations complex (MOC4) including: • Ventilation facility • Ventilation outlet • Substation	Shadows from the ventilation outlet would impact on an adjoining residential property on the west side of Callan Street in the mid-morning. The shadows would be likely to affect habitable rooms and private open space of these properties for up to two hours in the worst-case shadow scenario (21 July). Shadows from the ventilation facility building would impact on an adjoining residential property on the eastern side of Callan Street in the mid to late morning. The impact is likely to affect habitable rooms and private open space of these properties for up to three hours in the worst-case shadow scenario (21 July). The habitable rooms and private open space are already likely to be impacted by overshadowing from existing buildings and structures along their northern boundary during at least part of this period. Shadows from the ventilation facility would also impact on a small number of adjoining residential properties on the west side of Springside Street in the mid to late morning and early afternoon. The impact is likely to affect habitable rooms and private open space of these properties for up to five hours. The habitable rooms and private open space are already likely to be impacted by overshadowing from existing buildings and structures along their northern boundary during at least part of this period.

Location	Description of potential impacts
Campbell Road motorway operations complex (MOC5) including: • Ventilation supply facility • Ventilation exhaust facility • Four ventilation outlets • Intake substation	Shadows from the ventilation building and associated infrastructure would fall within the St Peters interchange site, impacting on areas containing other operational infrastructure or proposed landscaping areas. There are no residential properties in the vicinity that would be affected by overshadowing. Areas of proposed open space being delivered by the New M5 project to the south east would not be impacted other than minor overshadowing impacts on a limited section of an adjacent pedestrian and cyclist path in the early to mid-afternoon.

Overall, residential properties affected by overshadowing from permanent operational components of the project would receive a minimum of three hours of direct sunlight in habitable rooms and in at least 50 per cent of principal private open space between 9.00 am and 3.00 pm on 21 June. The exception to this is the adjoining residential properties on the west side of Springside Street at Rozelle.

Where existing residential development currently receives less than this requirement, access to sunlight would not be unreasonably reduced. Detailed overshadowing analysis would be undertaken during detailed design to confirm the exact nature of any overshadowing impacts. This would include an analysis of dwelling layouts, levels and overshadowing from existing structures and to confirm the number of dwellings that would be affected.

Detailed design of the ventilation facility building at the Iron Cove Link motorway operations complex (MOC4) would include consideration of treatments to minimise overshadowing on properties south of Victoria Road. This may include reducing the height of the building and/or increasing building setbacks or recessing the building.

12.5 Management of impacts

Environmental management measures relating to land use and property are outlined in **Table 12-7**.

Table 12-7 Environmental management measures – land use and property

Impact	No.	Environmental management measure	Timing
Construction			
Acquisition of property required for the project	PL1	Land acquisition for the project will be undertaken in accordance with the *Land Acquisition (Just Terms Compensation) Act 1991* (NSW) and the *Roads and Maritime Services Land Acquisition Information Guide* (Roads and Maritime 2014) and the land acquisition reforms announced by the NSW Government in 2016.	Construction
Impacts on property access	PL2	The requirement for temporary changes to property access will be minimised during development of the detailed construction methodology. Affected landowners will be consulted when temporary, short-term changes to access to their property will occur. This will include advanced notification of relevant project schedules, construction works and changes to access arrangements.	Construction

<table>
<tr><th>Impact</th><th>No.</th><th>Environmental management measure</th><th>Timing</th></tr>
<tr><td>Uncertain future land use</td><td>PL3</td><td>A Residual Land Management Plan will be prepared in consultation with relevant local councils and other key stakeholders. The plan will:
• Identify and illustrate all remaining project land following construction of the project, including the physical location, land use characteristics, size and adjacent land uses
• Identify of feasible uses for remaining project land including justification for the selected use
• Identify timeframes for implementation of the actions in relation to the identified feasible uses.</td><td>Construction</td></tr>
<tr><td rowspan="2">Overshadowing of residential properties</td><td>PL4</td><td>Existing residential properties (and approved residential developments) that are affected by overshadowing from the final detailed design of the project (including any noise mitigation measures) are to receive a minimum of three hours of direct sunlight in habitable rooms and in at least 50 per cent of the principal private open space area between 9:00 am and 3:00 pm on 21 June. Such properties must be identified for further consideration by the Proponent in a Solar Access and Overshadowing Report which addresses compliance with these requirements:
• Where existing residential development currently receives less than the required amount of solar access, existing access to sunlight during operation should not be unreasonably reduced
• Where affected properties include dwellings held under strata or community title, these requirements must be interpreted in relation to individual units within those properties.</td><td>Construction</td></tr>
<tr><td>PL5</td><td>Detailed design of the ventilation facility building at the Iron Cove Link motorway operations complex (MOC4) will include consideration of treatments to minimise overshadowing on properties south of Victoria Road. This may include reducing the height of the building and/or increasing building setbacks or recessing the building.</td><td>Construction</td></tr>
<tr><td>Ground settlement</td><td>PL6</td><td>Ground settlement will be managed to comply with the following criteria where possible:
<table>
<tr><th>Beneath structure/facility</th><th>Maximum settlement</th><th>Maximum angular distortion</th><th>Limiting tensile strain (per cent)</th></tr>
<tr><td>Buildings – Low or non-sensitive properties (ie less than or equal to two levels and carparks)</td><td>30 mm</td><td>1 in 350</td><td>0.1</td></tr>
<tr><td>Buildings – High or sensitive properties (ie greater than or equal to 3 levels and carparks)</td><td>20 mm</td><td>1 in 500</td><td>0.1</td></tr>
<tr><td>Roads and parking areas</td><td>40 mm</td><td>1 in 250</td><td>N/A</td></tr>
<tr><td>Parks</td><td>50 mm</td><td>1 in 250</td><td>N/A</td></tr>
</table></td><td>Construction and operation</td></tr>
</table>

Impact	No.	Environmental management measure	Timing
Ground settlement	PL7	Further assessment of potential settlement impacts, including numerical modelling, will be undertaken based on detailed design. In areas where ground movement in excess of settlement criteria are predicted, feasible and reasonable measures would be investigated and implemented to ensure predicted settlement is within the criteria. Measures that will be considered may include (but are not limited to): • Review of the proposed tunnel design including: – the depth and alignment of tunnels – the proximity of multiple tunnels to each other – the proposed tunnel support system – the tunnel lining to manage groundwater inflows • Rationalising the layout of the proposed ventilation tunnels including the number, location and length of tunnels • Review of the proposed construction methodology • Consideration of ground improvement options.	Construction
	PL8	A Settlement Monitoring Plan will be prepared that will provide details on: • Settlement criteria and predictions • Location of monitoring points • Duration of monitoring • Data collection and review • Triggers and corrective actions.	Construction
	PL9	Settlement monitoring will be carried out in accordance with the Settlement Monitoring Plan for the period starting prior to commencement of tunnel construction through to until all settlement has stabilised following completion of tunnel construction. The results of settlement monitoring will be compared to predicted settlement. Where actual settlement is greater than predicted settlement, the assessment and the proposed measures to reduce settlement will be reviewed. The revised measures will be implemented to ensure that settlement does not exceed the criteria.	Construction
	PL10	Building condition surveys will be offered to property owners within the zone of influence of tunnel settlement (within 50 metres from the edges of the tunnels and ramps). In the event that damage occurs to a property as a result of the construction of the project, the damage will be appropriately rectified.	Construction
	PL11	An Independent Property Impact Assessment Panel, comprising geotechnical and engineering experts, will be established prior to the commencement of works with the potential to result in ground movement and settlement. The panel will be responsible for: • Independently verifying building condition survey reports • Resolving any property damage disputes • Establishing on-going settlement monitoring requirements.	Construction

Impact	No.	Environmental management measure	Timing
	PL12	Interface agreements will be entered into with the owners of infrastructure and utility services likely to be impacted by construction of the project. The agreements will likely identify: • Minimum separation distances and appropriate settlement criteria for utility infrastructure • Settlement monitoring requirements during construction • Contingency actions in the event that settlement limits are exceeded.	Construction

13 Urban design and visual amenity

This chapter provides an assessment of the urban design, landscape character and visual amenity for the M4-M5 Link project (the project). A detailed urban design report has been carried out for the project and is provided in **Appendix L** (Technical working paper: Urban design) and a detailed landscape and visual impact assessment has been carried out for the project and is provided in **Appendix O** (Technical working paper: Landscape and visual impact).

The Secretary of the NSW Department of Planning and Environment (DP&E) has issued environmental assessment requirements for the project. These are referred to as the Secretary's Environmental Assessment Requirements (SEARs). **Table 13-1** sets outs these requirements and the associated desired performance outcomes that relate to urban design and visual amenity, and identifies where they have been addressed in this environmental impact statement (EIS).

Table 13-1 - SEARs – urban design and visual amenity

Desired performance outcome	SEARs	Where addressed in the EIS
8. Visual amenity The project minimises adverse impacts on the visual amenity of the built and natural environment (including public open space) and capitalises on opportunities to improve visual amenity.	1. The Proponent must assess the visual impact of the project and any ancillary infrastructure on: a) views and vistas; b) streetscapes, key sites and buildings; c) heritage conservation areas and heritage items including Aboriginal places and environmental heritage; and d) the local community (including view loss and overshadowing).	Visual impacts are assessed in **section 13.4**, **section 13.5**, and **Appendix O** (Technical working paper: Landscape and visual impact). Visual impacts on heritage conservation and heritage items are assessed in **Chapter 20** (Non-Aboriginal heritage) and **Chapter 21** (Aboriginal heritage). Impacts on overshadowing are assessed in **Chapter 12** (Land use and property) and **Appendix M** (Shadow diagrams and overshadowing).
	2. The proponent must provide artist impressions and perspective drawings of the project from a variety of locations along and adjacent to the route to illustrate how the project has responded to the visual impact through urban design and landscaping.	Urban design and landscaping aspects and visualisations of the project are described in **section 13.5** and **Appendix L** (Technical working paper: Urban design).
7. Urban design The project design complements the visual amenity, character and quality of the surrounding environment.	1. The Proponent must: a) identify the urban design and landscaping aspects of the project and its components to enhance the appearance of ventilation outlets, interchanges, potential connections to The Bays Precinct and transport linkages, tunnel portals, bridges, noise walls, ancillary buildings, and any additional surface infrastructure, 'cut and cover' arrangements;	Urban design and landscaping aspects of the project are identified in **section 13.5**.

Desired performance outcome	SEARs	Where addressed in the EIS
The project contributes to the accessibility and connectivity of communities.	b) identify measures aimed at improving 'north-south' connectivity between Balmain/Rozelle and Sydney Harbour;	Measures to preserve north–south connectivity are discussed in **section 13.5.3**, **section 13.5.4** and **Appendix N** (Technical working paper: Active transport strategy).
	c) identify measures aimed at preserving the 'east-west' connectivity between White Bay and the Rozelle Rail Yards;	Measures to preserve east–west connectivity are discussed in **section 13.5.3** and **Appendix N** (Technical working paper: Active transport strategy).
	d) consider resulting residual land treatments, and demonstrate how the proposed hard and soft urban design elements of the proposal would be consistent with the existing and desired future character of the area traversed or affected by the proposal;	An assessment of the consistency of the project with the desired future character of the project footprint is provided in **Appendix O** (Technical working paper: Landscape and visual impact).
	e) identify opportunities to utilise surplus or residual land, particularly for the provision of community space (passive and recreational) and utilise key structures (such as ventilation outlets) for multiple uses i.e. integration with other structures;	Consideration of residual land treatments are discussed in **section 13.5.7** and **Chapter 12** (Land use and property).
	f) evaluate the visual impacts and urban design aspects of the proposal and its components (such as the ventilation outlets and interchanges) on surrounding areas, taking into consideration the urban and landscape design of the M4 East and New M5 Motorways and WestConnex Urban Design Corridor Framework;	A visual impact assessment is outlined in **section 13.5** and an assessment against urban design principles developed for the project is provided in **section 13.5.9**.
	g) explore the use of Crime Prevention Through Environmental Design (CPTED) principles during the design development process, including natural surveillance, lighting, walkways, signage and landscape;	CPTED principles are discussed in **section 13.5.8**.
	h) identify urban design strategies and opportunities to enhance healthy, cohesive and inclusive communities;	Urban design strategies are discussed in **section 13.5** and **Appendix L** (Technical working paper: Urban design) and benefits to the community associated with these strategies are discussed in **Chapter 14** (Social and economic).
	i) describe urban design and landscape mitigation measures, having regard to the urban design and landscape objectives for the proposal.	Urban design and landscape mitigation measures are provided in **section 13.6**.

Desired performance outcome	SEARs	Where addressed in the EIS
	3. The Proponent must identify opportunities for local centre street revitalisation improvements, pedestrian and cyclist access and connectivity and provision of community and social facilities.	Opportunities for urban renewal and local revitalisation are identified in **Chapter 14** (Social and economic).
9. Socio-economic, land use and property The project minimises adverse social and economic impacts and capitalises on opportunities potentially available to affected communities. The project minimises impacts to property and business and achieves appropriate integration with adjoining land uses, including maintenance of appropriate access to properties and community facilities, and minimisation of displacement of existing land use activities, dwellings and infrastructure.	3. The Proponent must identify opportunities for local centre street revitalisation improvements, pedestrian and cyclist access and connectivity and provision of community and social facilities.	Opportunities for urban renewal and local revitalisation are identified in **Chapter 14** (Social and economic).

13.1 Assessment methodology

The landscape character and visual impact assessment presented in this chapter has been undertaken in accordance *with Environmental Impact Assessment Practice Note – Guidelines for Landscape Character and Visual Impact Assessment* (EIAG) (NSW Roads and Maritime Services (Roads and Maritime) 2013a). This method is widely accepted by the NSW Government and is relevant to the project in that it addresses changes to corridor infrastructure within an urban setting.

The methodology comprised two components: an urban design process and a landscape character and visual impact assessment. These are described in the following sections.

An integrated urban design and engineering process

The urban design, landscape character and visual impact assessment presented in this chapter is based on the concept design for the project. The concept design defines:

- A definition of property acquisition requirements sufficient to allow construction to proceed
- A project footprint, including for construction and operation
- A clear description of the design principles, extent of impacts and impact management requirements
- A sound and clear basis for later development of the detailed design to a standard required to support project delivery.

The concept design would continue to be refined where relevant to improve road network and safety performance, minimise impacts on receivers and the environment, and in response to feedback from stakeholders.

Landscape character and visual impact assessment

An assessment of landscape character involves the assessment of the built, natural and cultural character or sense of place whereas an assessment of visual impacts assesses the day to day impacts of a project on views.

The assessment methodology involved:

- A desktop assessment including:
  - Consideration of relevant legislation and policy requirements
  - Review of the landscape context of the study area (defined below)
  - Determination of sensitive receiver locations and potential viewpoints
  - Review of the WestConnex Motorway Urban Design Framework (Roads and Maritime 2013a)
- Surveys of the study area to confirm significant landforms and existing viewpoints
- Assessment of potential landscape character and visual impacts (including cumulative impacts)
- Identification of measures to mitigate potential impacts.

13.2 Landscape character and visual impact assessment

Landscape character zones

To assess landscape character impact, landscape character zones (LCZ) were identified within the study area. The landscape character zones are defined as areas of landscape with similar properties or strongly defined spatial qualities that are visually distinct from adjoining areas. As much of the project would comprise of tunnelled motorway, the landscape character zones were focussed around areas of proposed surface works where permanent operational infrastructure would be located.

LCZs related to the Wattle Street interchange at Haberfield were assessed as part of the M4 East EIS. Where components of the M4-M5 Link project would be located within the footprint of the M4 East project, with no additional operational impacts resulting from the M4-M5 Link project, these LCZs have not been re-assessed. A description of LCZs identified for Haberfield can be found within WestConnex M4 East Urban Design, Landscape Character and Visual Impact Assessment (AECOM 2015) (refer to LCZ 10 and LCZ 12 for relevance to M4-M5 Link project).

Existing views

In order to assess visual impact, existing views have been identified based on a range of criteria, including:

- Where there is potential for a significant change between the before and after view
- Where there is potential for a significant adverse visual outcome for sensitive receptors
- Where there is potential for a significant adverse visual outcome to locations of high visual amenity
- Where there is potential for a significant adverse visual outcome to heritage listed items or Heritage Conservation Areas (HCAs)
- Where the view is representative of other similar settings, in which there was potential for a similar adverse outcome, eg on the character of a streetscape.

Site management works

Roads and Maritime is carrying out a suite of site management works on part of the Rozelle Rail Yards site. The works are needed to manage the existing environmental and safety issues at the site and would also improve access to surface conditions, which would allow for further investigation into the location of utilities and the presence of contamination and waste.

The existing landscape character and visual setting of the Rozelle Rail Yards would be characterised by these completed site management works. The assessment presented in this EIS assumes that the site management works are completed.

Refer to **Chapter 2** (Assessment process) for further detail regarding the site management works.

13.2.1 Legislation and policy framework

The legislation and policy framework for the landscape character and visual aspects of the project has been established with regard to relevant local environment plans, development control plans, and regional planning documents. The desired future character of the area to be occupied by the project has been determined based on the strategic direction provided in these documents. Further detail on the existing land use zonings and land use and property impacts are provided in **Chapter 12** (Land use and property).

In addition, guidelines relating to urban design and visual amenity have been considered in the development of the project. A full list of the local environment plans, development control plans, regional planning documents, as well as guidelines relating to urban design and visual amenity is provided in **Appendix O** (Technical working paper: Landscape and visual impact).

13.2.2 Urban and landscape design

Key objectives outlined in the WestConnex Motorway Urban Design Framework (Roads and Maritime Services 2013a) and Beyond the Pavement: Urban Design Procedures and Design Principles (Roads and Maritime Services 2014a) have informed the development of guiding principles for the urban design for the M4-M5 Link. The relevant urban design principles of the project are outlined in **Table 13-2**.

Table 13-2 Urban design principles and their application to the project

Principle	Application to the project
Integrated and collective approach Create holistic and integrated design solutions generated by collaboration across disciplines, the community, stakeholders and government bodies.	• Working across disciplines • Holding regular stakeholder workshops and contributing to design outcomes • Prioritising community input • Working with all future plans and government bodies • Considering all relevant regulatory frameworks.
Environmental vision Create a sustainable and enduring design response which enhances and connects local ecologies and green spaces.	• Enhancing waterways, creeks and rivers • Utilising, where possible water-sensitive urban design • Connecting disconnected green spaces • Enhancing local ecology and vegetation • Utilising durable, sustainable and long lasting materials and timeless design.
Cross scale connection of spaces Prioritise both locally and regionally significant connections that respond to the broader issues of the local neighbourhoods and city.	• Enhancing connectivity between streets, facilities, neighbourhoods, green spaces, cyclist and pedestrian connections across the project footprint and city • Integrating and connecting transport modes • Connecting local and regional road, cyclist, public transport and pedestrian links.
A motorway integrated within its context Understand the existing landscape and respond in a respectful manner that seeks to enhance and or contribute back to its context.	• Responding to landform natural patterns • Respecting and working with the local landform • Enhancing the interface between existing open spaces and the motorway.
Place sensitive design Celebrate and work with the character of each place and destination, responding to their unique histories, materiality, architecture, built fabric, cultural context, landform and topography.	• Incorporating heritage items and areas into the urban design • Respecting and responding to cultural contexts • Complementing the existing built fabric • Increasing the legibility of places, buildings, streets and landmarks.
Multidimensional user force Consider holistically how a diversity of users experience space including all ages, abilities and transport modes for a truly inclusive, universally accessible and safe outcome.	• Ensure Crime Prevention Through Environmental Design (CPTED) driven designs (see **section 13.5.8**) • Safe, legible connections with way finding for all user types • Ensuring universal design outcomes • Considering the user experience for all modes including drivers, pedestrians, cyclists and public transport.
Revitalisation, opportunity and economics Establish opportunities for development that supports and connects existing neighbourhoods, complements and stimulates local economies and provides opportunity for growth across existing and future local industries.	• Contributing to urban structure and revitalisation • Capitalising on traffic reduction to enhance local streets and increase neighbourhood liveability • Creating opportunities for urban renewal.

The urban design principles of the project are outlined in **Table 13-2** would be developed into detailed designs under Urban Design and Landscape Plans (UDLPs) for the various components of the project. These UDLPs would relate to one another and the other stages of WestConnex.

13.2.3 Approach to the assessment of potential impacts

Assessment of landscape character and visual impacts

The method applied to measure both landscape character and visual impact comprised a sensitivity analysis of existing landscape zones or views subject to change, and an assessment of the magnitude of change on that zone or view.

Sensitivity and magnitude ratings are applied according to the matrix provided in **Table 13-3**. Concepts such as sensitivity and magnitude are explained further in **Appendix O** (Technical working paper: Landscape and visual impact).

Table 13-3 Landscape character and visual impact rating matrix

Visual impact		Magnitude of change			
		High	**Moderate**	**Low**	**Negligible**
Sensitivity of receivers	**High**	High	High–Moderate	Moderate	Negligible
	Moderate	High–Moderate	Moderate	Moderate–Low	Negligible
	Low	Moderate	Moderate–Low	Low	Negligible
	Negligible	Negligible	Negligible	Negligible	Negligible

Source: Roads and Maritime (2013)

Landscape character and visual impact ratings represent the potential impact of the project before the environmental management measures outlined in **section 13.6** have been applied. Potential landscape character and visual impact would be reduced by the application of environmental management measures.

Visual envelope mapping

The likely visibility of the permanent project infrastructure from surrounding areas has been broadly mapped to create a visual envelope. This provides a measure of the parts of the project that are likely to be viewed from large areas of surrounding development, and which may potentially be more visually sensitive when compared to other components of the project where direct views may be limited. The mapping typically shows ‘worst case’, ie some receivers may only see the tip of a ventilation facility; closer receivers may view a substantial part of the infrastructure element.

Consideration of landscape treatments

Vegetation proposed as part of the project is considered in the assessment process, but only applies to the early stage (ie after 12–18 months after planting), in accordance with the EIAG as outlined in **Appendix O** (Technical working paper: Landscape and visual impact).

Visualisations

Photographic panoramas have been used as a base for graphic visualisations which depict the concept designs for elements of the project. These ‘artists impressions’ illustrate what the project infrastructure may look like in the landscape. The final design of the infrastructure is subject to a detailed design process during the preparation of UDLPs. Visualisations are included in **section 13.5** and **Appendix O** (Technical working paper: Landscape and visual impact).

Assessment of night lighting impacts

A broad assessment of the impacts of night lighting during both the construction and operation of the project was undertaken, by applying the methodology for assessment of visual impacts described above. Key visual receivers have been separately assessed and include neighbouring residential properties, users of recreational space and motorists in local streets.

A detailed lighting concept would be developed and would be based around the considerations identified in **Appendix L** (Technical working paper: Urban design), and would be developed in accordance with AS/NZS 1158 Lighting for roads and public spaces, AS 2560 Guide to sports lighting, AS 4282 Control of the obtrusive effects of outdoor lighting, and AS/NZS 60598 – Series Luminaires.

The assessment of night lighting impacts is therefore based on assumptions that have been made with regard to the types and extent of lighting likely to be installed for both the construction and operation phases consistent with applicable guidelines.

13.3 Existing environment

The existing environment of the areas that would be subject to the operational components of the project is highly urbanised, and is broadly comprised of:

- Major roads such as Victoria Road, City West Link, Parramatta Road and the Princes Highway
- Residential areas including established low density residential areas at Rozelle, Haberfield, Lilyfield and Leichhardt, and medium and high density residential development around Rozelle and St Peters
- Commercial and industrial areas, predominantly around St Peters, Victoria Road at Rozelle, Rozelle Rail Yards and marine and port areas of Rozelle Bay
- Open space including King George Park and Easton Park at Rozelle and Sydney Park at St Peters.

13.3.1 Landscape character zones

LCZs have been identified in those areas that have the potential to be impacted by the operational components of the project. The LCZs reflect the differences in character that are inherent in such a densely urbanised setting, due to factors such as the mix and period of housing types, interweaving of land uses, and the number of different land uses as described above. Thirty-three LCZs have been identified within the study area. These are described in the following sections and shown in **Figure 13-1** to **Figure 13-4.**

State and locally listed Aboriginal and non-Aboriginal heritage items located within or closely adjoining identified LCZs have been identified and taken into consideration when assessing the sensitivity of these zones and potential impacts on important views. Visual impacts on non-Aboriginal heritage are discussed in **Chapter 20** (Non-Aboriginal Heritage) and mapping of listed Aboriginal and non-Aboriginal heritage items within the LCZs for the study area is provided in **Appendix O** (Technical working paper: Landscape and visual impact). As identified in **Chapter 21** (Aboriginal heritage), no surface expressions of Aboriginal objects or places were identified within areas of surface disturbance within the project footprint. Visual impacts related to Aboriginal heritage are therefore not considered further.

Darley Road

The existing landscape character and visual setting in this area is characterised by:

- Low density, single storey residential buildings on small lots at Leichhardt
- A large commercial building and ancillary parking located north of Darley Road and the Inner West light rail line, including the Leichhardt North light rail stop located south of City West Link, to the north of the site area.

The existing landscape character and visual setting at Darley Road has been characterised into three distinct LCZs (the central west LCZs). The area of the central west LCZs is generally bound by City West Link to the north, Catherine Street to the east, Darley Road to the west and Allen Street and Hill Street to the south. The central west LCZs are shown in **Figure 13-1**.

Rozelle interchange

The existing landscape character and visual setting in this area is centred on the Rozelle Rail Yards. The Rozelle Rail Yards consist of disused land which is mainly flat with some gentle gradients. The landscape character of the Rozelle Rail Yards would be influenced by the completion of site management works (see **section 13.2 and Chapter 2** (Assessment process)). A summary of the historical significance of the Rozelle Rail Yards is provided in **Chapter 20** (Non-Aboriginal heritage).

The existing landscape character and visual setting surrounding the Rozelle Rail Yards is characterised by:

- Primarily one to two storey residential buildings and neighbourhood centres in the suburbs of Lilyfield, Rozelle and Annandale
- Commercial land uses (low rise factories and warehouses) on Lilyfield Road and Halloran Street
- Rozelle Bay and the Rozelle Bay wharves and associated maritime land uses
- Transport infrastructure including City West Link, Victoria Road and the Inner West light rail line
- Areas of open space including Easton Park, Whites Creek Valley Park and the adjoining Federal Park, Jubilee Park and Bicentennial Park which form the Glebe foreshore parklands
- The decommissioned White Bay Power Station.

The existing landscape character and visual setting at the Rozelle interchange has been characterised into 16 distinct LCZs (the central east LCZs). The area of the central east LCZs is generally centred on the Rozelle Rail Yards and is bound by Darling Street to the north, Balmain Road and Cecily Street to the west, White Bay and Anzac Bridge to the east and Annandale Street to the south and east. The central east LCZs are shown in **Figure 13-2**.

Existing active transport networks around the Rozelle Rail Yards include the Bay Run, Glebe Foreshores, Anzac Bridge cycleway and GreenWay (between Cooks River and Iron Cove). At present there is poor connectivity between these networks, as the Rozelle Rail Yards is a significant barrier between the communities of Annandale, Rozelle and Lilyfield.

Iron Cove Link

The existing landscape character and visual setting in this area is characterised by:

- The Victoria Road corridor east of Iron Cove Bridge
- Single storey residential buildings on small lots to the south of Victoria Road
- Medium to high density buildings including high-rise apartment buildings to the north of Victoria Road
- Areas of open space including active and passive recreation facilities such as King George Park along the foreshore area south of Iron Cove Bridge
- A light industrial precinct to the east of Victoria Road north of Wellington Street
- Darling Street, which is characterised by a mix of restaurants, retail shops, community facilities and commercial enterprises.

The existing landscape character and visual setting at the Iron Cove Link has been characterised into seven distinct LCZs (the northern LCZs). The area of the northern LCZs is generally centred on Victoria Road and is bound by the Parramatta River and Rozelle Bay to the west, Manning Street to the south, the Rozelle/Balmain suburb boundary to the north and Darling Street to the east. The northern LCZs are shown in **Figure 13-3**.

Active transport networks at Iron Cove consist primarily of the Bay Run and Victoria Road. Iron Cove is bordered by the Bay Run which is a seven kilometre shared pedestrian and cyclist path that is a popular regional walk for a range of users. Victoria Road is lined on both the northern and southern sides of the road with a shared pedestrian and cyclist path. The path does not adequately serve the needs of pedestrians and cyclists due to the width of the path, uneven surface and lack of amenity due to the proximity to traffic on Victoria Road.

St Peters interchange

The existing landscape character and visual setting in this area is characterised by

- Residential areas around Campbell Road consisting primarily of double storey 'Victorian' terrace houses
- Sydney Park, which comprises open space areas and pockets of dense 'bush character' vegetation
- Industrial land uses around the Alexandra Canal
- Commercial and medium to high density mixed land uses around the Princes Highway.

The existing landscape character and visual setting at St Peters interchange has been characterised into seven distinct LCZs (the southern LCZs). The area of the southern LCZs is generally bound by the Princes Highway to the north, Sydney Park to the east, Canal Road to the west and the Alexandria Canal to the south. The southern LCZs are shown in **Figure 13-4**.

LEGEND

Existing features
- Light rail
- Light rail stop
- Community facility

Landscape character zones
- Darley Road commercial precinct
- Darley Road residential precinct
- Leichhardt light rail precinct

Local Environmental Plan
- Heritage item
- Heritage conservation area

Figure 13-1 Central west landscape character zones

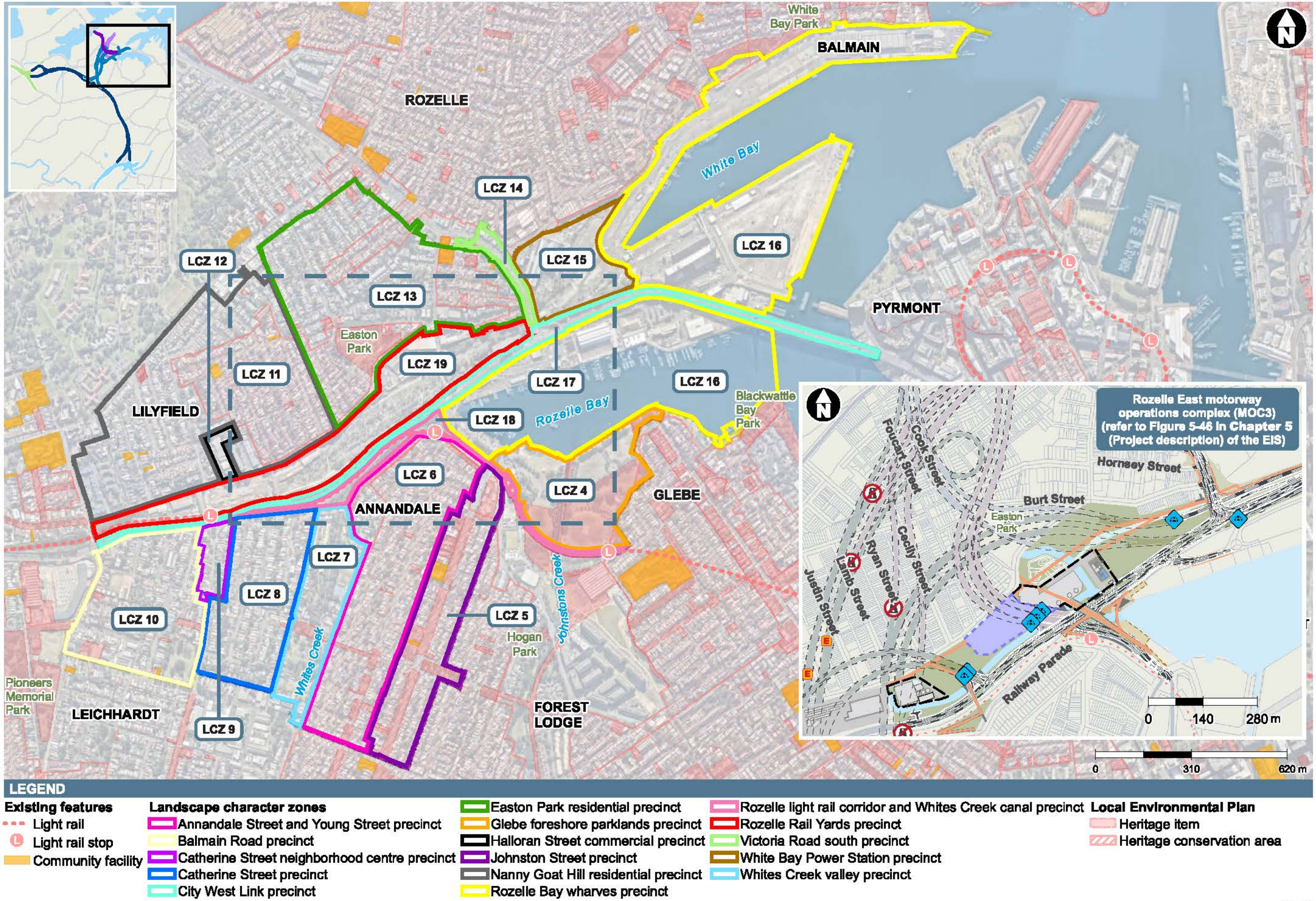


Figure 13-2 Central east landscape character zones

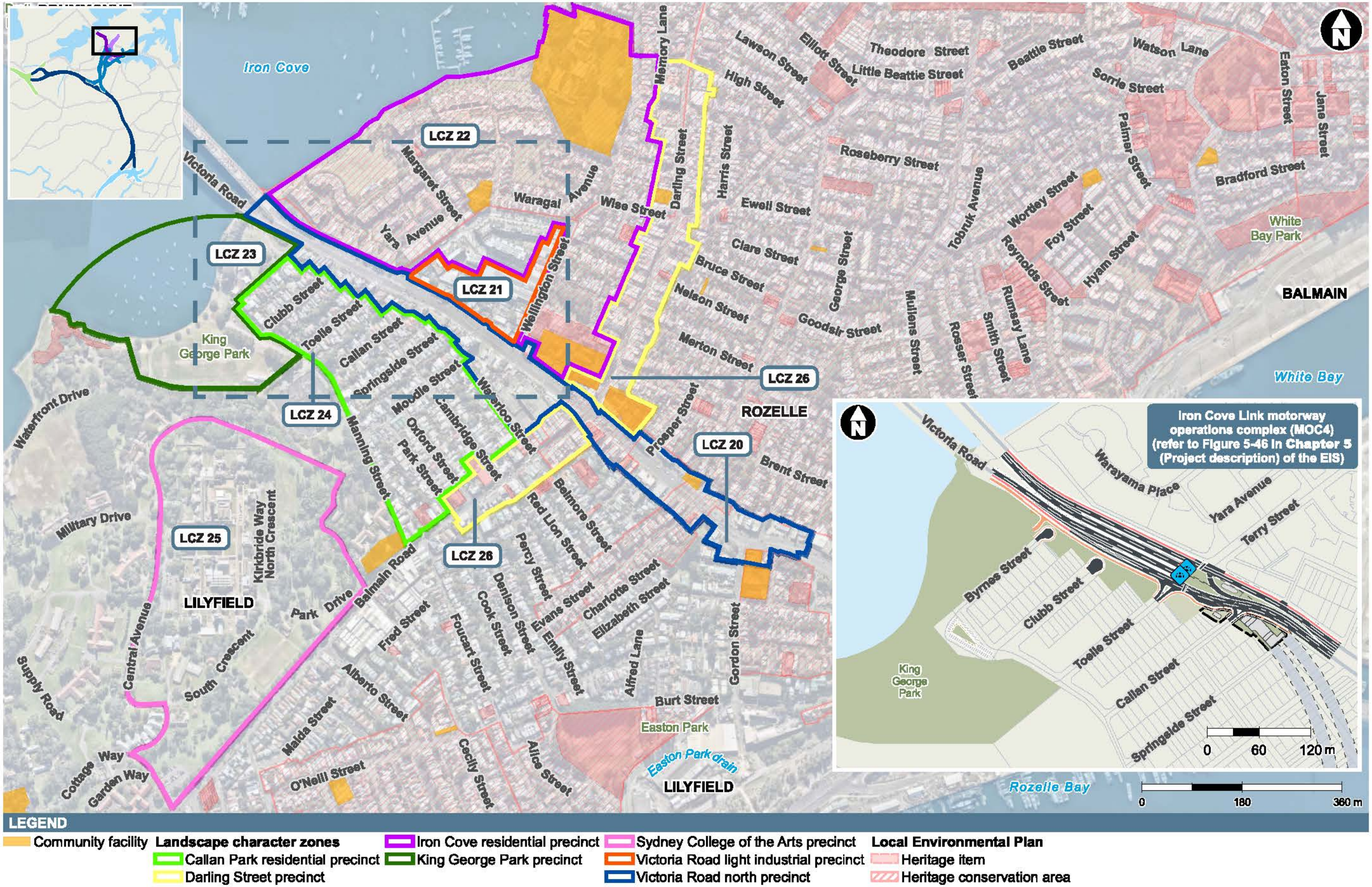


Figure 13-3 Northern landscape character zones

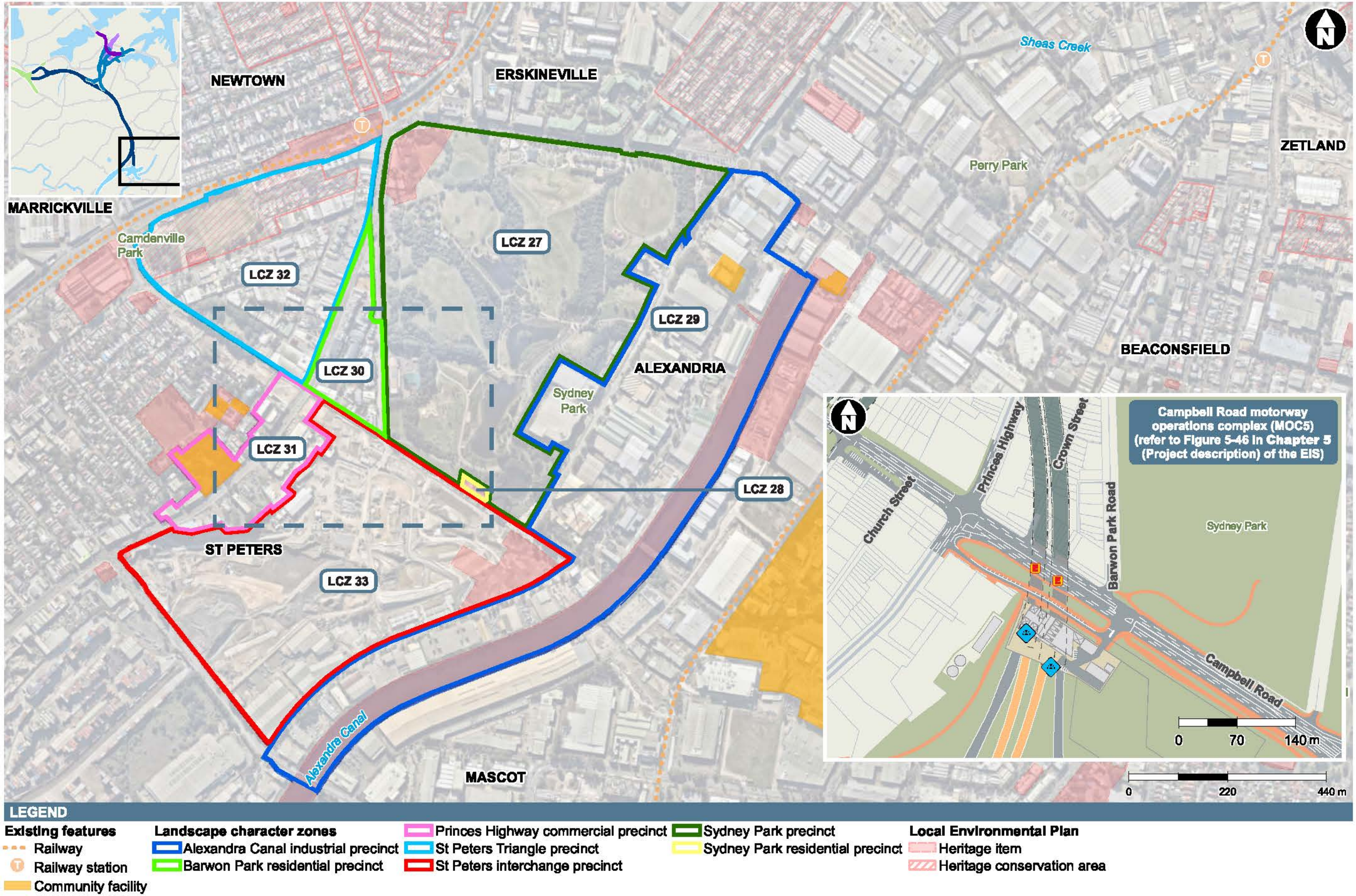


Figure 13-4 Southern landscape character zones

13.3.2 Existing night lighting environment

The existing night lighting environment at the sites where the construction ancillary facilities would be located is outlined in **Table 13-4**. Construction ancillary facilities that would operate during daytime construction hours only have not been assessed for night lighting impacts. At each construction ancillary facility, lighting would be designed to minimise light spillage to adjoining properties and would be generally consistent with the requirements of AS 4282-1997 Control of the obtrusive effects of outdoor lighting. Lighting would also adhere to established guidelines to avoid impacts on airport operations as discussed in **Chapter 25** (Hazard and risk). The impact on pedestrians has not been assessed due to the relatively low number of pedestrians walking at night for recreation.

Table 13-4 Existing night lighting environment

Construction ancillary facility	Existing sources of night lighting
Wattle Street civil and tunnel site (C1a)	Street lighting associated with Parramatta Road, local streets and associated vehicular traffic, lighting associated with construction activities being undertaken at the site as part of the M4 East project and illuminated windows of surrounding residential properties on Wattle Street.
Haberfield civil and tunnel site (C2a)/Haberfield civil site (C2b)	Street lighting associated with Parramatta Road, local streets and associated vehicular traffic, lighting associated with construction activities being undertaken at the site as part of the M4 East project and illuminated windows of surrounding residential properties on Walker Avenue and the commercial buildings along Parramatta Road.
Northcote Street civil site (C3a)	Street lighting associated with Parramatta Road, Wattle Street and Northcote Street local streets, lighting associated with construction activities being undertaken at the site as part of the M4 East project and associated vehicular traffic and illuminated windows of the surrounding residential properties and the commercial buildings along Parramatta Road.
Parramatta Road West civil and tunnel site (C1b)	Security lighting associated with the existing use of the site, street lighting associated with Parramatta Road, local streets and associated vehicular traffic, and illuminated windows of the surrounding residential properties.
Parramatta Road East civil site (C3b)	Security lighting associated with the existing use of the site, street lighting associated with Parramatta Road, Alt Street and Bland Street with associated vehicular traffic and illuminated windows of the surrounding residential properties.
Darley Road civil and tunnel site (C4)	Street lighting associated with the Leichhardt North light rail stop, City West Link, Darley Road, local streets, traffic, illuminated windows of surrounding residential properties and illuminated windows of the existing commercial warehouse building (located within the identified facility footprint). Lighting associated with City West Link is predominantly screened by a vegetated buffer, a high noise wall and the commercial warehouse building currently on the site (about 13 metres high at its western end).
Rozelle civil and tunnel site (C5)	Street lighting associated with City West Link, Lilyfield Road, Victoria Road and Catherine Street as large arterial roads, local streets, associated vehicular traffic and illuminated windows of surrounding residential properties.
Pyrmont Bridge Road tunnel site (C9)	Street lighting associated with Parramatta Road and Pyrmont Bridge Road as large arterial roads, local streets, vehicular traffic and illuminated windows of the commercial properties at the site and surrounding residential and commercial properties.

Construction ancillary facility	Existing sources of night lighting
Campbell Road civil and tunnel site (C10)	Street lighting associated with Campbell Road including a new signalised intersection, Albert Street, the share pathway running along the western edge of the interchange, some lighting to the facades and windows of fringing industrial and residential development, lighting associated with construction activities being undertaken at and around the site as part of the New M5 project and illuminated windows of the surrounding residential properties.

13.4 Assessment of potential construction impacts

This section assesses visual impacts on receivers during construction. An overview of visual impacts is provided, including the impact assessment ratings for sensitivity and magnitude at each facility. Site layouts are indicative and dimensions of structures and buildings mentioned in this section, including noise walls, hoarding, fences and acoustic sheds, would be confirmed during detailed design.

Receivers with views of construction ancillary facilities and construction activities could include:

- Residents that adjoin and/or have views of the project
- Workers in commercial properties that adjoin and/or have views of the project
- Road users and pedestrians
- Users of recreation areas/reserves with views of the project.

Visual impacts during construction would result from the introduction of construction ancillary facilities into the existing landscape. This would include night lighting at sites that involve tunnelling activities or that support tunnelling activities.

Construction activities that would take place at the construction ancillary facilities are discussed in **Chapter 6** (Construction work). In general, visible construction activities would include (where required):

- Vegetation removal
- Noise barriers/hoarding/fencing
- Heavy and/or light vehicle access potentially 24 hours a day, seven days a week
- Staff amenities buildings
- Workshops and storage containers
- Stockpile and laydown areas
- The operation of plant and equipment, including cranes
- Lighting for night-time works
- Water storage tanks
- The construction of infrastructure for the operation of the project.

The potential night lighting impacts at the relevant construction ancillary facilities are also assessed.

Impact ratings for visual and night lighting impacts during construction are included in the summary tables for each construction ancillary facility assessed in this section. A detailed explanation of these impact ratings is provided **Appendix O** (Technical working paper: Landscape and visual impact).

The detailed design of construction ancillary facilities would include the consideration of CPTED principles, which are outlined in **section 13.5.8**.

13.4.1 Visual impacts on sensitive receivers

Representative receiver locations have been identified at each construction facility and potential visual impacts on these receivers are summarised in **Table 13-5**. The location of representative receiver locations is shown in **Figure 13-5** to **Figure 13-16**.

Table 13-5 Summary of construction visual impacts on sensitive receivers

Receiver		Sensitivity to change	Magnitude of change	Overall impact rating
Wattle Street civil and tunnel site (C1a)[1]				
C1a-1	Religious congregation – Wattle Street	Low	Moderate	Moderate–Low
C1a-2	Residents – Wattle Street, Walker Avenue and Ramsay Street	High	Moderate	High–Moderate
C1a-3	Motorists on Wattle Street, Ramsay Street and Parramatta Road	Low	Low	Low
C1a-4	Pedestrians –Wattle Street, Walker Avenue, Ramsay Street and Parramatta Road	Low	Low	Low
Haberfield civil and tunnel site (C2a)				
C2a-1	Motorists on Wattle Street, Walker Avenue and Parramatta Road	Low	Low	Low
C2a-2	Religious congregation – Wattle Street	Low	Moderate	Moderate–Low
C2a-3	Residents – Wattle Street and Walker Avenue	High	Moderate	High-Moderate
C2a-4	Pedestrians – Wattle Street, Walker Avenue and Parramatta Road	Low	Moderate	Moderate–Low
Northcote Street civil site (C3a)[1]				
C3a-1	Religious congregation – Wattle Street	Low	Low	Low
C3a-2	Motorists – Wattle Street, Parramatta Road	Low	Moderate	Moderate-Low
C3a-3	Residents – Wattle Street, Northcote Street, Wolseley Street, Parramatta Road	Moderate	Moderate	Moderate
C3a-4	Pedestrians – Wattle Street, Northcote Street, Wolseley Street, Parramatta Road, Page Avenue, Earle Avenue, Frederick Street	Low	Low	Low
Parramatta Road West civil and tunnel site (C1b)				
C1b-2	Residents – Alt Street, Bland Street and Parramatta Road	High	High	High
C1b-1	Motorists on Alt Street, Bland Street and Parramatta Road	Low	Moderate	Moderate–Low
C1b-3	Pedestrians – Alt Street, Bland Street and Parramatta Road	Low	Moderate	Moderate–Low
Parramatta Road East civil site (C3b)				
C3b-1	Motorists – Alt Street, Bland Street and Parramatta Road	Low	Moderate	Moderate–Low
C3b-2	Residents – Alt Street, Bland Street and Parramatta Road	Moderate	Moderate	Moderate
C3b-3	Pedestrians – Alt Street, Bland Street and Parramatta Road	Low	Low	Low

Receiver		Sensitivity to change	Magnitude of change	Overall impact rating
Darley Road civil and tunnel site (C4)				
C4-1	Pedestrians – Darley Road, City West Link pedestrian bridge	Low	Low	Low
C4-2	Motorists – Darley Road	Moderate	Low	Moderate-Low
C4-3	Residents – Darley Road, Charles Street, Hubert Street (south of Darley Road), Francis Street (south of Darley Road) and James Street	High	High	High
C4-4	Light rail users – Leichhardt North light rail stop	Low	High	Moderate
Rozelle civil and tunnel site (C5)				
C5-1	Motorists – City West Link	Moderate	Moderate	Moderate
C5-2	Residents – Foucart Street and Cecily Street	High	High	High
C5-3	Residents – Lilyfield Road near Denison Street	High	High	High
C5-4	Residents – Breillat Street	Moderate	Low	Moderate–Low
C5-5	Recreational users – Easton Park	Moderate	High	High–Moderate
C5-6	Recreational users – Glebe Foreshore Parklands	High	Moderate	High–Moderate
The Crescent civil site (C6)				
C6-1	Residents – Bayview Crescent and Johnston Street	High	High	High
C6-2	Motorists – The Crescent	Low	Moderate	Moderate–Low
C6-3	Recreational users – Rozelle Bay	Moderate	Moderate	Moderate
C6-4	Recreational users – Glebe Foreshore Parklands	High	Moderate	High–Moderate
Victoria Road civil site (C7)				
C7-1	Residents – Lilyfield Road	Moderate	Moderate	Moderate
C7-2	Residents – Hornsey Street and Quirk Street	High	High	High
C7-3	Motorists – Victoria Road	Low	Low	Low
Iron Cove Link civil site (C8)				
C8-1	Recreational users – King George Park	Moderate	Moderate	Moderate
C8-2	Pedestrians – footpath across Iron Cove bridge	Low	High	Moderate
C8-3	Pedestrians – footpath near Byrnes Street	Low	Moderate	Moderate–Low
C8-4	Residents – Callan Street, Springside Street, Toelle Street and Clubb Street	High	High	High
C8-5	Residents – Nagurra Place, Terry Street and Victoria Road	Moderate	Moderate	Moderate
C8-6	Motorists – Victoria Road	Low	Moderate	Moderate–Low
Pyrmont Bridge Road tunnel site (C9)				
C9-1	Residents – Pyrmont Bridge Road	Moderate	High	High–Moderate
C9-2	Residents – Booth Street and Mallett Street	High	Moderate	High–Moderate
C9-3	Motorists – Parramatta Road	Low	Low	Low
C9-4	Residents – Parramatta Road	Moderate	Moderate	Moderate

Receiver		Sensitivity to change	Magnitude of change	Overall impact rating
Campbell Road civil and tunnel site (C10)				
C10-1	Residents – houses on Campbell Street	High	High	High
C10-2	Residents – corner of Barwon Park Road and Campbell Street	High	Moderate	High–Moderate
C10-3	Pedestrians –Campbell Road	Moderate	Low	Moderate–Low
C10-4	Residents – terraces on Campbell Road	High	Moderate	High–Moderate
C10-5	Motorists – Campbell Road	Low	Low	Low

Note 1: The visual impact of this facility during construction of the M4–M5 Link project would be comparable to the visual impact associated with the existing use of the site as a construction ancillary facility (civil and tunnelling) for the M4 East.

13.4.2 Construction lighting impacts

Potential night lighting impacts on receivers at representative receiver locations for each construction ancillary facility are summarised in **Table 13-6**. It is anticipated that construction works at The Crescent civil site (C6), the Victoria Road civil site (C7) and the Iron Cove Link civil site (C8) would be carried out during standard daytime construction hours and therefore impacts on night lighting have not been assessed at these locations. The location of representative receiver locations is shown in **Figure 13-5** to **Figure 13-16**.

Table 13-6 Summary of construction lighting impacts

Receiver		Sensitivity to change	Magnitude of change	Overall impact rating
Wattle Street civil and tunnel site (C1a)[1]				
C1a-1	Religious congregation – Wattle Street	Low	Low	Low
C1a-2	Residents – Wattle Street, Walker Avenue and Ramsay Street	Low	Moderate	Moderate–Low
C1a-3	Motorists on Wattle Street, Ramsay Street and Parramatta Road	Low	Low	Low
C1a-4	Pedestrians –Wattle Street, Walker Avenue, Ramsay Street and Parramatta Road	Low	Low	Low
Haberfield civil and tunnel site (C2a)				
C2a-1	Motorists on Wattle Street, Walker Avenue and Parramatta Road	Low	Low	Low
C2a-2	Religious congregation – Wattle Street	Low	Moderate	Moderate–Low
C2a-3	Residents – Wattle Street and Walker Avenue	Low	Moderate	Moderate–Low
C2a-4	Pedestrians – Wattle Street, Walker Avenue and Parramatta Road	Low	Low	Low
Northcote Street civil site (C3a)				
C3a-1	Religious congregation – Wattle Street	Low	Low	Low
C3a-2	Motorists – Wattle Street, Parramatta Road	Low	Low	Low
C3a-3	Residents – Wattle Street, Northcote Street, Wolseley Street, Parramatta Road	Low	Moderate	Moderate–Low
C3a-4	Pedestrians – Wattle Street, Northcote Street, Wolseley Street, Parramatta Road, Page Avenue, Earle Avenue, Frederick Street	Low	Low	Low

Receiver		Sensitivity to change	Magnitude of change	Overall impact rating
Parramatta Road West civil and tunnel site (C1b)				
C1b-2	Residents – Alt Street, Bland Street and Parramatta Road	Low	Moderate	Moderate–Low
C1b-1	Motorists on Alt Street, Bland Street and Parramatta Road	Low	Low	Low
C1b-3	Pedestrians – Alt Street, Bland Street and Parramatta Road	Low	Low	Low
Parramatta Road East civil site (C3b)				
C3b-1	Motorists – Alt Street, Bland Street and Parramatta Road	Low	Low	Low
C3b-2	Residents – Alt Street, Bland Street and Parramatta Road	Low	Moderate	Moderate–Low
C3b-3	Pedestrians – Alt Street, Bland Street and Parramatta Road	Low	Low	Low
Darley Road civil and tunnel site (C4)				
C4-1	Pedestrians – Darley Road, City West Link pedestrian bridge	Low	Low	Low
C4-2	Motorists – Darley Road	Low	Low	Low
C4-3	Residents –Darley Road, Charles Street, Hubert Street (south of Darley Road), Francis Street (south of Darley Road) and James Street	High	Moderate	High–Moderate
C4-4	Light rail users – Leichhardt North light rail stop	Low	Moderate	Moderate–Low
Rozelle civil and tunnel site (C5)				
C5-1	Motorists – City West Link	Low	Moderate	Moderate–Low
C5-2	Residents – Foucart Street and Cecily Street	Moderate	Moderate	Moderate
C5-3	Residents – Lilyfield Road near Denison Street	High	High	High
C5-4	Residents – Breillat Street	Low	Low	Low
C5-5	Recreational users – Easton Park	Low	High	Moderate
C5-6	Recreational users – Glebe Foreshore Parklands	Low	Low	Low
Pyrmont Bridge Road tunnel site (C9)				
C9-1	Residents – Pyrmont Bridge Road	Low	Low	Low
C9-2	Residents – Booth Street and Mallett Street	Moderate	Low	Moderate–Low
C9-3	Motorists – Parramatta Road	Low	Low	Low
C9-4	Residents – Parramatta Road	Low	Low	Low
Campbell Road civil and tunnel site (C10)				
C10-1	Residents – houses on Campbell Street adjacent to the western end of site	Low	Low	Low
C10-2	Residents – corner of Barwon Park Road and Campbell Street	Moderate	Low	Moderate–Low
C10-3	Pedestrians –Campbell Road	Low	Low	Low
C10-4	Residents – terraces on Campbell Road	High	Moderate	High–Moderate
C10-5	Motorists – Campbell Road	Low	Low	Low

Note 1: The night lighting impacts of this facility during construction of the M4–M5 Link project would be comparable to the night lighting impact associated with the existing use of the site as a construction ancillary facility (civil and tunnelling) for the M4 East.

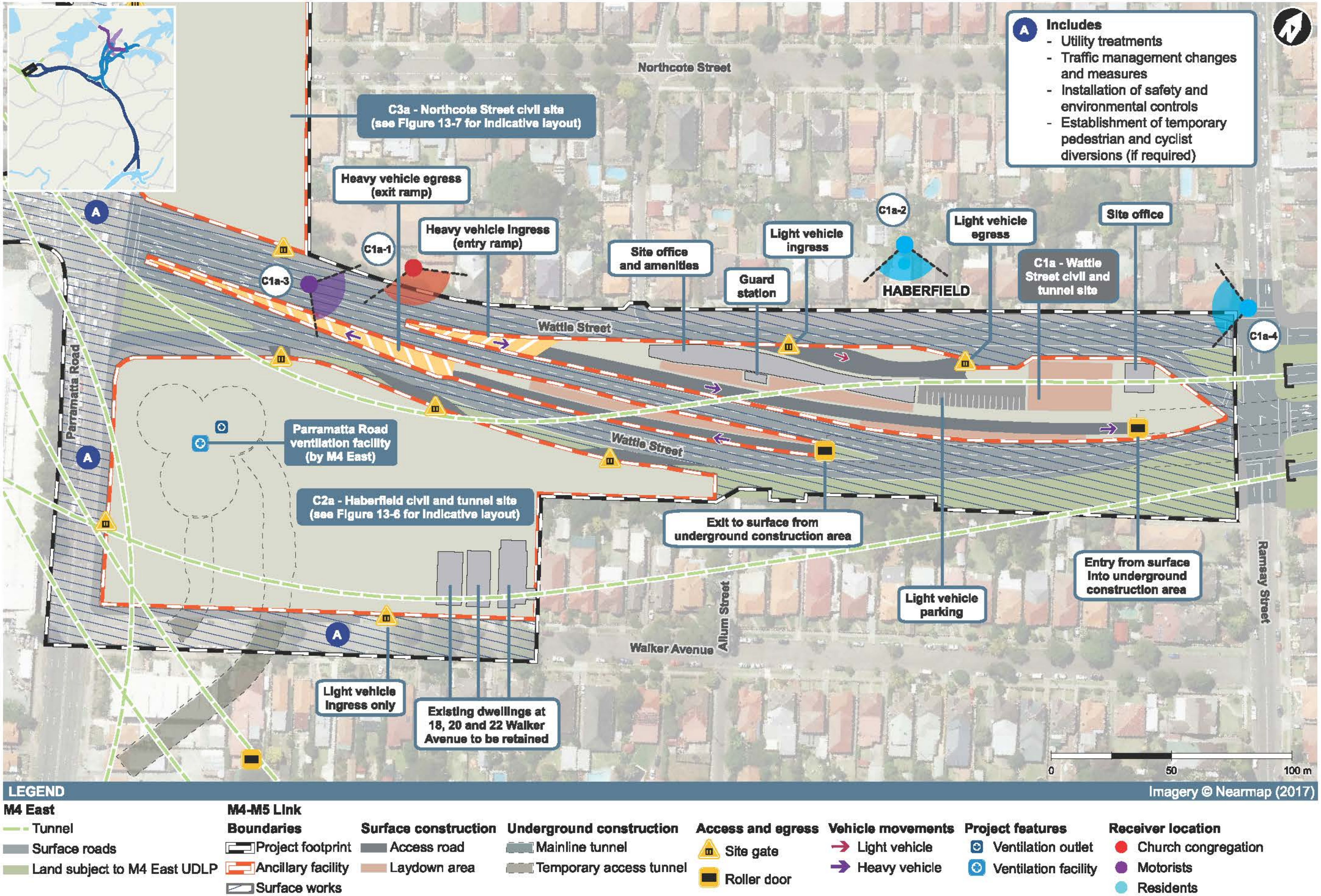


Figure 13-5 Wattle Street civil and tunnel site (C1a) representative receiver locations

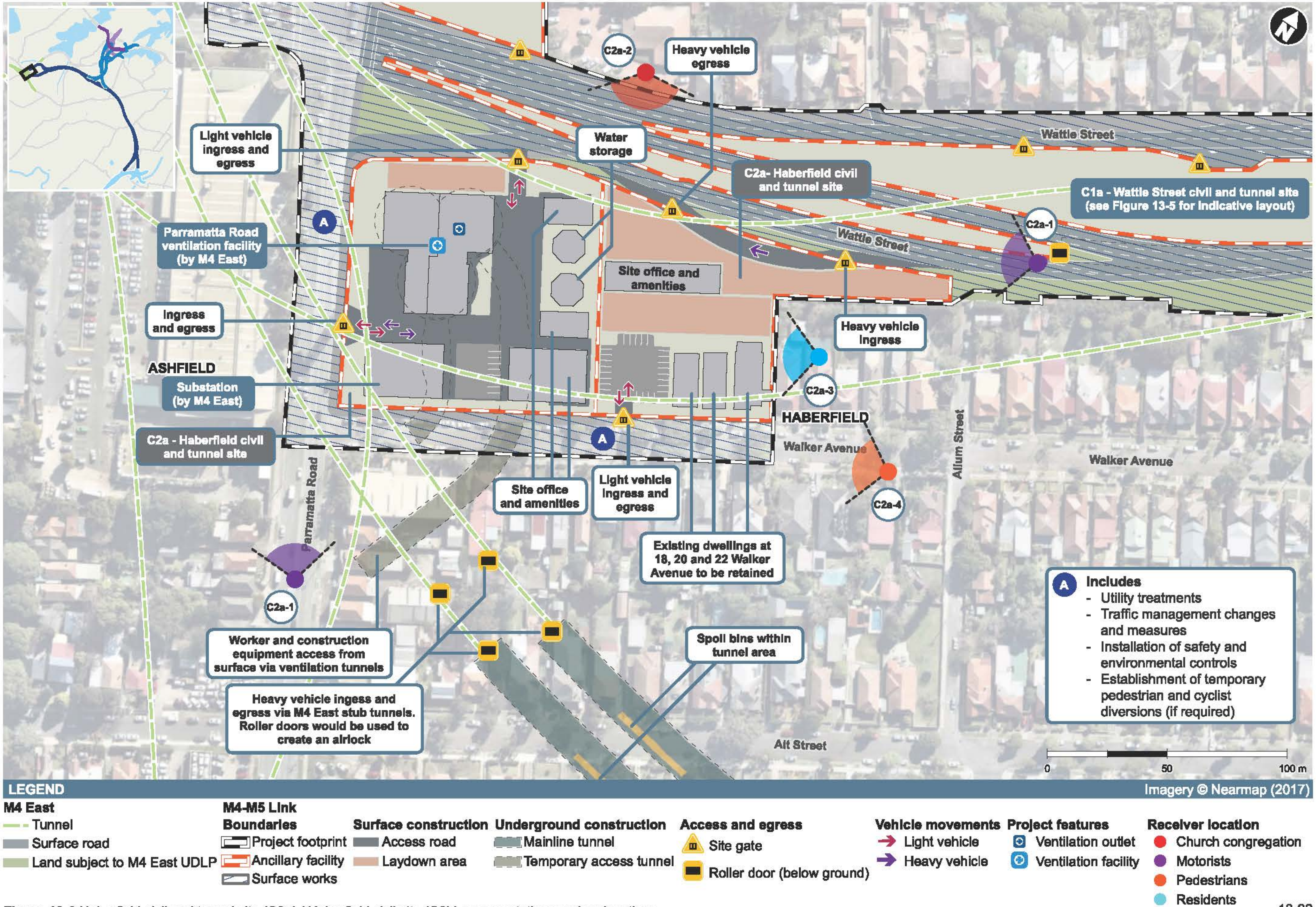


Figure 13-6 Haberfield civil and tunnel site (C2a) / Haberfield civil site (C2b) representative receiver locations

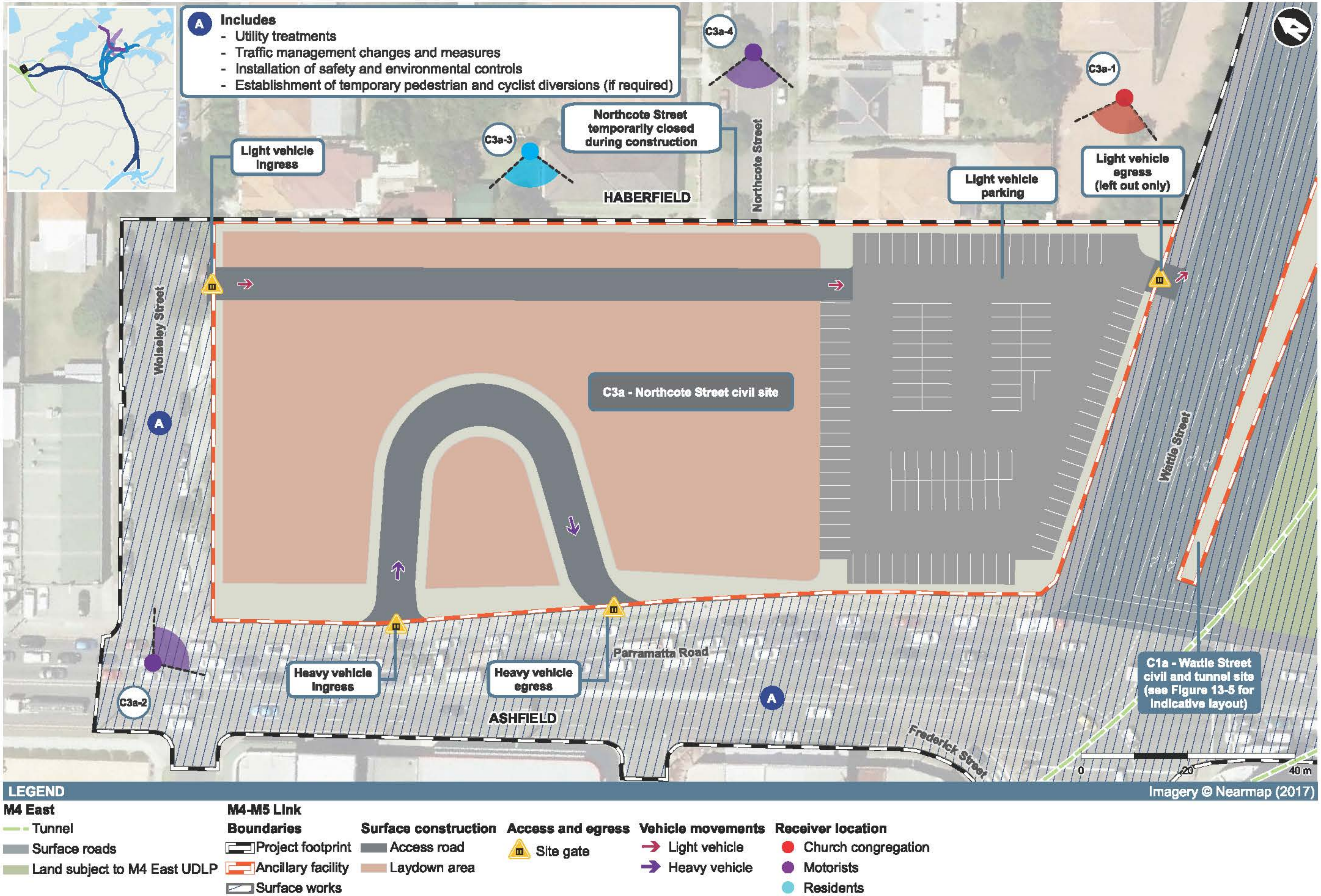


Figure 13-7 Northcote Street civil site (C3a) representative receiver locations

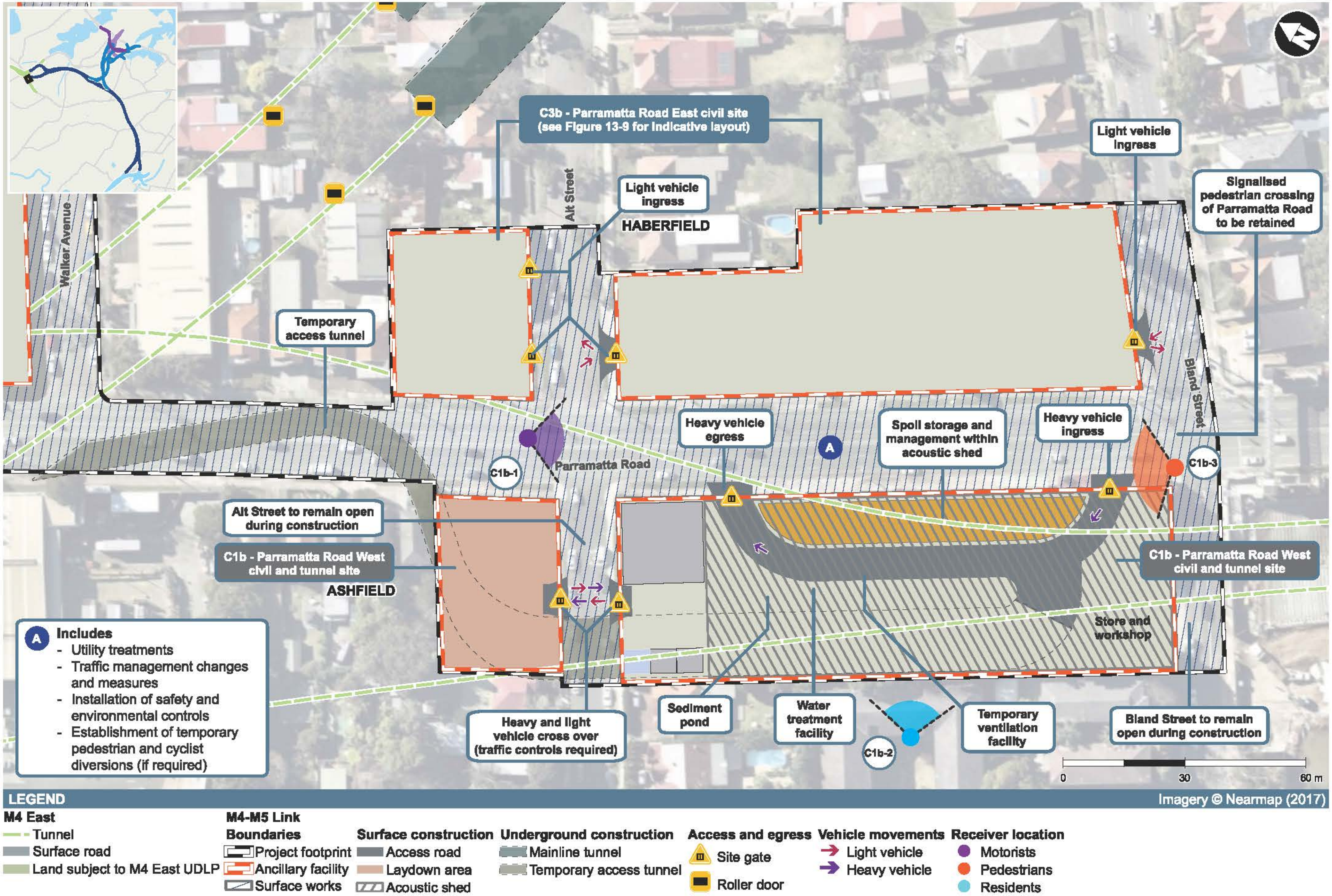


Figure 13-8 Parramatta Road West civil and tunnel site (C1b) representative receiver locations

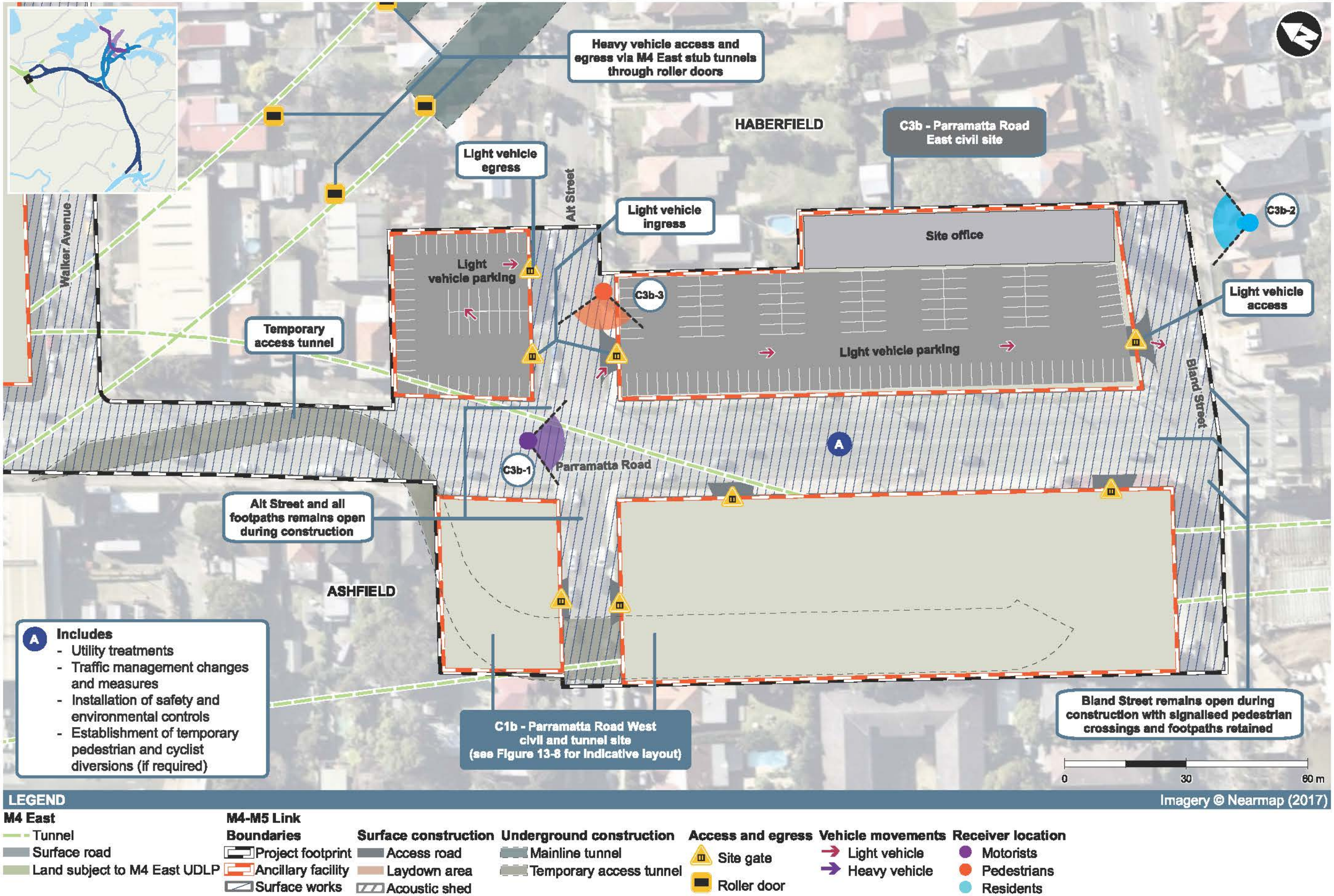


Figure 13-9 Parramatta Road East civil site (C3b) representative receiver locations

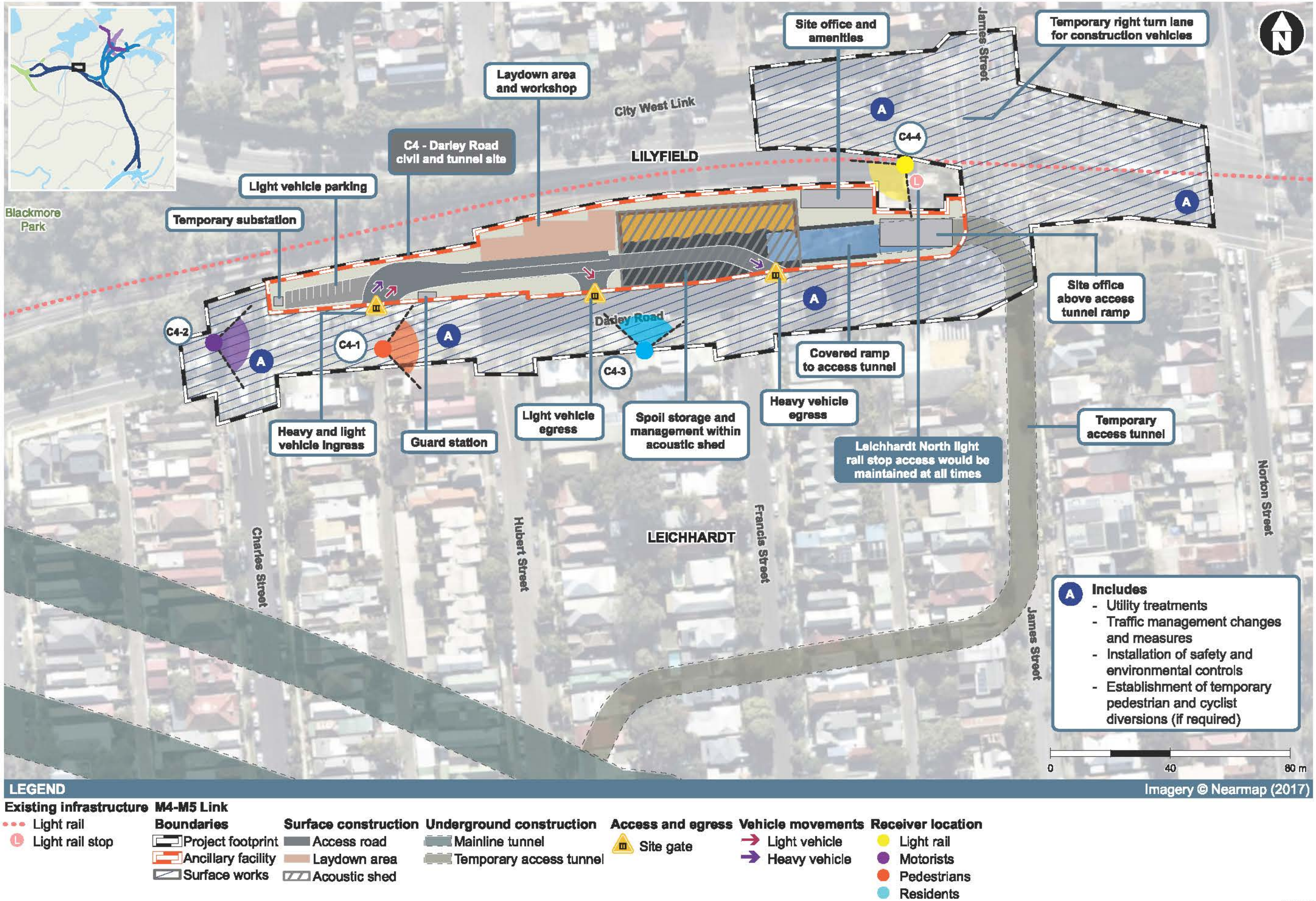


Figure 13-10 Darley Road civil and tunnel site (C4) representative receiver locations

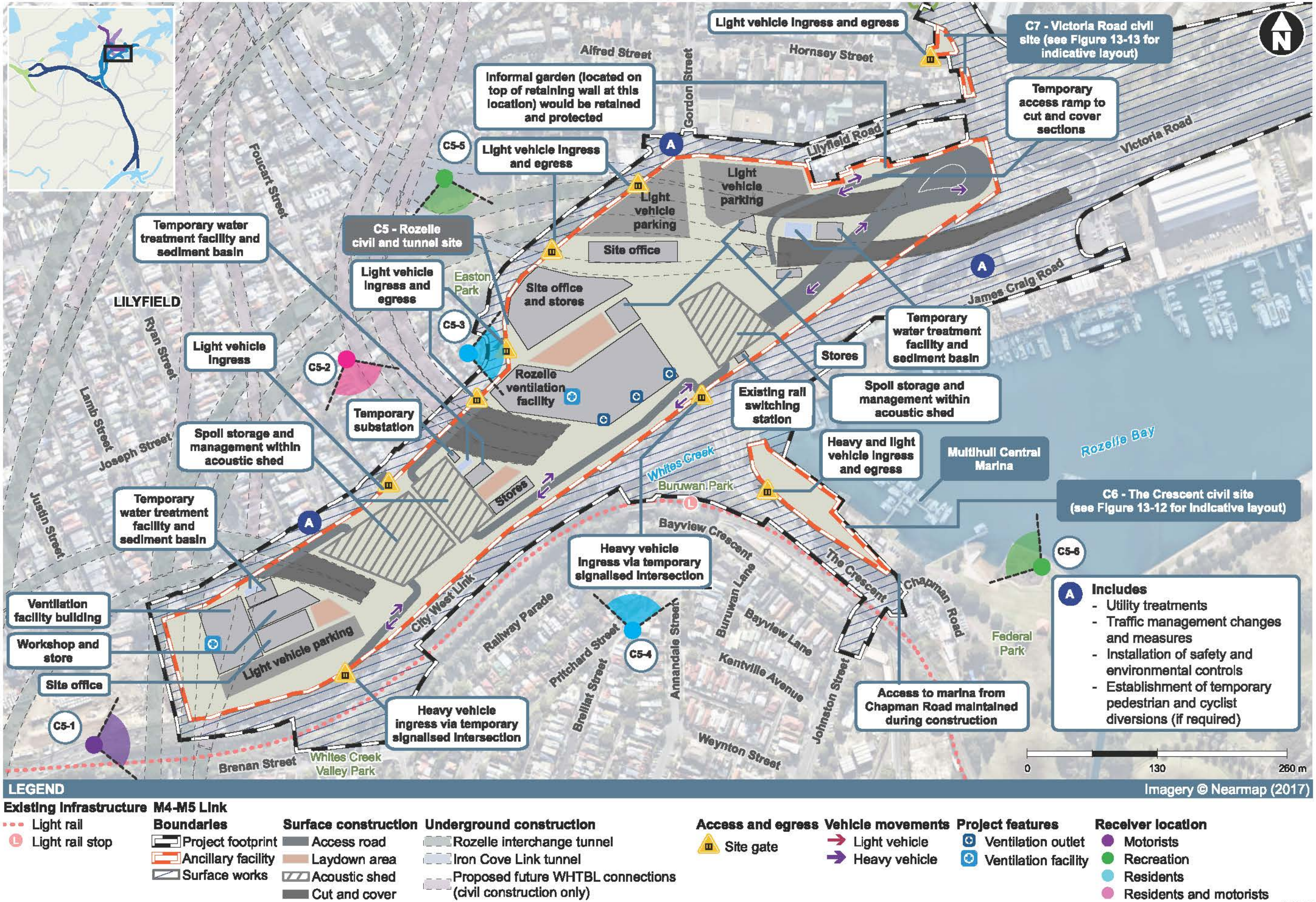


Figure 13-11 Rozelle civil and tunnel site (C5) representative receiver locations

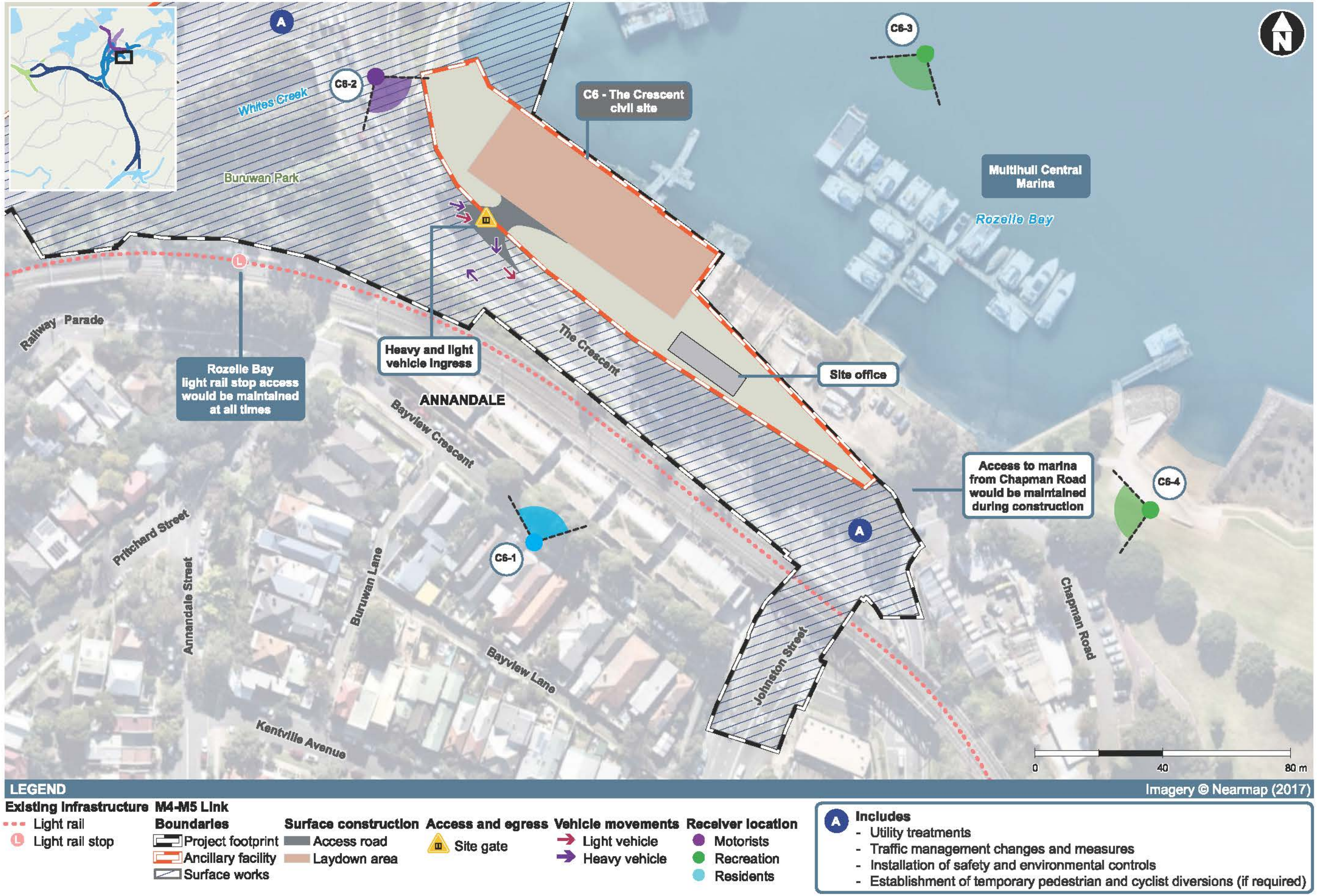


Figure 13-12 The Crescent civil site (C6) representative receiver locations

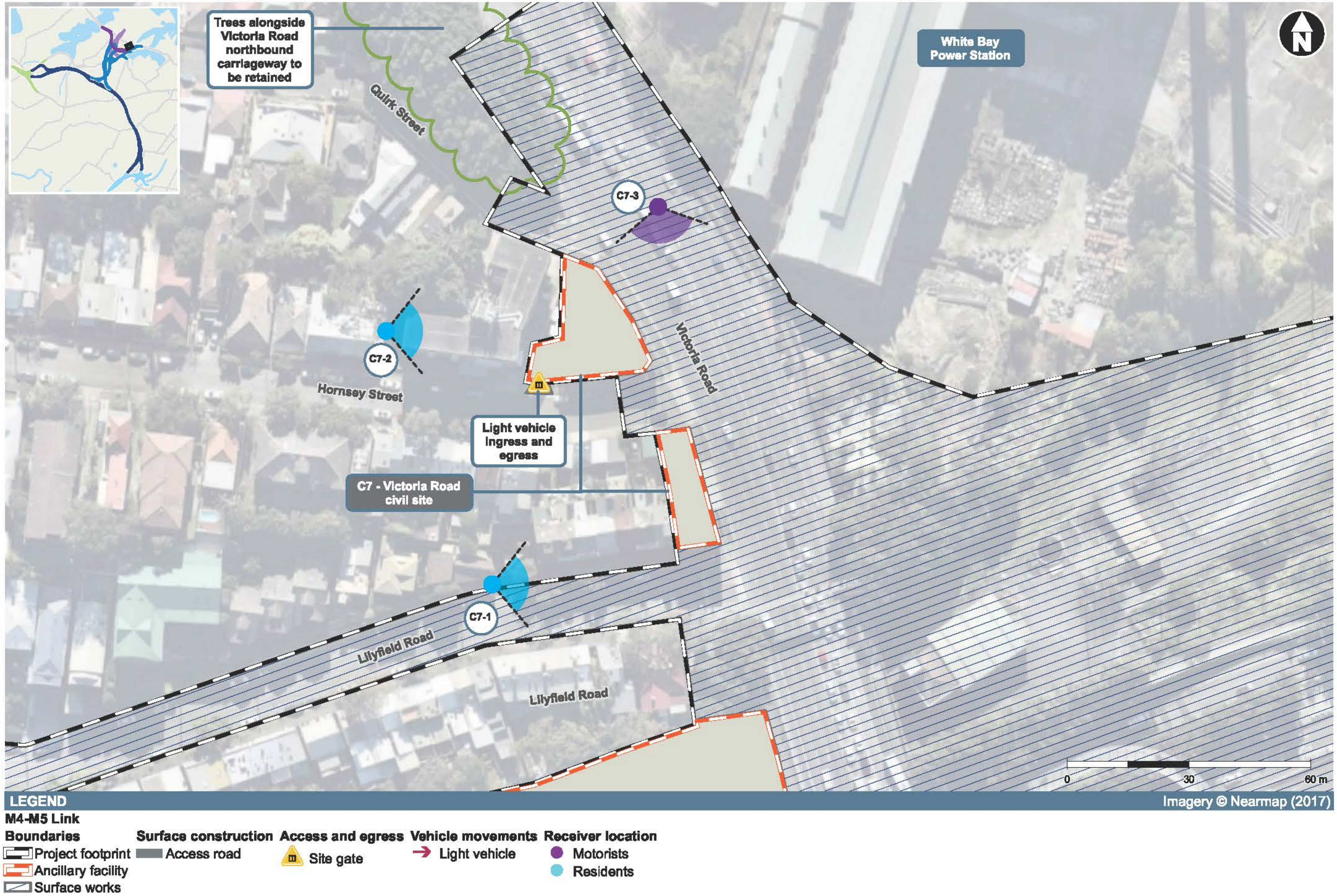
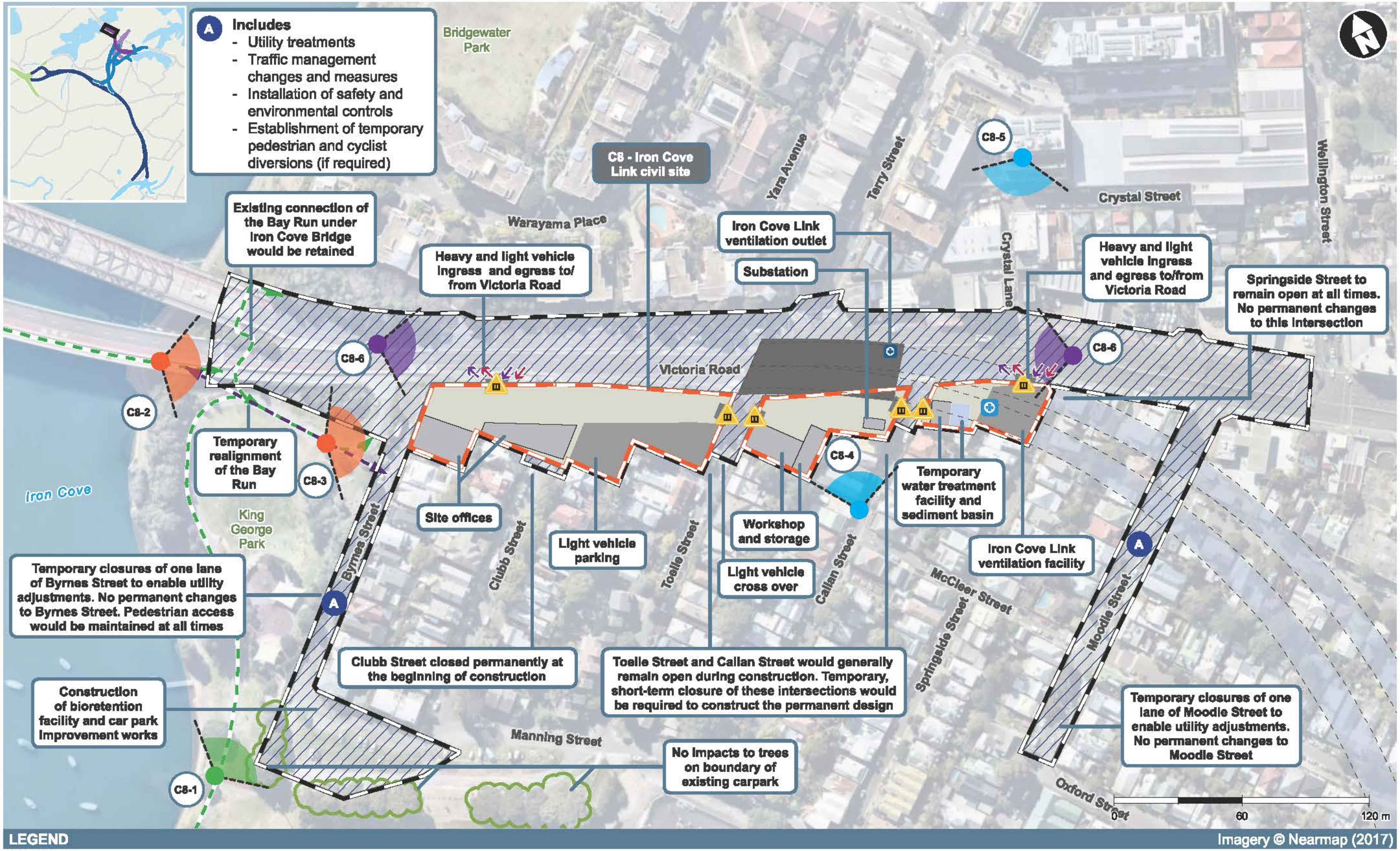


Figure 13-13 Victoria Road civil site (C7) representative receiver locations



LEGEND

M4-M5 Link

Boundaries	Surface construction	Underground construction	Access and egress	Vehicle movements	The Bay Run	Project features	Receiver location
Project footprint	Access road	Iron Cove Link tunnel	Site gate	Light vehicle	Temporary diversion	Ventilation outlet	Motorists
Ancillary facility	Cut and cover			Heavy vehicle	Existing shared path	Ventilation facility	Pedestrians
Surface works							Recreation
							Residents

Figure 13-14 Iron Cove Link civil site (C8) representative receiver locations

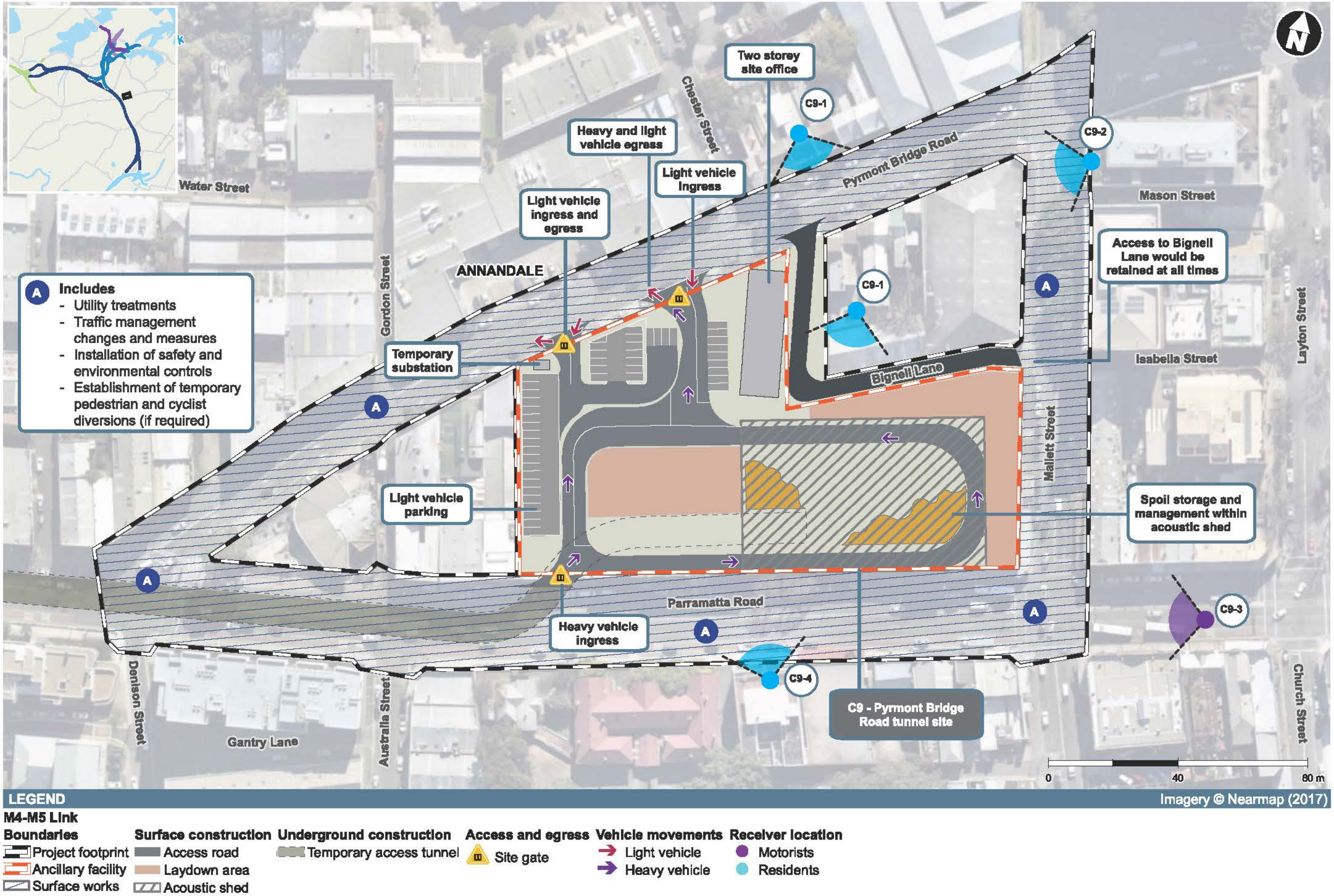


Figure 13-15 Pyrmont Bridge Road tunnel site (C9) representative receiver locations

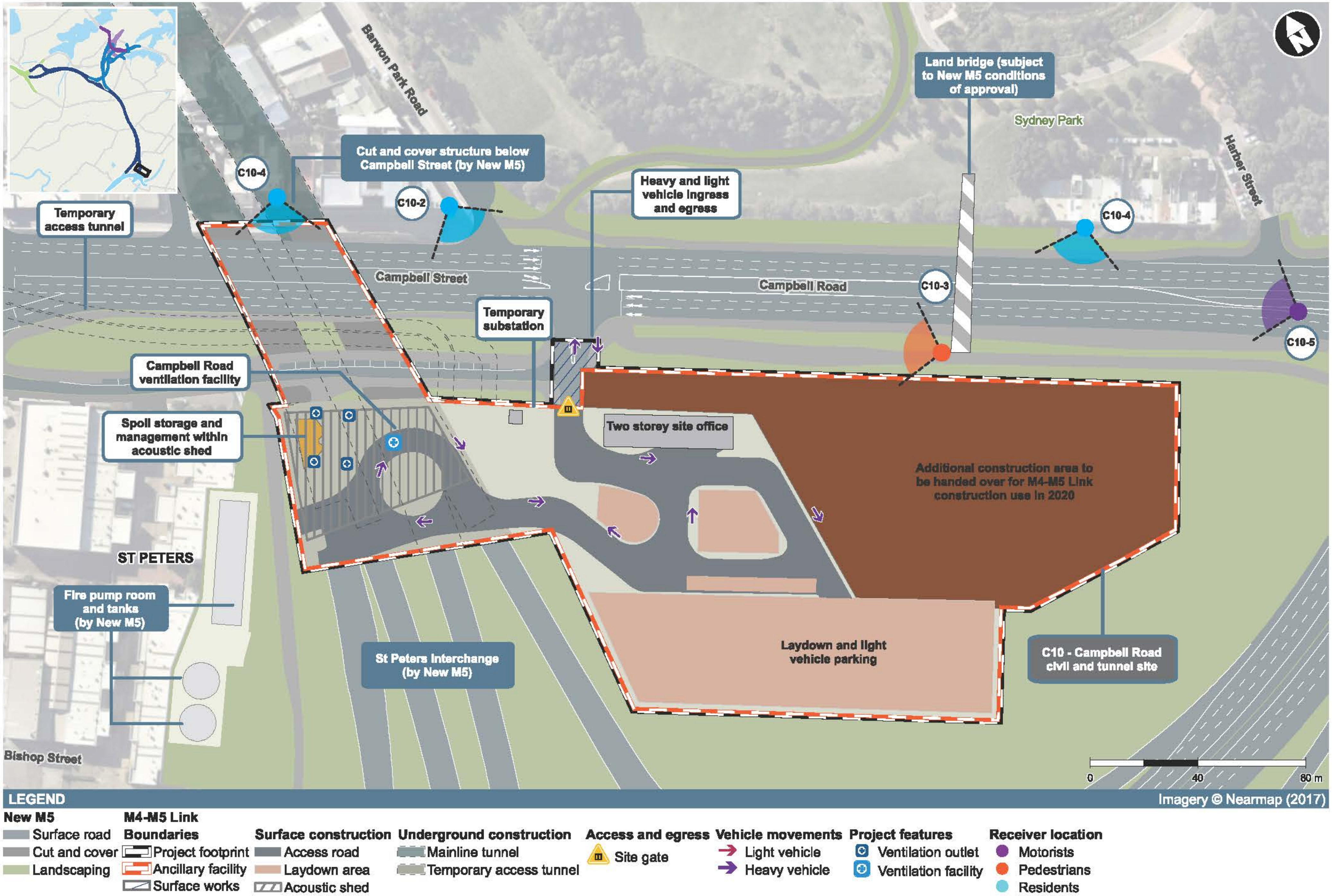


Figure 13-16 Campbell Road civil and tunnel site (C10) representative receiver locations

13.5 Assessment of operational impacts

The operational landscape character and visual impacts (including impacts on views, landscape character and night lighting) and urban design aspects of the project have been assessed at the following areas where built form operational infrastructure would be visible:

- Wattle Street interchange
- Darley Road motorway operations complex (MOC1) at Leichhardt
- The Rozelle interchange, including the Rozelle Rail Yards and adjacent areas along City West Link, The Crescent and Victoria Road (including the Rozelle West motorway operations complex (MOC2) and Rozelle East motorway operations complex (MOC3))
- The Iron Cove Link, predominantly along the Victoria Road corridor and on land that would be acquired for the project along the southern side of Victoria Road between Byrnes Street and Springside Street at Rozelle (including the Iron Cove Link portals and the Iron Cove Link motorway operations complex (MOC4))
- Campbell Road motorway operations complex (MOC5) at the St Peters interchange.

A selection of artists impressions are provided in the sections below for project operational infrastructure. The bulk, mass and scale of motorway operational infrastructure such as the motorway operations complexes shown in the artists impressions based on the concept design developed for the project. Detailed depictions of these built form elements associated with the project would be prepared during detailed design, in consultation with relevant stakeholders and the community. These would be included in the UDLPs that would be prepared for the project.

The urban design principles and objectives described in **section 13.2.2** form the basis for the development of detailed plans that would identify the form and typology of landscaping that would be carried out as part of the project. These include creating a sustainable and enduring design, and integrating the motorway in its context. The project has committed to delivering new open space at the Rozelle Rail Yards, which are currently disused and inaccessible (refer to **section 13.5.3**). Explicit measures to integrate and/ or shield operational elements of the project through landscaping would be developed in consultation with relevant stakeholders (including UrbanGrowth NSW as appropriate) and the community, and in consideration of broader strategic planning objectives, and would be documented in the UDLPs that would be prepared for the project.

Ratings for landscape character impact, visual impact and night lighting impacts during construction are included in the summary tables for area of operational infrastructure assessed in this section. A detailed explanation of these impact ratings is provided **Appendix O** (Technical working paper: Landscape and visual impact).

The total potential visibility of built form operational infrastructure has also been identified through visual envelope mapping which is provided in full in **Appendix O** (Technical working paper: Landscape and visual impact). along with a full suite of visualisations of existing viewpoints and artist impressions of these viewpoints at 12 to 18 months and 10 years after operation.

13.5.1 Wattle Street interchange

The design of the Wattle Street interchange has been developed and assessed as part of the M4 East EIS. The approach is detailed in the Draft M4 East Urban Design and Landscape Plan which was publicly exhibited and made available for community feedback between 19 September and 17 October 2016. Community submissions were reviewed following exhibition and would be addressed in the next revision of the plan.

Once construction of both projects is completed, remaining project land not required for operational infrastructure or subject to landscape works as part of the M4 East project would be rehabilitated and would be subject to the M4 East project’s Residual Land Management Plan, UDLPs and/or the M4 East Legacy Project. These plans are currently being prepared by the M4 East project team and would be subject to the consultation requirements and timeframes set out in the M4 East project conditions of approval. The project would not impact on the implementation of these plans, but may impact the timing in which in the plans are carried out.

13.5.2 Darley Road

Operational infrastructure at the Darley Road would be located south of City West Link and the Inner West light rail line, on part of the land occupied during construction by the Darley Road civil and tunnel site (C4) (the western portion of the site). Key visual features of the project include:

- The Darley Road motorway operations complex (MOC1) which would be about two storeys in height and would include:
  - Water treatment plant
  - Substation (the need for a substation is being investigated and would be confirmed during detailed design)
  - Car parking
  - Workshop/offices and storage facilities.

The indicative siting of operational project infrastructure (as shown in **Chapter 5** (Project description)) has been developed in consideration of maximising areas of land that would be available for potential future development (remaining project land). This has primarily been achieved by optimising the design to co-locate facilities, therefore reducing land-take. The siting of the operational project infrastructure at the western end of the site also allows for the remaining project land component to be located nearest to the Leichhardt North light rail stop.

The landscape works and architectural design of operational infrastructure at Darley Road would be undertaken in accordance with a project UDLP and the urban design principles developed for the project (see **section 13.2.2**).

The remainder of the Darley Road site would become remaining project land and rehabilitated for future development, in accordance with the Residual Land Management Plan. See **section 13.5.7** and **Chapter 12** (Land use and property) for further discussion regarding the future use of remaining project land for the project.

Landscape character impacts

The visual impact assessment did not identify the potential for 'high' landscape character impacts for any LCZs at Darley Road. A summary of the outcomes of the landscape impact assessment are provided in **Table 13-7**.

Table 13-7 Visual impact assessment summary – Darley Road landscape character

Landscape character zone	Sensitivity to change	Magnitude of change	Overall rating
LCZ 1 – Darley Road residential precinct	Low	Low	Low
LCZ 2 – Darley Road commercial precinct	Moderate	Moderate	Moderate
LCZ 3 – Leichhardt light rail precinct	Low	Low	Low

Visual impacts

Key viewpoints to the Darley Road motorway operations complex (MOC1) were identified and are shown in **Figure 13-17**. A selection existing views and associated artist impressions from these key viewpoints during 12 to 18 months of the operation of the project are provided in **Figure 13-18** and **Figure 13-19**. Views to the north of the site the Darley Road motorway operations complex (MOC1) would be highly obscured by existing noise walls, intervening vegetation and differences in relative level and were therefore not considered further in the assessment (see **Appendix O** (Technical working paper: Landscape and visual impact) for detail regarding visual envelope mapping).

The operational visual impact assessment did not identify the potential for 'high' visual impacts on views for any key viewpoints at Darley Road. A summary of the outcomes of the visual impact assessment are provided in **Table 13-8**.

Table 13-8 Visual impact assessment summary – Darley Road viewpoints

Receiver location	Receiver type	Sensitivity	Magnitude	Overall rating
View looking east from Darley Road near corner of Charles Street (D1)	Residents	Low	Moderate	Moderate–Low
	Pedestrians	Low	Low	Low
View looking west from Darley Road at entry to lane between James Street and Francis Street (D2)	Residents	Low	Low	Low
	Pedestrians	Low	Low	Low

Night lighting impacts

The visual impact assessment did not identify the potential for 'high' night lighting impacts for any receiver locations at Darley Road. A summary of the outcomes of the visual impact assessment are provided in **Table 13-9**.

Table 13-9 Visual impact assessment summary – Darley Road night lighting

Receiver location	Receiver type	Sensitivity	Magnitude	Overall rating
View looking east from Darley Road near corner of Charles Street (D1)	Residents	Low	Low	Low
	Pedestrians	Low	Low	Low
View looking west from Darley Road at entry to lane between James Street and Francis Street (D2)	Residents	Low	Negligible	Negligible
	Pedestrians	Negligible	Low	Negligible

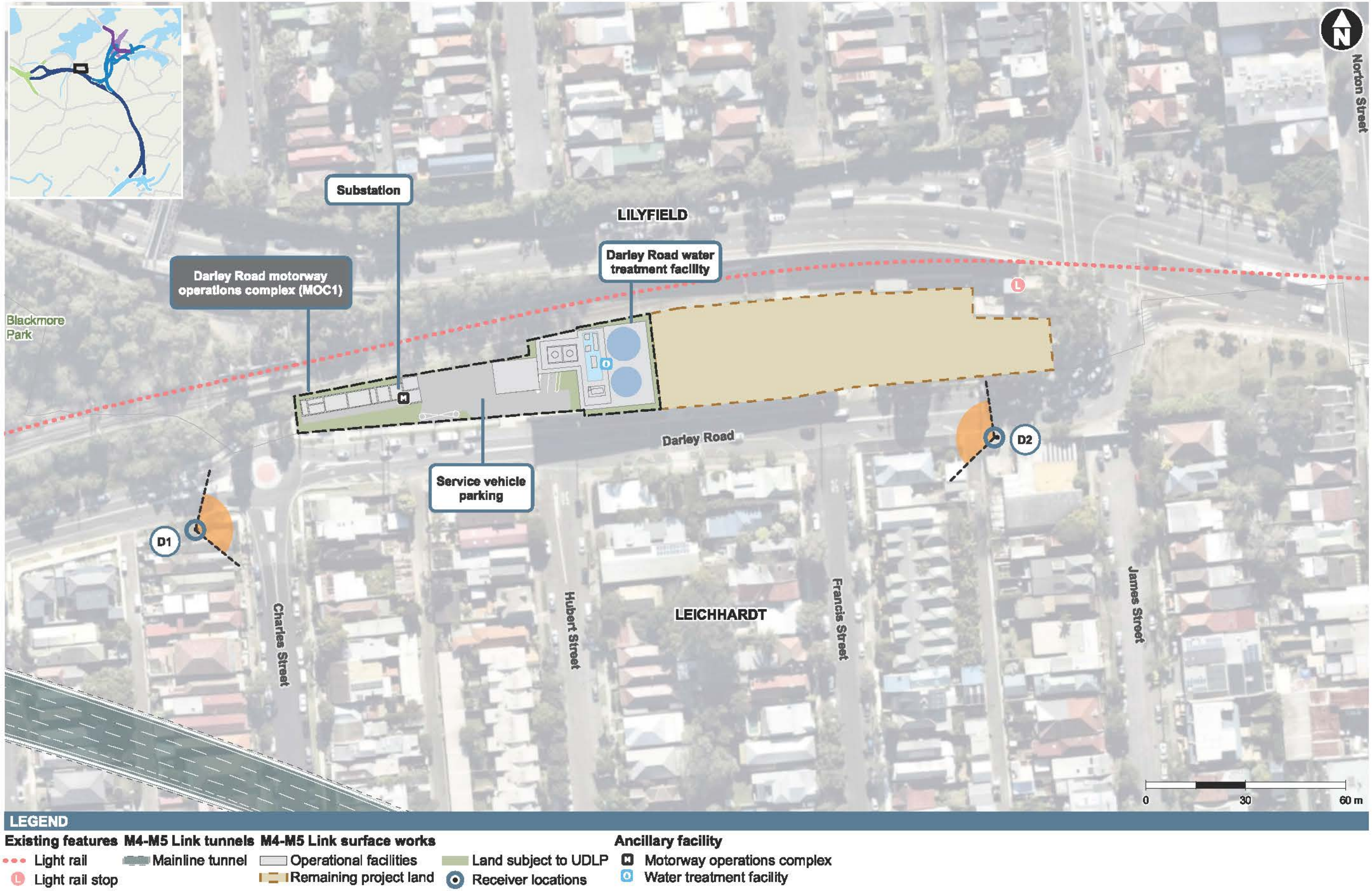


Figure 13-17 Key viewpoints at the Darley Road motorway operations complex (MOC1)

Figure 13-18 Existing view looking east along Darley Road near the corner of Charles Street (D1)

Figure 13-19 Artist's impression at 12-18 months of project operation of view looking east along Darley Road near the corner of Charles Street (D1) (subject to detailed design as part of an UDLP)

13.5.3 Rozelle interchange

Operational infrastructure associated with the Rozelle interchange would generally be located within the Rozelle Rail Yards, with some infrastructure components extending to The Crescent, along City West Link, and along Victoria Road including the approaches to and from Anzac Bridge.

Key visual features of the project around the Rozelle interchange include:

- Cut-and-cover tunnels and tunnel portal structures
- The Rozelle West motorway operations complex (MOC2) at Rozelle – located at the western end of the Rozelle Rail Yards, including:
  - Ventilation supply facility
  - Substation
  - Fire suppression pump station
- The Rozelle East motorway operations complex (MOC3) at Rozelle - located at the central/eastern end of the Rozelle Rail Yards, including:
  - Ventilation exhaust facility including three ventilation outlets which would have a height of up to 35 metres above existing ground level (note that one outlet is being constructed for the proposed future Western Harbour Tunnel project)
  - Substation
  - Water treatment plant
- Realignment and upgrade of City West Link and The Crescent between around 300 metres east of Catherine Street at Lilyfield, and The Crescent/Victoria Road intersection
- Widening and improvement works to the channel and bank of Whites Creek at Annandale, between around the light rail bridge and Rozelle Bay. These works would be carried out to manage flooding and drainage for the surface road network
- Two new pedestrian and cyclist bridges over City West Link to connect Lilyfield Road and Victoria Road with The Crescent and Annandale, and a new pedestrian and cyclist underpass below Victoria Road to connect Lilyfield Road with Anzac Bridge
- Integration of the salvaged rail infrastructure including the rail gantries and lighting tower into the open space (subject to interpretation)
- Urban design and landscape works including a constructed wetland and active transport routes (discussed further in the sections below).

The proposed built form for the Rozelle Rail Yards is provided in **Figure 13-20**. The landscape works and architectural design of operational infrastructure at the Rozelle interchange would be undertaken in accordance with a project UDLP and the urban design principles developed for the project (see **section 13.2.2**).

Key viewpoints to the Rozelle Rail Yards were identified and are shown in **Figure 13-21.** A selection of existing viewpoints and artist impressions of these viewpoints at 12 to 18 months of project operation are provided in **Figure 13-22** to **Figure 13-29**.

Urban design and landscape works

The project would include the provision of new open space within the Rozelle Rail Yards. The works that would be carried out at the Rozelle interchange would include (but not be limited to):

- Detailed review and finalisation of the architectural treatment of the motorway operational infrastructure
- Reshaping of the landform at the site around the motorway operational infrastructure
- Provision of pedestrian and cyclist paths and bridges
- Provision of new open space within the Rozelle Rail Yards, including landscape works

- Revegetation and planting, including tree planting, at key locations including:
  - Around motorway operational infrastructure such as the ventilation facility
  - Around the constructed wetland, bioretention swale and the drainage channels
  - Adjacent to pedestrian and cyclist paths
  - Around the perimeter of the Rozelle Rail Yards.

A concept design for these works has been prepared, included in **Appendix L** (Technical working paper: Urban design). The concept design would be refined during the development of UDLPs, which would be prepared based on the detailed design and in accordance with relevant commitments in this EIS. The UDLPs would be prepared in consultation with relevant councils, stakeholders and the community.

Connectivity

An active transport strategy has been developed for the project and is provided in full at **Appendix N** (Technical working paper: Active transport strategy). The active transport strategy was developed in consultation with stakeholders and through analysis of current and proposed active transport routes and relevant active transport policies and guidelines (see **Appendix N** (Technical working paper: Active transport strategy) for further information regarding the development of the active transport strategy).

At the Rozelle interchange, new pedestrian and cyclist infrastructure would be provided that would connect with existing and proposed active transport networks. Delivery of active transport links around the Rozelle interchange would significantly improve pedestrian and cyclist connectivity in the area. Four active transport links would be developed for the project within and around this area including the Rozelle Rail Yards Link, Whites Creek Link (including bridge crossing over City West Link), Rozelle land bridge and Victoria Road to City West Link connection.

A summary of the proposed connectivity around the Rozelle interchange that would be delivered by the M4-M5 Link and delivered by other separate projects subject to separate environmental assessment is provided in **Table 13-10**. Proposed open space and connectivity at the Rozelle interchange is shown in **Figure 13-30**. Wayfinding measures to facilitate connectivity would be developed as part of the UDLPs for the project as outlined in **section 13.6**.

Key north–south connectivity would be established via the two new bridges over City West Link. These links would greatly improve accessibility between Glebe/Annandale and Rozelle/Lilyfield. They would also provide connectivity between the Rozelle Bay and Iron Cove, through key green spaces of Bicentennial Park, open space at the Rozelle Rail Yards, Easton Park and Callan Park.

East–west connectivity would be provided through the site connecting to the Lilyfield Road cycleway adjacent to the Central Business District (CBD) and South East Light Rail (CSELR) Rozelle maintenance depot. A path would be provided that connects to the existing Anzac Bridge shared path by travelling underneath the Victoria Road/City West Link intersection. This connection would provide future possibilities for connections into The Bays Precinct.

The concept plans for the Rozelle Rail Yards and the Iron Cove Link (included in **Appendix L** (Technical working paper: Urban design) have been developed in consideration of ensuring the existing and proposed active transport networks are separated from, or can traverse efficiently, tunnel portals and entry and exit ramps. In the Rozelle Rail Yards, tunnel portals are proposed to be incorporated into the design of the open space, with active transport paths traversing over the top of these structures. In addition, the elevated grades provided by these structures simplify the design of the new north-south active transport connections over City West Link by minimising the amount of ramping needed to ensure sufficient clearance over the road network can be provided. At the Iron Cove Link portals, the portals have been located west of the Toelle Street – Terry Street connection, enabling upgrades to this existing signalised pedestrian crossing to provide a strong north-south connection. This would include providing for north-south traverse above the tunnel portals.

Connectivity that would be provided by the project at the Rozelle Rail Yards would contribute to the enhancement of healthy, cohesive and inclusive communities. The community benefits that would be associated increased connectivity are discussed in **Chapter 14** (Social and economic).

Table 13-10 Summary of proposed connectivity around the Rozelle interchange

Route	Rationale	Type	Length (indicative)	Delivery
Rozelle Rail Yards Link	Link the Anzac Bridge through The Bays Precinct to Lilyfield Road at the western end of the Rozelle Rail Yards	Separated cycle path	250 metres	M4–M5 Link (the link to The Bays Precinct is part of future works in coordination with UrbanGrowth NSW)
	Provide the junction connecting Rozelle Rail Yards and Victoria Road to The Bays Precinct	Underpass	150 metres	M4–M5 Link
	Provide the link between Victoria Road and the CSELR Rozelle Maintenance Depot	Separated cycle path	1,000 metres	M4–M5 Link
	Connect the CSELR Rozelle Maintenance Depot to Charles Street and Canal Road linking onto the Bay Run	Separated cycle path	1,800 metres	Inner West Council/Roads and Maritime/Transport for NSW
	Connect the eastern side of the Rozelle Rail Yards along Victoria Road to the intersection of Robert Street	Separated cycle path	250 metres	M4–M5 Link
	Connect Victoria Road to The Crescent over the Rozelle Rail Yards	Bridge	200 metres	M4–M5 Link
	Connect Victoria Road to The Crescent	Shared path	400 metres	M4–M5 Link
	Connect The Crescent to James Craig Road existing active transport network	Shared path	500 metres	M4–M5 Link
Johnston Street link	Connect Parramatta Road to The Crescent	Separated cycle path	1,800 metres	Inner West Council & Roads and Maritime
Whites Creek Link	Link the intersection of Brenan Street and Railway Parade over or under City West Link connecting to the Rozelle Rail Yards link	Bridge	200 metres	M4–M5 Link
	Link Railway Parade through Cohen Park, Whites Creek Valley Park and connects onto Whites Creek Lane	Shared path	750 metres	Inner West Council
	Link Whites Creek Valley Park to Macquarie Street and further onto Parramatta Road	Laneway	1,000 metres	Inner West Council
Johnstons Creek Valley Link	Connect Easton Park to The Crescent through the Rozelle Rail Yards	Bridge / shared path	300 metres	M4–M5 Link
	Provide a suitable cycling space for the connection along The Crescent, into Jubilee Park and linking to the existing Glebe Foreshore	Shared path	500 metres	M4–M5 Link
	Link the Glebe Foreshore to the north end of Taylor Street alongside Johnstons Creek using the existing pedestrian infrastructure to link	Existing shared path	500 metres	Inner West Council
	Prove a connection from the north end of Taylor Street, under the Wigram Road bridge, under the Booth Street bridge and linking onto the Douglas Grant Memorial Park	Bridge over canal	500 metres	Sydney Water and Inner West Council

Route	Rationale	Type	Length (indicative)	Delivery
	Provide the connection through Douglas Grant Memorial Park	Existing shared path	100 metres	Sydney Water and Inner West Council
	Connect Douglas Grant Memorial Park to the laneway to the east of Susan Street, following the creek line	Bridge over canal	50 – 100 metres	Sydney Water and Inner West Council
	Connect the north end of the laneway to Cahill Lane and Parramatta Road	Shared path	200 metres	Inner West Council

Notes:
Shading denotes active transport infrastructure that would be provided by the M4-M5 Link project

Future opportunities

The urban design principles and objectives outlined in **section 13.2.2** form the basis for the development of detailed plans that would identify the types of locations of community and social infrastructure that would be provided by the project, or enabled for future provision by others. These would be determined in consultation with relevant stakeholders (including UrbanGrowth NSW) and the community, and in consideration of broader strategic planning objectives, and would be documented in an UDLP that would be prepared for the project.

As part of an UDLP, an urban design master plan for the Rozelle interchange would identify opportunities to deliver outcomes that support and connect existing neighbourhoods, complement and stimulate local economies and provide opportunities for growth across existing and future local industries along and around Victoria Road at Rozelle. This could include provision of community and social infrastructure such as sporting fields and other active recreational facilities.

The ultimate decision as to the types of facilities that would be provided by the project would be determined in consultation with relevant stakeholders, the community, and in consideration of council and state planning documents, including recreational needs analysis and strategic policy such as The Bays Precinct Transformation Plan.

Further information regarding future opportunities is provided in **Appendix L** (Technical working paper: Urban design.

Landscape character impacts

The visual impact assessment did not identify the potential for 'high' landscape character impacts for any LCZs around the Rozelle interchange. A summary of the outcomes of the visual impact assessment are provided in **Table 13-11**.

Table 13-11 Visual impact assessment summary – Rozelle interchange landscape character

Landscape character zone	Sensitivity to change	Magnitude of change	Overall rating
LCZ 4 – Glebe Foreshore Parklands precinct	Moderate	Moderate	Moderate
LCZ 5 – Johnston Street precinct	High	Negligible	Negligible
LCZ 6 – Annandale Street and Young Street precinct	Moderate	Low	Moderate–Low
LCZ 7 – Whites Creek Valley precinct	High	Low	Moderate
LCZ 8 – Catherine Street precinct	Moderate	Negligible	Negligible
LCZ 9 – Catherine Street neighbourhood centre precinct	Low	Low	Low
LCZ 10 – Balmain Road precinct	Low	Negligible	Negligible
LCZ 11 – Nanny Goat Hill residential precinct	Low	Low	Low
LCZ 12 – Halloran Street commercial precinct	Low	Negligible	Negligible
LCZ 13 – Easton Park residential precinct	High	Moderate	High–Moderate
LCZ 14 – Victoria Road south precinct	Low	Moderate	Moderate–Low
LCZ 15 – White Bay Power Station precinct	High	Moderate	High-Moderate
LCZ 16 – Rozelle Bay wharves precinct	Low	Moderate	Moderate–Low
LCZ 17 – City West Link precinct	Low	Moderate	Moderate–Low
LCZ 18 – Rozelle light rail corridor and Whites Creek canal precinct	Moderate	Moderate	Moderate
LCZ 19 – Rozelle Rail Yards precinct	Low	Moderate	Moderate–Low

Visual impacts

A summary of the outcomes of impacts on views from key viewpoints around the Rozelle interchange are provided in **Table 13-12.** The visual impact assessment identified the potential for ‘high’ visual impacts for the view looking south from Easton Park (R5) to the project for residents (see **Figure 13-26** and **Figure 13-27**).

For residents, the ventilation facility (primarily the ventilation outlets as part of the facility), from this view would be in a high to moderate level of contrast with that of the existing view, notwithstanding that much of this would comprise open space. While the architecture and design of the ventilation facility would be well considered for the surrounding area, the structure may nonetheless be perceived as a low quality element given its purpose, bulk and scale in an open area and subsequent visual prominence.

For receiver locations around the Rozelle interchange, the ventilation outlets as part of the ventilation facility would be viewed within the context of other proximate, large infrastructure elements in the skyline, such as the White Bay Power Station chimney stacks, the Glebe Island grain silos, and Anzac Bridge.

The visual impact assessment also identified ‘high’ visual impacts for pedestrians for the view looking north from the Rozelle Bay light rail stop (R7) (see **Figure 13-28** and **Figure 13-29**).

For pedestrians, views along Annandale Street and Pritchard Lane would be aligned with the ventilation facility, potentially providing framed views of this contrasting element. Given the quality of the existing streetscape view is high, as is the importance of these views being located within the Annandale Heritage Conservation Area, it was determined that pedestrians would experience a ‘high’ visual impact for this view.

Table 13-12 Visual impact assessment summary – Rozelle interchange viewpoints

Receiver location	Receiver type	Sensitivity	Magnitude	Overall rating
View looking east from Catherine Street entry to Lilyfield light rail stop (R1)	Light rail users	Moderate	Low	Moderate–Low
	Residents	Low	Moderate	Moderate- Low
View looking west along City West Link to M5 portals tunnel portals (R2)	Motorists	Low	Moderate	Moderate–Low
View looking west from City West Link to the Crescent (R3)	Pedestrians/ cyclists	Low	Moderate	Moderate–Low
	Motorists	Low	Moderate	Moderate–Low
View looking east along Lilyfield Road at corner of Foucart Street (R4)	Residents	Moderate	Moderate	Moderate
	Motorists	Negligible	Low	Negligible
View looking south from Easton Park to the Rozelle Rail Yards (R5)	Residents	High	High	High
	Active recreational users	Low	Moderate	Moderate–Low
	Passive recreational users	Moderate	High	High–Moderate
View looking north from Glebe Foreshore Parklands to the Rozelle Rail Yards (R6)	Active recreational users	Low	Moderate	Moderate–Low
	Passive recreational users	High	Moderate	High–Moderate
View looking north from Rozelle Bay light rail stop to the Rozelle Rail Yards (R7)	Light rail users	Moderate	High	High–Moderate
	Residents	High	Moderate	High–Moderate
	Pedestrians	High	High	High

Night lighting impacts

A summary of the outcomes of the visual impact assessment for night lighting are provided in **Table 13-13**. The visual impact assessment identified the potential for 'high' night lighting impacts for the view looking north from Rozelle Bay light rail stop (R7) for pedestrians and residents.

For residents, a moderate and potentially high number of residential receptors would have direct visibility of what would be anticipated to be a significant increase in road lighting levels associated with the project, particularly at the intersection of the Iron Cove Link interchange, City West Link, and The Crescent. The quality of the night-time city views over Rozelle Bay from this view was considered to be very high. The extent of increased night lighting visible to residential receptors could be high, resulting in moderate to high levels of night-time contrast with the existing views.

For pedestrians, sensitivity to the introduction of a potentially high or even moderate point source of high light levels could be expected to be high, especially where seen from multiple locations. A point source of light in this view would be in strong contrast to the generally well screened, low light suburban environment of Annandale. The magnitude of change would be high due to the introduction of a bright point source of light within an intrinsically low light suburban, heritage landscape setting.

Table 13-13 Visual impact assessment summary – Rozelle interchange night lighting

Receiver location	Receiver type	Sensitivity	Magnitude	Overall rating
View looking east from Catherine Street entry to Lilyfield light rail stop (R1)	Light rail users	Low	Low	Low
	Residents	Low	Low	Low
View looking west along City West Link to M5 portals (R2)	Motorists	Low	Moderate	Moderate–Low
View looking west along City West Link to The Crescent (R3)	Pedestrians /cyclists	Low	Moderate	Moderate–Low
	Motorists	Low	Moderate	Moderate-Low
View looking east along Lilyfield Road at corner of Foucart Street (R4)	Residents	Negligible	Low	Negligible
	Motorists	Low	Low	Low
View looking south from Easton Park to the project (R5)	N/A[1]	N/A	N/A	N/A
View looking north from Glebe Foreshore Parklands to the project (R6)	Passive recreational users	Low	Moderate	Moderate–Low
	Active recreational users	Negligible	Moderate	Low
View looking north from Rozelle Bay light rail stop (R7)	Light rail users	Low	High	Moderate
	Residents	High	High	High
	Pedestrians	Moderate	High	High–Moderate

Note 1: Additional lighting seen from this location would comprise that to share pathways and potentially nodal lighting at activity locations such as a skate park within the vicinity of the ventilation facility.

View loss

A summary of the assessment of impacts on view loss the local community at the Rozelle interchange is provided in **Table 13-14**. The assessment identified the potential for 'high' view loss impacts for the free-standing dwellings located on Foucart Street near the corner of Lilyfield Road and for the residences within the vicinity of Hutcheson Street and Denison Street near Lilyfield Road.

Table 13-14 View loss assessment summary – Rozelle interchange viewpoints

Receiver location	Sensitivity	Magnitude	Overall rating
Free-standing dwellings located on Foucart Street near the corner of Lilyfield Road	High	High	High
Residences within the vicinity of Hutcheson Street and Denison Street near Lilyfield Road	High	High	High

The sensitivity to change for these two views was considered to be 'high' considering the context of the elevated residential settings and quality of the skyline view of the CBD. The magnitude of the potential change was considered to be 'high' given the scale, form and mass of the ventilation exhaust facility as part of the Rozelle East motorway operations complex (MOC3) that would be visible in these views and the potential for a moderate portion of the views being lost in addition to the interruption of the broader view.

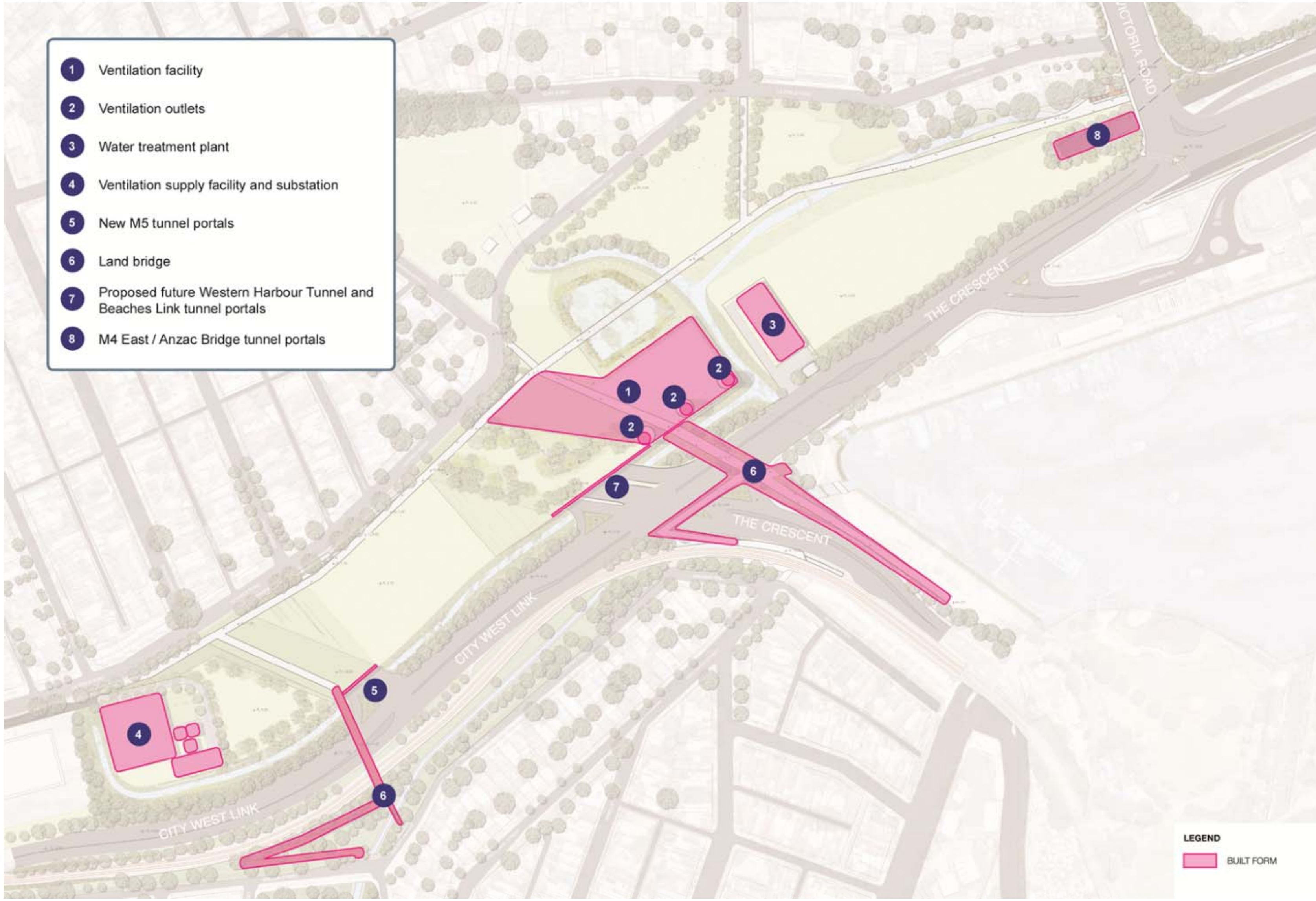


Figure 13-20 Rozelle Rail Yards built form and landscape

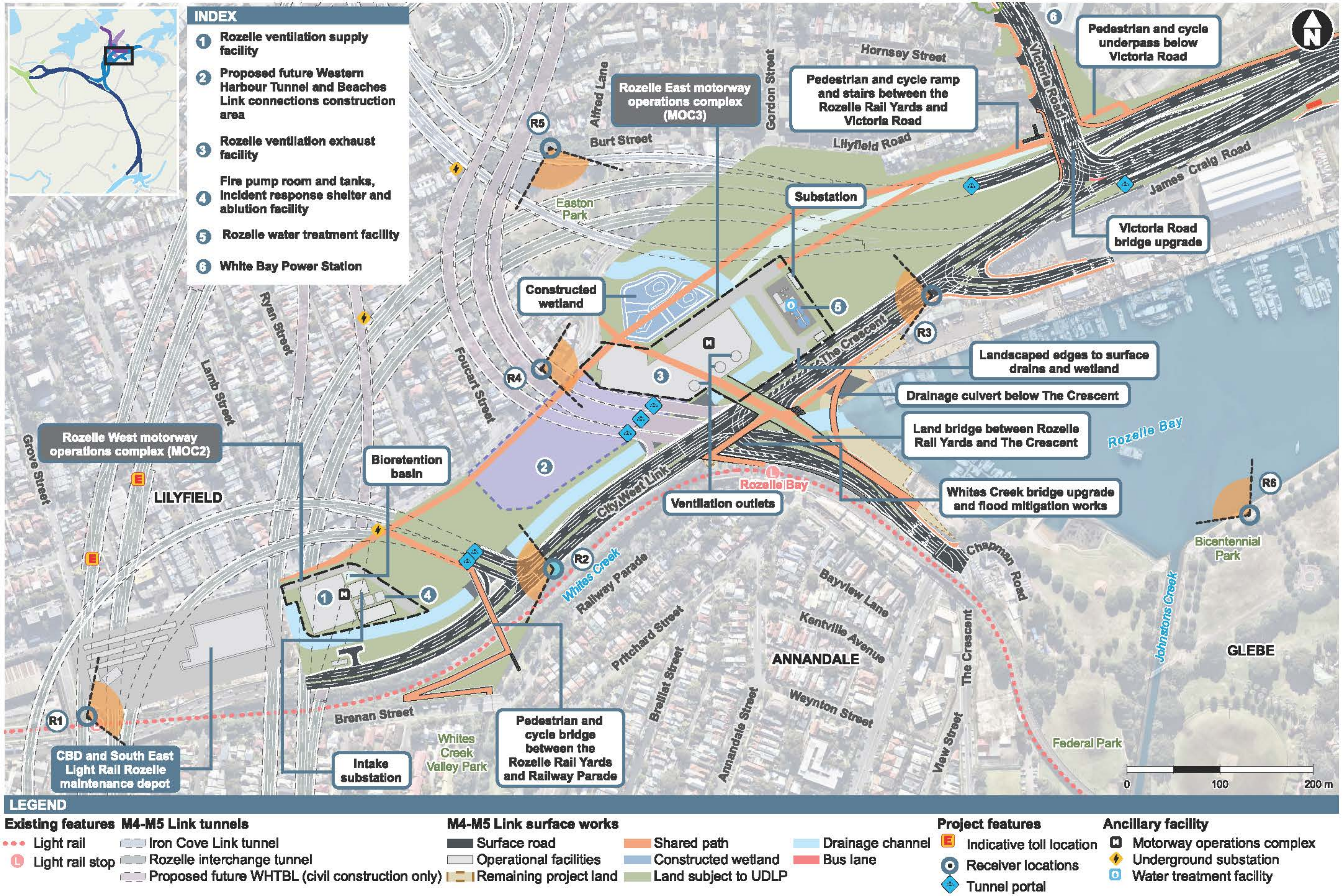


Figure 13-21 Key viewpoints at the Rozelle interchange

Figure 13-22 Existing view looking west along City West Link to New M5 portals (R2)

Figure 13-23 Artist's impression at 12-18 months of project operation of view looking west along City West Link to New M5 portals (R2) (subject to detailed design as part of an UDLP)

Figure 13-24 Existing view from City West Link to The Crescent (R3)

Figure 13-25 Artist's impression at 12-18 months of project operation of view from City West Link to The Crescent (R3) (subject to detailed design as part of an UDLP)

Figure 13-26 Existing view looking south from Easton Park to the Rozelle Rail Yards (R5)

Figure 13-27 Artist's impression at 12-18 months of project operation of view looking south from Easton Park to the Rozelle Rail Yards (R5) (subject to detailed design as part of an UDLP)

Figure 13-28 Existing view looking north from Rozelle Bay light rail stop to the Rozelle Rail Yards (R7)

Figure 13-29 Artist’s impression at 12-18 months of project operation of view looking north from Rozelle Bay light rail stop to the Rozelle Rail Yards (R7) (subject to detailed design as part of an UDLP)

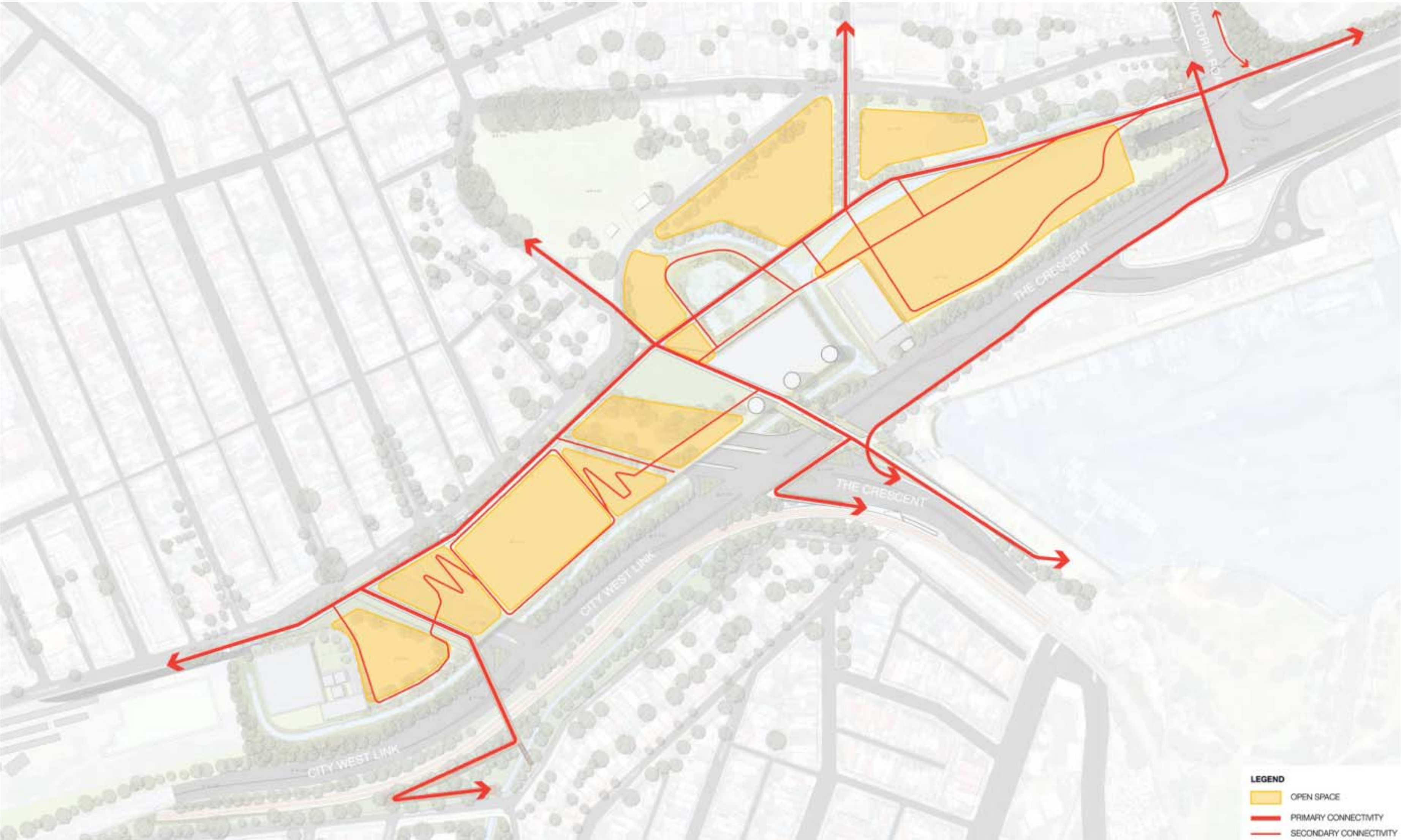


Figure 13-30 Rozelle Rail Yards open space and connectivity

13.5.4 Iron Cove Link

Operational infrastructure associated with the Iron Cove Link would generally be located within the Victoria Road corridor and on land that would be acquired for the project along the southern side of Victoria Road between Byrnes Street and Springside Street at Rozelle.

Key visual features of the project around the Iron Cove Link include:

- Realignment and modifications to the surface carriageways of Victoria Road, between around Springside Street and the eastern abutment of Iron Cove Bridge
- Construction of west-facing tunnel portals, dive structures and cut-and-cover structures between the eastbound and westbound surface lanes of Victoria Road, to connect Victoria Road with the Iron Cove Link
- The Iron Cove Link motorway operations complex (MOC4) at Rozelle – located south of the realigned Victoria Road carriageway between Callan Street and Springside Street at Rozelle, on land occupied during construction by the Iron Cove Link civil site (C8) including:
  - A tunnel ventilation facility within the widened Victoria Road carriageway between Toelle Street and Springside Street at Rozelle including a ventilation exhaust facility and ventilation outlet (which would have a height of about 20 metres above existing ground level) in the middle of the widened Victoria Road carriageway, and ventilation tunnel connections and other ancillary infrastructure on the south side of the widened Victoria Road corridor
  - Substation
- Realignment and improvements to the shared pedestrian and cyclist path that runs along the southern side of the westbound carriageway of Victoria Road, including reinstatement of the Bay Run connection to Iron Cove Bridge
- A new stormwater bioretention facility and upgrades to the existing car park within King George Park (adjacent to Manning Street) at Rozelle, to treat stormwater runoff generated by the surface road works associated with the Iron Cove Link. Around 30 car parking spaces would be formalised as part of these works.

The proposed built form for the Iron Cove Link is provided in **Figure 13-38**. The landscape works and architectural design of operational infrastructure at the Iron Cove Link would be undertaken in accordance with a project UDLP and the urban design principles developed for the project (see **section 13.2.2**).

Key viewpoints to the Iron Cove Link (including the Iron Cove Link motorway operations complex (MOC4)) were identified and are shown in **Figure 13-31**. A selection of existing viewpoints and artist impressions of these viewpoints at 12 to 18 months of project operation are provided in **Figure 13-32** to **Figure 13-37**.

Urban design and landscape works

As part of the project, urban design and landscape works would be carried out adjacent to disturbed areas associated with the Iron Cove Link surface works. The urban design and landscape works that would be conducted as part of the Iron Cove Link surface works would include (but not be limited to):

- Detailed review and finalisation of the architectural treatment of the motorway operational infrastructure
- Reshaping of the landform at the site around the motorway operational infrastructure
- Reinstatement of an improved pedestrian and cyclist path along the southern side of Victoria Road, that would connect to the Bay Run and Iron Cove Bridge and local streets
- Provision of new open space, including landscape works

- Revegetation, including tree planting, at key locations including:
  - Around permanent operational infrastructure such as the ventilation facility
  - Adjacent to pedestrian and cyclist paths
  - Along the southern boundary.

A concept design for these urban design and landscape works has been prepared having regard to the urban design objectives and principles. The concept design is included in **Appendix L** (Technical working paper: Urban design) and includes identification of potential future uses of land around the Iron Cove Link surface works that could be delivered as part of the urban design and landscape works, including the provision of social and community facilities.

The concept design would be refined during the development UDLPs for the project, which would be prepared, based on the detailed design and in accordance with relevant commitments in this EIS, and in consultation with relevant councils, stakeholders and the community.

Connectivity

In addition to urban design and landscape works, new pedestrian and cyclist infrastructure would be provided that would connect with existing and proposed active transport networks. Connectivity that would be provided by the project at the Iron Cove Link would contribute to the enhancement of healthy, cohesive and inclusive communities. The community benefits that would be associated increased connectivity are discussed in **Chapter 14** (Social and economic).

Delivery of an active transport link at Iron Cove would improve pedestrian and cyclist connectivity in the area. The Iron Cove active transport link would be developed for the project and would be a key connector that would:

- Connect the northern suburbs of Drummoyne (and Russel Lea and Five Dock via the Bay Run) to The Bays Precinct and the CBD
- Connect the existing retail centres on Darling Street and Victoria Road as well as local schools and other community services
- Provide a direct route, notwithstanding significant gradient changes, from Iron Cove towards Darling Street
- Connect to active transport routes on local routes
- Link significant open space from the Bay Run, Callan Park and the future open space at Rozelle Rail Yards and foreshore along The Bays Precinct.

The increased width of the Victoria Road carriageway for the project has the potential to exacerbate the existing separation between the communities of Rozelle and Balmain that exists because of the poor north–south links associated with Victoria Road. The design of the portals in this location would address this by providing improved pedestrian and cyclist accessibility between Toelle Street and Terry Street. The portals have been located to allow a direct link between these streets that would provide a crossing over Victoria Road, with a pedestrian refuge in the centre of the road above the portals.

A new pedestrian footpath and separated cycleway would be provided between Springside Street connecting to the Bay Run at Byrnes Street on the southern side of Victoria Road. It is anticipated that sufficient space would be provided for a two-way cycleway as well as a separate footpath that meets required standards.

A summary of the proposed connectivity around the Iron Cove Link that would be delivered by the M4-M5 Link and delivered by other separate projects subject to separate environmental assessment is provided in **Table 13-15**.

Table 13-15 Summary of proposed connectivity around the Iron Cove Link

Route	Rationale	Type	Length (indicative)	Delivery
	Connect the intersection of Robert Street up and over Victoria Road to the intersection of Springside Street	Separated cycle path	900 metres	Inner West Council
	Link the intersection of Springside Street to the Iron Cove Bridge and the Bay Run	Separated cycle path	450 metres	M4–M5 Link

Notes:
Shading denotes active transport infrastructure that would be provided by the M4-M5 Link project

The proposed streetscape and connectivity at the Iron Cove Link is shown in **Figure 13-39**. The active transport strategy for the project is provided in full at **Appendix N** (Technical working paper: Active transport strategy). Wayfinding measures to facilitate connectivity would be developed as part of the UDLPs for the project as outlined in **section 13.6**.

Future opportunities

The project would potentially facilitate urban regeneration along Victoria Road, due to forecast traffic reductions from the operation of the Iron Cove Link. Targeted development control and land use planning could potentially maximise the potential of redevelopment sites along the Victoria Road. A revitalised Victoria Road could present new opportunities for businesses, locals and visitors, while providing strong local pedestrian and cyclist connections between Lilyfield and Rozelle. Revitalisation of sections of Victoria Road outside the project footprint does not form part of the project and would be subject to separate environmental assessment.

Further information regarding future opportunities is provided in **Appendix L** (Technical working paper: Urban design).

Landscape character impacts

The visual impact assessment did not identify the potential for ‘high’ landscape character impacts for any LCZs at the Iron Cove Link. A summary of the outcomes of the visual impact assessment are provided in **Table 13-16**.

Table 13-16 Visual impact assessment summary – Iron Cove Link landscape character

Landscape character zone	Sensitivity to change	Magnitude of change	Overall rating
LCZ 20 – Victoria Road north precinct	Low	Moderate	Moderate–Low
LCZ 21 – Victoria Road light industrial precinct	Moderate	Negligible	Negligible
LCZ 22 – Iron Cove residential precinct	Low	Moderate	Moderate–Low
LCZ 23 – King George Park precinct	Moderate	Moderate	Moderate
LCZ 24 – Callan Park residential precinct	High	Moderate	High–Moderate
LCZ 25 – Sydney College of the Arts precinct	High	Negligible	Negligible
LCZ 26 – Darling Street precinct	Low	Negligible	Negligible

Visual impacts

A summary of the outcomes of impacts on views from key viewpoints at the Iron Cove Link are provided in **Table 13-17**. The visual impact assessment identified the potential for ‘high’ visual impacts for residents on the west side of Terry Street for the view looking south along Terry Street towards project (IC4) (see **Figure 13-34** and **Figure 13-35**). The sensitivity of the residents of the three storey apartments on the west side of Terry Street was considered to be high as the apartments look out onto a well-considered, almost entirely residential streetscape of substantial visual quality.

The magnitude of the change for residents on the west side of Terry Street was also considered to be high given that the view of the ventilation outlet (as part of the Iron Cove Link motorway operations complex (MOC4)) would comprise a substantial, highly contrasting element within the context of a well-articulated and substantially detailed residential development within this part of the street, and the revealed, small scale, period housing profiles on the opposite side of Victoria Road.

However, the removal of residential and commercial development fronting onto Victoria Road, and replacement with well setback, lower scale existing period housing profiles and streetscape improvements, in addition to centre median planting with substantial tree cover, is considered to comprise an improvement in the visual character of this central part of the view. 'High' visual impacts are not anticipated for the other viewpoints identified around the Iron Cove Link.

Table 13-17 Visual impact assessment summary – Iron Cove Link viewpoints

Receiver location	Receiver type	Sensitivity	Magnitude	Overall rating
View looking east along Victoria Road near Iron Cove Bridge (IC1)	Residents	Moderate	Moderate	Moderate
	Pedestrians	Low	Moderate	Moderate–Low
	Recreation	Moderate	Moderate	Moderate
	Motorists/public transport/cyclists	Low	Moderate	Moderate–Low
View looking west from Manning Street towards bioretention facility (IC2)	Residents	Moderate	Low	Moderate–Low
	Recreational users	Moderate	Low	Moderate–Low
	Pedestrians	Moderate	Low	Moderate–Low
View looking east along Victoria Road near Terry Street (IC3)	Pedestrians	Low	Moderate	Moderate–Low
	Motorists/public transport/cyclists	Low	Moderate	Moderate–Low
View looking south along Terry Street towards Victoria Road (IC4)	Residents – Balmain Shores corner of Terry Street	Low	Moderate	Moderate–Low
	Residents – Nagurra Place: north side	Low	Low	Low
	Residents – Nagurra Place: south side	Moderate	High	High–Moderate
	Residents – Terry Street: west side	High	High	High
	Residents – Terry Street: east side	Moderate	Low	Moderate-Low
	Pedestrians	Low	Low	Low
	Motorists/cyclists	Low	Low	Low
View looking north along Springside Street towards Victoria Road (IC5)	Residents	Moderate	Moderate	Moderate
	Pedestrians	Moderate	Moderate	Moderate
View looking east along Victoria Road at corner of Crystal Street (IC6)	Pedestrians	Low	Moderate	Moderate–Low
	Motorists/public transport/cyclists	Low	Moderate	Moderate–Low

Night lighting impacts

The visual impact assessment did not identify the potential for 'high' night lighting impacts for any receiver locations at the Iron Cove Link. A summary of the outcomes of the visual impact assessment are provided in **Table 13-18**.

Table 13-18 Visual impact assessment summary – Iron Cove Link night lighting

Receiver location	Receiver type	Sensitivity	Magnitude	Overall rating
View looking east along Victoria Road near Iron Cove Bridge (IC1)	Residents	Moderate	Moderate	Moderate
	Pedestrians	Low	Moderate	Moderate–Low
	Recreation	Low	Moderate	Moderate–Low
	Motorists/public transport/cyclists	Low	Moderate	Moderate–Low
View looking west from Manning Street towards bioretention facility (IC2)	N/A[1]	N/A	N/A	N/A
View looking east along Victoria Road near Terry Street (IC3)	Pedestrians	Low	Low	Low
	Motorists/public transport/cyclists	Low	Low	Low
View looking south along Terry Street towards Victoria Road (IC4)	Residents	Low	Low	Low
	Pedestrians	Low	Low	Low
	Motorists/cyclists	Low	Low	Low
View looking north along Springside Street towards Victoria Road (IC5)	Residents	Low	Low	Low
	Pedestrians	Low	Low	Low
View looking east along Victoria Road at corner of Crystal Street (IC6)	Pedestrians	Low	Moderate	Moderate–Low
	Motorists/public transport/cyclists	Low	Low	Low

Note 1: There would be no additional lighting proposed for this part of the project, subject to detail design.

View loss

A summary of the assessment of impacts on view loss the local community at the Iron Cove Link is provided in **Table 13-19**. The assessment did not identify the potential for 'high' view loss impacts on the community at the Iron Cove Link.

Table 13-19 View loss assessment summary – Iron Cove Link

Receiver location	Sensitivity	Magnitude	Overall rating
Medium rise residential apartments ('Union Balmain'), Nagurra Place	Moderate	Low	Moderate–Low
Low rise residential apartments 'Balmain Shores'	Moderate	Low	Moderate–Low
Low rise residential apartments '43 Terry Street'	Moderate	Moderate	Moderate

Urban design and landscaping

Land on the southern side of Victoria Road would provide a buffer between the Victoria Road carriageway and the existing residential houses as shown in **Figure 13-31**. This land would be subject to UDLP and provides opportunities for future uses, in consultation with local council and the community. See **section 13.5.7** and **Chapter 12** (Land use and property) for further discussion regarding the future use of remaining project land for the project.

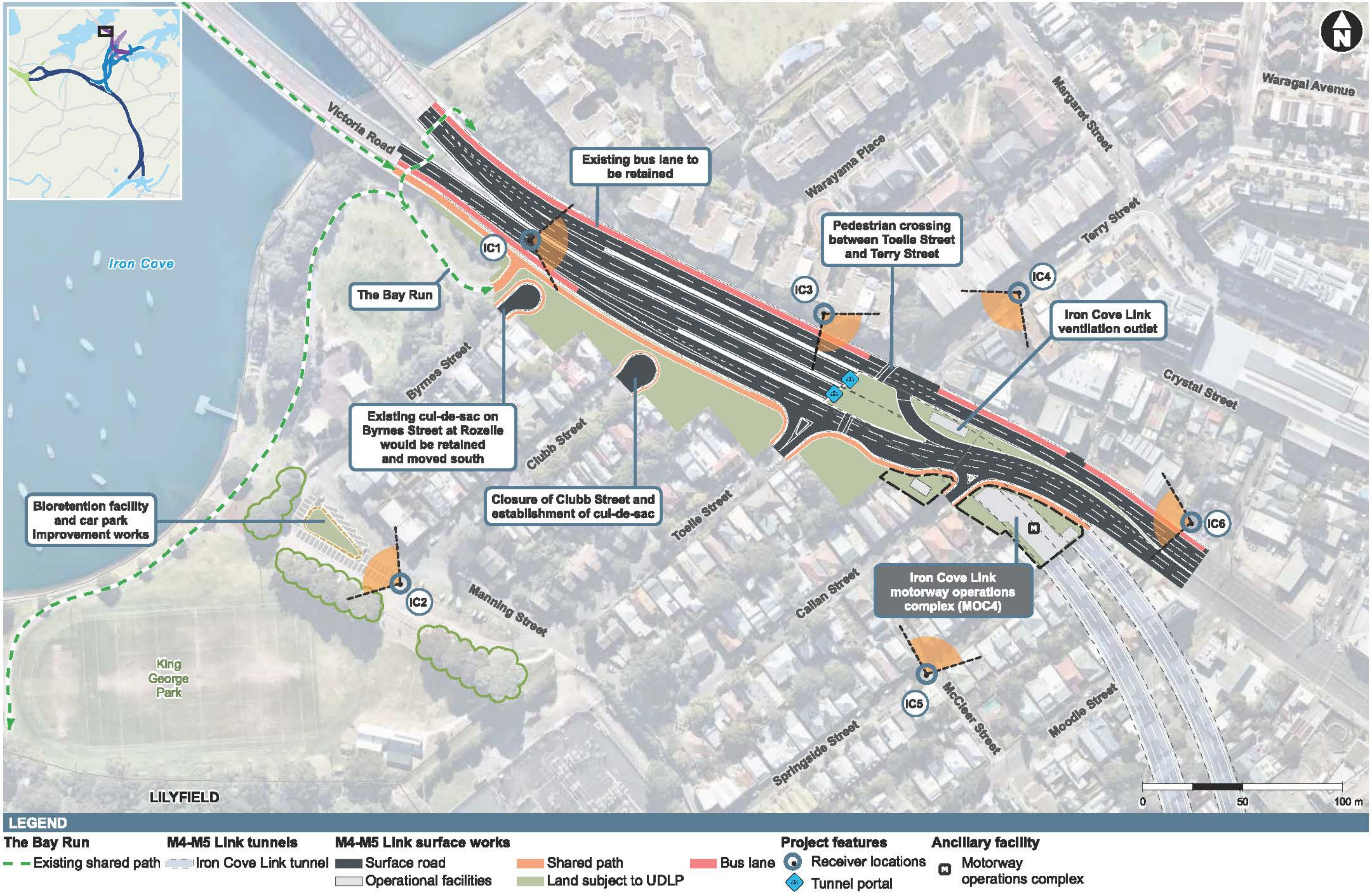


Figure 13-31 Key viewpoints at the Iron Cove Link

Figure 13-32 Existing view from Victoria Road near Iron Cove Bridge looking east (IC1)

Figure 13-33 Artist's impression at 12–18 months of project operation of view from Victoria Road near Iron Cove Bridge looking east (IC1) (subject to detailed design as part of an UDLP)

Figure 13-34 Existing view looking south along Terry Street towards Victoria Road (IC4)

Figure 13-35 Artist's impression at 12–18 months of project operation of view looking south along Terry Street towards Victoria Road (IC4) (subject to detailed design as part of an UDLP)

Figure 13-36 Existing view looking east along Victoria Road at corner of Crystal Street (IC6)

Figure 13-37 Artist's impression at 12–18 months of project operation for the view looking east along Victoria Road at corner of Crystal Street (IC6) (subject to detailed design as part of an UDLP)

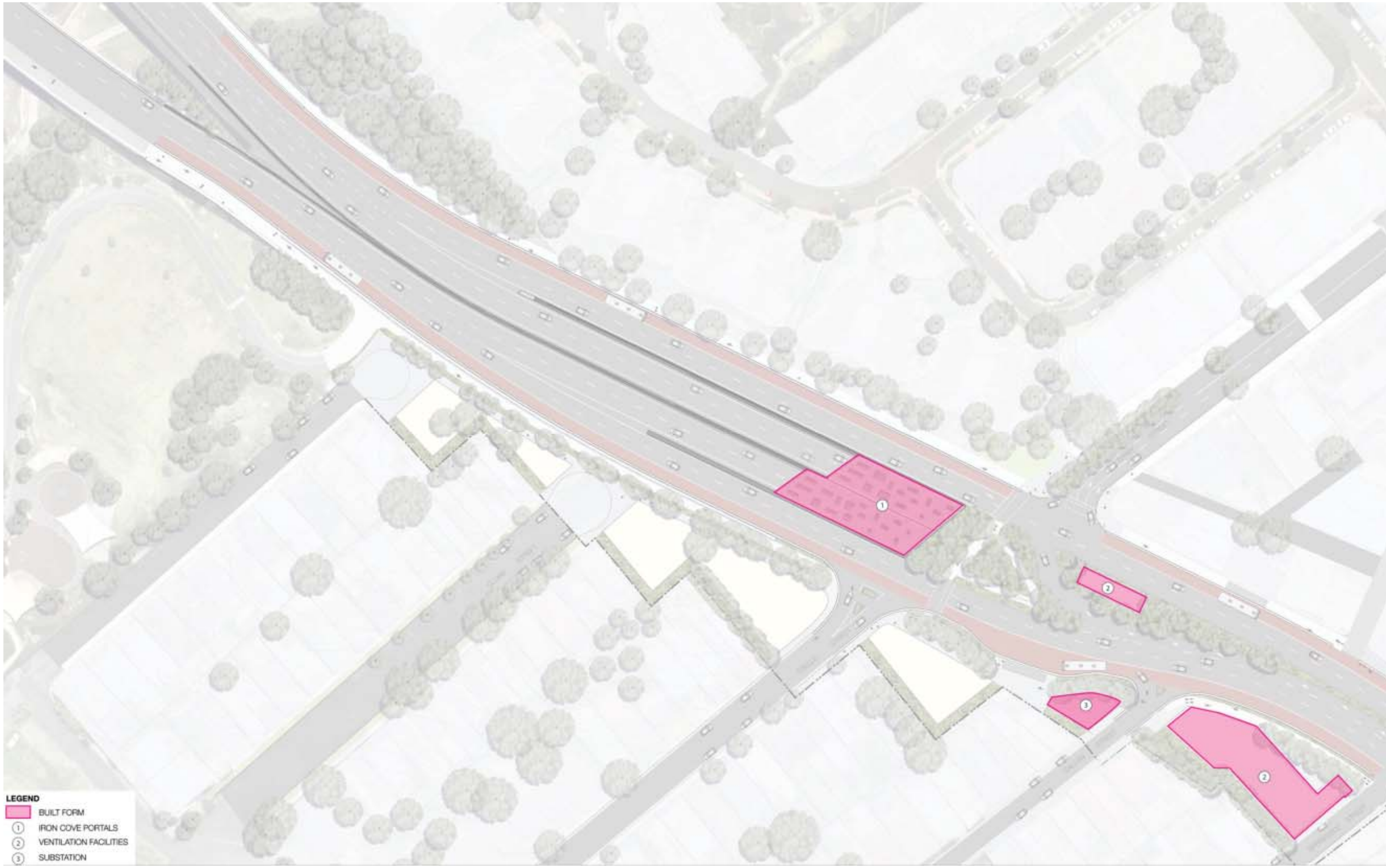


Figure 13-38 Iron Cove Link built form

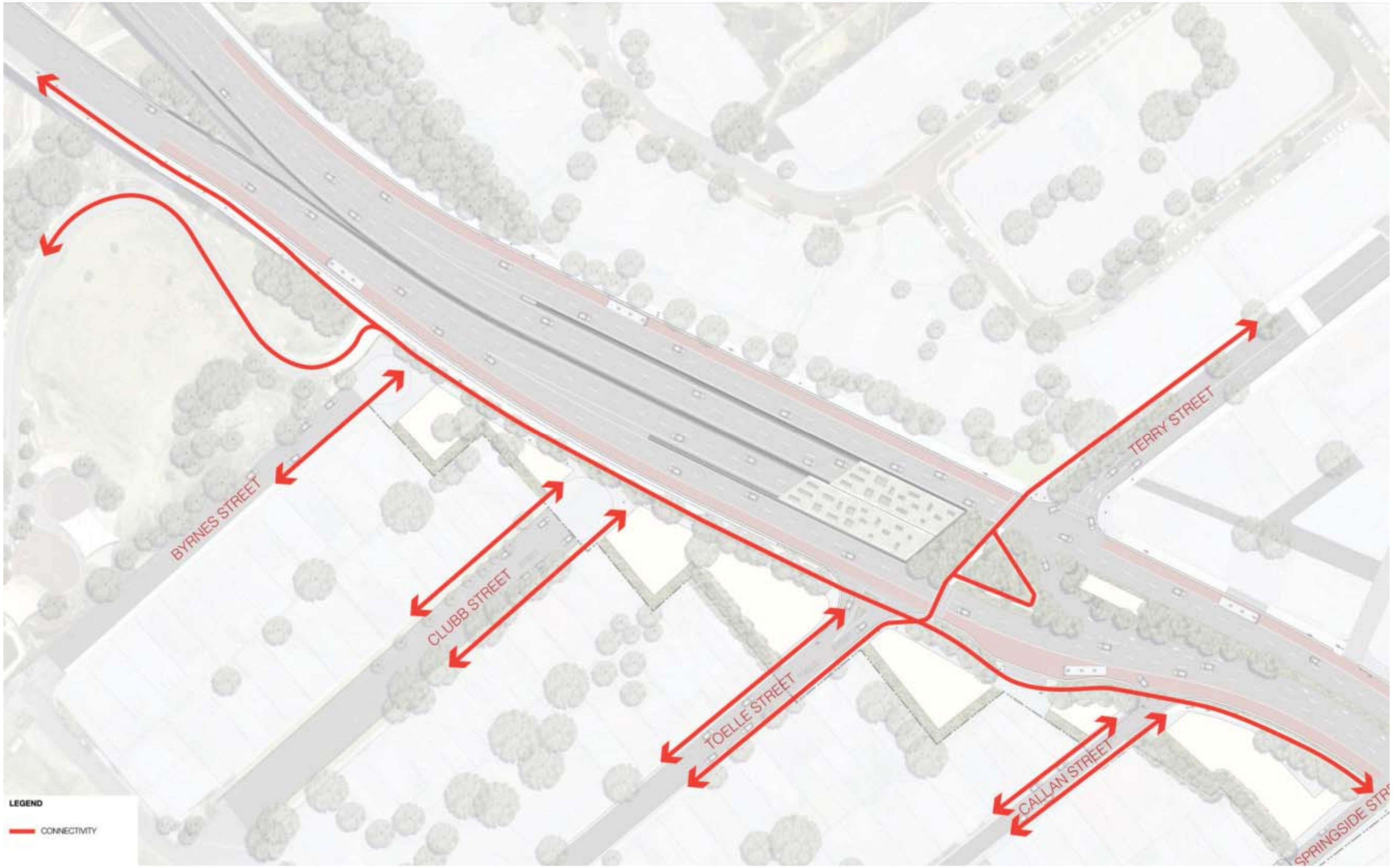


Figure 13-39 Iron Cove Link streetscape and connectivity

13.5.5 St Peters interchange

Operational infrastructure at the St Peters interchange would be located south of Campbell Road at St Peters, on land occupied during construction by the Campbell Road civil and tunnel site (C10). A description of built form operational infrastructure potentially visible from the receivers at the St Peters interchange is provided below:

- The Campbell Road motorway operations complex (MOC5) including:
  - A ventilation exhaust facility which would consist of one building, with four outlets (the ventilation outlets would have a height of around 22 metres above existing ground level)
  - Workshop/offices
  - Storage facilities
  - Car parking
  - Substation.

Operational infrastructure would be located above the St Peters interchange portals in the northwest corner of the site. The ventilation facility has been designed to minimise land-take from the St Peters interchange open space areas. The landscape works and architectural design of operational infrastructure at the St Peters interchange would be undertaken in accordance with a project UDLP and the urban design principles developed for the project (see **section 13.2.2**).

Once construction of both projects is completed, remaining project land would be subject to the New M5 project's UDLP, Residual Land Management Plan and other applicable conditions of approval. These plans are currently being prepared by the New M5 project team and would be subject to the consultation requirements and timeframes set out in the New M5 project conditions of approval.

Key viewpoints to the Campbell Road motorway operations complex (MOC5) were identified and are shown in **Figure 13-40**. A selection of existing viewpoints and artist impressions of these viewpoints at 12 to 18 months are provided in **Figure 13-41** to **Figure 13-42**.

Landscape character impacts

The visual impact assessment did not identify the potential for 'high' landscape character impacts for any LCZs at the St Peters interchange. Operational infrastructure at this location would be appreciated within the context of the landscape created by the St Peters interchange and ventilation facility to be constructed as part of the New M5 project and would comprise an element of low to moderate contrast with this infrastructure. A summary of the outcomes of the visual impact assessment are provided in **Table 13-20**.

Table 13-20 Visual impact assessment summary – Campbell Road landscape character

Landscape character zone	Sensitivity to change	Magnitude of change	Overall rating
LCZ 27 – Sydney Park precinct	High	Low	Moderate
LCZ 28 – Sydney Park residential precinct	Moderate	Moderate	Moderate
LCZ 29 – Alexandra Canal industrial precinct	Low	Negligible	Negligible
LCZ 30 – Barwon Park precinct	High	Moderate	High–Moderate
LCZ 31 – Princes Highway precinct	Low	Low	Low
LCZ 32 – St Peters triangle precinct	Moderate	Negligible	Negligible
LCZ 33 – St Peters interchange precinct	Negligible	Low	Negligible

Visual impacts

The visual impact assessment did not identify the potential for 'high' visual impacts for any receiver locations at the St Peters interchange. A summary of the outcomes of the visual impact assessment are provided in **Table 13-21**.

Table 13-21 Visual impact assessment summary – Campbell Road viewpoints

Receiver location	Receiver type	Sensitivity	Magnitude	Overall rating
View looking south from corner of Barwon Park Road and Campbell Road (SP1)	Residents	Moderate	Moderate	Moderate
	Pedestrians	Moderate	Moderate	Moderate
	Motorists/cyclists	Low	Moderate	Moderate–Low
View from Campbell Road verge looking west (SP2)	Pedestrians	Low	Moderate	Moderate–Low
	Motorists/public transport/cyclists	Low	Moderate	Moderate–Low
View looking north from St Peters interchange shared pathway (SP3)	Pedestrians/ recreational cyclists	Low	Moderate	Moderate–Low

Night lighting impacts

The visual impact assessment did not identify the potential for 'high' night lighting impacts for any receiver locations at the St Peters interchange. A summary of the outcomes of the visual impact assessment are provided in **Table 13-22**.

Table 13-22 Visual impact assessment summary – Campbell Road night lighting

Receiver location	Receiver type	Sensitivity	Magnitude	Overall rating
View looking south from corner of Barwon Park Road and Campbell Road (SP1)	Residents	Low	Low	Low
	Pedestrians	Low	Low	Low
	Motorists/cyclists	Negligible	Negligible	Negligible
View from Campbell Road verge looking west (SP2)	Pedestrians	Low	Low	Low
	Motorists/cyclists/public transport	Negligible	Negligible	Negligible
View looking north from St Peters interchange share pathway (SP3)	Pedestrians/recreational cyclists	Low	Low	Low

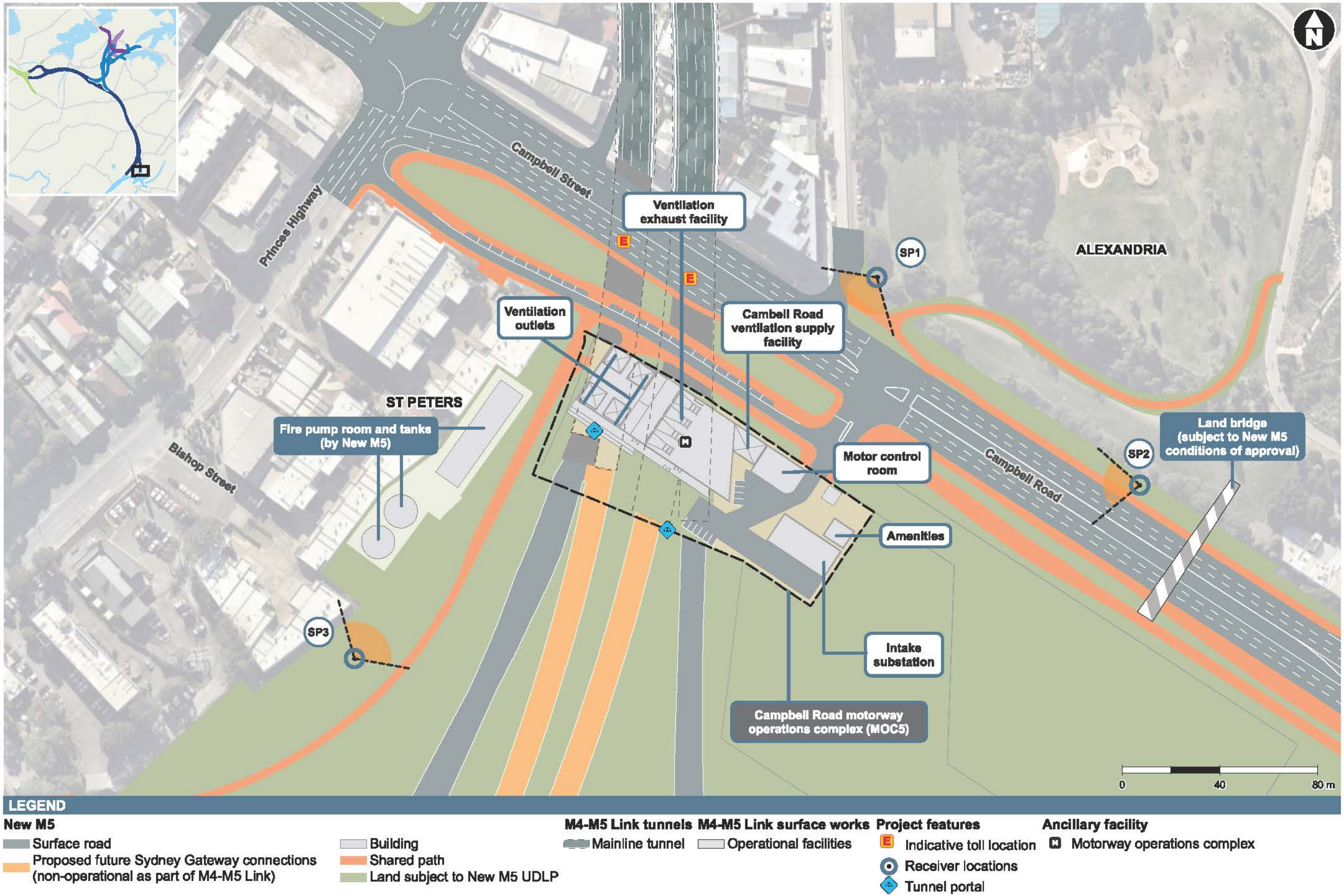


Figure 13-40 Key viewpoints at the Campbell Road motorway operations complex (MOC5)

Figure 13-41 Existing view looking south from corner of Barwon Park Road and Campbell Road (SP1)

Figure 13-42 Artist's impression at 12–18 months of project operation of view looking south from corner of Barwon Park Road and Campbell Road (SP1) (subject to detailed design as part of an UDLP)

13.5.6 Mainline tunnels

A concept for in-tunnel experience would be prepared as part of the UDLPs for the project (refer to **section 13.5.9**). The in-tunnel experience for the M4–M5 Link would be developed to be consistent with and to complement the adjoining M4 East and New M5 tunnels, and in accordance with the following principles:

- Creation of landmark or site specific/unique experiences
- Use of optimal lighting / adaptable luminance
- Creation of subtle variations to keep drivers alert
- Measures to break up long continuous travel distances
- Shifting gradients and alignments to avoid monotony
- Providing clear speed and distance references
- Legible wayfinding.

13.5.7 Remaining project land

Subject to future detailed design and the requirements of the project, parts of the project footprint not required for operational infrastructure and/or landscaping may be contemplated for separate future redevelopment. In some instances, areas of land may also be retained by Roads and Maritime for future (separate) road infrastructure projects. Where this is the case, the land would be rehabilitated and stabilised in preparation for the potential future use. This land is identified as remaining project land.

Remaining project land would be subject to the provisions of a Residual Land Management Plan that would be prepared in consultation with the relevant council and would identify (and consider), but not be limited to:

- Identification and illustration of all remaining project land, including the location, land use characteristics, size and adjacent land uses
- Identification of feasible uses for remaining project land including justification for the selected use
- Timeframes for implementation of the actions in relation to the identified feasible uses.

Future development would be subject to separate development assessment and approval. The project would not rezone or consolidate remaining project land and therefore there would be no changes to land use zoning for future development.

In addition, remaining project land around the Wattle Street interchange at Haberfield and the St Peters interchange at St Peters would be managed to be consistent with the M4 East and New M5 projects' respective Residual Land Management Plans and UDLPs, including the M4 East Legacy Project (as required by the conditions of approval for the M4 East and New M5 projects). The project would not impact on the implementation of these plans, but may impact the timing in which in the plans are carried out.

Further discussion regarding remaining project land is provided in **Chapter 12** (Land use and property).

13.5.8 Crime Prevention Through Environmental Design

Principles of CPTED would be considered and incorporated into the urban design through the preparation of the UDLPs for the project. Key CPTED principles to reduce opportunities for crime are outlined below:

- Surveillance: the public realm and buildings should be designed and managed to maximise the potential for passive surveillance
- Legibility: the public domain should be designed, detailed and managed to make them easy to navigate and understand for users, especially pedestrians and cyclists, without losing the capacity for variety and interest
- Territoriality: security should be supported by designing and managing spaces and buildings to define clearly legitimate boundaries between private, semi-private, community group and public space
- Ownership of the outcomes: a feeling of individual and community ownership of the public realm and associated built environments must be promoted to encourage a level of shared responsibility for their security
- Management: the public realm should be designed and detailed to minimise damage and the need for undue maintenance, without undermining the aesthetic and functional qualities that make the places attractive to the community. Systems of both regular and reactive maintenance and repair should be implemented to maintain the quality of the places. A regular auditing system of CPTED issues in the public domain should be implemented
- Vulnerability:
  - The public domain should be designed and managed to reduce or limit risk from assault by providing well-lit, active and overlooked places and pedestrian and cyclist systems and routes to important places
  - The design and management of places should avoid creating or maintaining hidden spaces close to pedestrian/cyclist travel routes in the public realm, in ways that remain consistent with the purpose of the place
  - The design and management of the public domain should provide a variety of routes and other ways to avoid potential or actual problems
  - The pursuit of safety should be delivered in ways consistent with the purpose of the place.

During detailed design, specific design measures at surface operational infrastructure would be identified to prevent crime.

13.5.9 Urban design and landscape assessment

The urban design and landscape works that would be carried out by the project would be documented in UDLPs. UDLPs would be prepared in consultation with stakeholders and the community prior to the commencement of permanent built surface works and/or landscape works and would present an integrated urban design for the project.

The concepts and principles outlined in the UDLPs would be developed into a detailed design for operational project infrastructure. The detailed design would be consistent with the project urban design principles (see **section 13.2.2**) and would include:

- Final land use for UDLP land
- Final design and material composition for built form structures
- Final landscape design
- Final heritage interpretation plan
- CPTED review of design (see **section 13.5.8**).

A detailed review and finalisation of architectural treatment of the project operational infrastructure, including ventilation facilities, would be undertaken during detailed design. The architectural treatment of these facilities would be guided by ventilation facility performance requirements, the outcomes of community consultation and the urban design principles identified in **section 13.2.2**.

Landscaping works would be carried out adjacent to disturbed areas, around operational infrastructure (such as ventilation facilities), and in areas of new open space that would be provided at the Rozelle Rail Yards and adjacent to Victoria Road at Rozelle.

Areas where permanent operational infrastructure is proposed have been reviewed against the urban design principles developed for the project, which are outlined in **Table 13-2.** The outcome of this assessment is provided in **Table 13-23**.

The review has been carried out using the concept design, including preliminary designs for the built form elements of the project. It is difficult at this early stage of the design resolution to be conclusive with regard to all of the required urban design elements. The structures and facilities that would be provided for the project such as ventilation facilities, tunnel portals and water treatment plans would be would be detailed in the UDLPs that would be prepared for the project. The built form structures and facilities would be designed to complement the surrounding context, with a materials palette that draws on the materials and textures of the surrounding areas to be developed during detailed design.

The nature of the design process is iterative and will continue to evolve as various elements become realised in detail and better coordinated as part of the whole project. With this in mind, a number of project design commitments are provided to guide the continued development of the project in line with the mitigation measures provided in **section 13.6**.

Urban design elements proposed for the areas where substantial surface infrastructure is planned (around the Rozelle interchange and the Iron Cove Link) is discussed in more detail in **Appendix L** (Technical working paper: Urban design).

Table 13-23 Review against urban design principles

Principle	Darley Road (MOC1)	Rozelle Rail Yards	Iron Cove Link	Campbell Road (MOC5)
Integrated and collective approach Create holistic and integrated design solutions generated by collaboration across disciplines, the community, stakeholders and government bodies.	The design has been developed in consideration of maximising areas of land that would be available for potential future development (remaining project land).	The design offers the opportunity for an open space destination that presents the opportunity to connect communities by providing a range of social infrastructure at a central, easily accessible location.	The design aims to bring local residents back to Victoria Road through the investigation of opportunities for the activation of remaining project land (see **section 13.5.4**)	The project has been designed to be consistent with implementation of the urban design and landscape plan for the New M5 project.
Environmental vision Create a sustainable and enduring design response which enhances and connects local ecologies and green spaces.	The project would provide the opportunity for remaining project land to be developed as open space, subject to separate environmental assessment.	The concept connects isolated land though new green spaces and active transport links. These strategically connect a series of disconnected green spaces. The design utilises Water Sensitive Urban Design to filter surrounding catchment runoff before it enters the harbour at Rozelle Bay.	The design connects green spaces and canopy along Victoria Road and recreational spaces with King George Park and Callan Park. The design utilises the topography along Victoria Road to harvest and polish water runoff from the road and pavements.	The ventilation facility has been designed to minimise land-take from the St Peters interchange open space areas.
Cross scale connection of spaces Prioritise both locally and regionally significant connections that respond to the broader issues of the local neighbourhoods and city.	The design would maintain existing active transport links along Darley Road.	The project would provide a new active transport corridor that would work directly with existing and future connections, providing a connection between previously disconnected communities, the Bay Run and the city.	The design would integrate the Iron Cove active transport network along the southern edge of Victoria Road, linking Rozelle in the east, Drummoyne and the Bay Run in the north and the wider network beyond.	The project would not inhibit the delivery of the land bridge or the active recreation to be delivered by the New M5 project.

Principle	Darley Road (MOC1)	Rozelle Rail Yards	Iron Cove Link	Campbell Road (MOC5)
A motorway integrated within its context Understand the existing landscape and respond in a respectful manner that seeks to enhance and or contribute back to its context.	The proposed built form would be consistent with the existing character of the local area and would maintain existing active transport links along Darley Road.	The design would utilise the open space landform to disguise the motorway and maximise useable open space. A new connection would be provided between the Rozelle Rail Yards and the Rozelle Bay light rail stop.	The design would terminate the portals to the west of the Terry Street and Toelle Street alignment enabling pedestrian and cyclist through connection across Victoria Road. Ventilation outlets would be located between the Victoria Road carriageways to improve the separation distance from residential and commercial receivers.	The design has located operational infrastructure primarily within the footprint of motorway infrastructure for the St Peters interchange to be delivered by the New M5 project.
Place sensitive design Celebrate and work with the character of each place and destination, responding to their unique histories, materiality, architecture, built fabric, cultural context, landform and topography.	The proposed built form would be consistent with the existing character of the local area at Darley Road.	The design would maintain the unique heritage, industrial character and typography of the Rozelle Rail Yards.	The proposed built form would be consistent with the existing character of the local area at Victoria Road.	The proposed built form would be consistent with the existing character of the local area at the St Peters interchange.
Multidimensional user force Consider holistically how a diversity of users experience space including all ages, abilities and transport modes for a truly inclusive, universally accessible and safe outcome.	Operational project infrastructure would be located at the western end of the site to allow for the remaining project land component to be located nearest to the Leichhardt North light rail stop. This would facilitate a safe and accessible journey to the light rail stop.	New public spaces, and universally accessible links would be provided to establish new 'public streets' and enhance the surrounding neighbourhood.	The design would improve connections of local streets such as Terry Street and Toelle Street at Rozelle with Victoria Road for pedestrians and cyclists.	The project would not inhibit the safety or accessibility of the land bridge or the active recreation to be delivered by the New M5 project.

Principle	Darley Road (MOC1)	Rozelle Rail Yards	Iron Cove Link	Campbell Road (MOC5)
Revitalisation, opportunity and economics Establish opportunities for development that supports and connects existing neighbourhoods, complements and stimulates local economies and provides opportunity for growth across existing and future local industries.	The design would maintain existing active transport links along Darley Road and provide the opportunity for remaining project land to be developed as open space, subject to separate environmental assessment.	With the intended future growth of the area, the design provides open space and social infrastructure that works for both for existing and future communities.	Opportunities would be investigated for UDLP land and remaining project land (refer **section 13.5.4** and **Chapter 12** (Land use and property)).	Opportunities would be investigated in the UDLP to integrate with the New M5 UDLP to support connectivity and support future uses for residential and recreational spaces.

13.6 Environmental management measures

The detailed design and construction of the M4-M5 Link project would be managed to ensure the identified landscape and visual impacts are minimised by implementation of a range of general and specific measures which are outlined in **Table 13-24**.

The environmental management measures provided in **Table 13-24** have been developed in order to:

- Avoid, reduce and manage identified potential landscape and visual impacts during construction and operation
- Provide substantial mature and semi-mature street-tree planting for screening and shade, and mixed sizing of planting where stratification of the canopy is desired
- Provide high quality finishes to buildings and vent facilities to facilitate long term durability of the design for effect with minimal maintenance, eg use of hard rock rather that concrete with a pigment which may fade over time
- Improve open space to offset additional infrastructure, eg provision of street trees to adjoining local streets affected by the project
- Improve active transport links to reduce reliance on motorway and local roads for short journeys.

Table 13-24 Environmental management measures - landscape and visual

Impact	No.	Environmental management measure	Timing
Urban design of project infrastructure	UD1	Prepare UDLPs for operational project infrastructure including final landscape works and architectural design in consultation with relevant councils, stakeholders and the community.	Construction
Potential for crime at or near construction ancillary facilities	UD2	Specific design measures at construction ancillary facilities will be identified and implemented to prevent crime, based on principles of CPTED.	Construction
Potential for crime at or near operational infrastructure CPTED	UD3	Specific design measures at surface operational infrastructure will be identified and implemented to prevent crime, based on principles of CPTED.	Construction
Disorientation while navigating project operational infrastructure	UD4	As part of the project UDLPs, wayfinding for the project will be developed and installed in accordance with relevant guidelines endorsed by Roads and Maritime.	Construction
General impacts to landscape and visual amenity	LV1	Ancillary facilities, including the locations of visible structures and plant and perimeter fencing and treatments, will be developed to minimise visual impacts for adjacent receivers where feasible and reasonable.	Construction
	LV2	Site lighting will be designed to minimise glare issues and light spillage in adjoining properties and would be generally consistent with the requirements of Australian Standard 4282-1997 Control of the obtrusive effects of outdoor lighting.	Construction
	LV3	Regular maintenance of site hoarding and perimeter site areas should be undertaken, including the prompt removal of graffiti.	Construction

Impact	No.	Environmental management measure	Timing
	LV4	Construction worksites and construction ancillary facilities will be established to minimise the need to remove screening vegetation wherever practicable.	Construction
	LV5	Hoardings and temporary noise walls will be erected as early as possible within the site establishment phase to provide visual screening.	Construction
	LV6	Acoustic sheds will be designed to be visually recessive and minimise potential overshadowing impacts where possible.	Construction
	LV7	Where necessary, construction lighting will comply with the requirements of the Civil Aviation Safety Authority and Sydney Airport at all times.	Construction
	LV8	Visible elements of operational facilities will be designed to satisfy functional requirements and adopt the design principles detailed in the M4-M5 Link Urban Design Report. The proposed designs will be documented in the UDLP for the project.	Construction
	LV9	The slopes of vegetated batters that form part of the final urban design and landscaping solution will be limited to no more than 1:4 where possible in order to maximise the impact of vegetation on these batters and minimise maintenance.	Construction
	LV10	Where construction ancillary facilities are located in close proximity to sensitive residential receivers such as residents and users of recreational space, high quality fencing suitable for parks and public spaces should be considered.	Construction
Impacts to visual amenity as a result of the Darley Road motorway operations complex	LV11	Investigate options for planting of vegetation to screen residents on the southern side of Darley Road from the Darley Road motorway operations complex. Include feasible and reasonable measures in the relevant UDLP.	Construction
	LV12	Architectural design and detailing of the water treatment facility, substation and front fencing should achieve articulation, visual interest, and integrate with the streetscape.	Construction
Impacts to visual amenity at the Rozelle interchange	LV13	Integrate the new open space at Rozelle with the Lilyfield Road streetscape through considered street tree planting and associated landscape works.	Construction
	LV14	Implement urban design and landscape measures that allow permeable views between the City West Link carriageway and the new open space to provide a sense of openness and connection with the open space for motorists and the community.	Construction
	LV15	Investigate measures to minimise view impacts of the project to sensitive residential receptors in the vicinity of the Rozelle Rail Yards as described in this assessment and include in the UDLP where reasonable and feasible.	Construction

Impact	No.	Environmental management measure	Timing
	LV16	Develop a design that aims to incorporate the ventilation outlets at the Rozelle Rail Yards as an integral component of the larger open space composition, with reference and consideration to the Ventilation Facility Design Review (Annexure 2 of **Appendix L** (Technical working paper: Urban design)).	Construction
	LV17	Consult with UrbanGrowth NSW regarding the interface between the project footprint and the White Bay Power Station precinct. Design the interface to ensure compatibility between the two areas from a landscaping, visual, heritage and active transport connectivity perspective.	Construction
	LV18	Investigate measures to retain the mature trees of high retention value adjacent to the light rail corridor at the corner of The Crescent and City West Link, or provide screen planting alongside the retaining wall edge of the light rail corridor, to minimise landscape and visual impacts.	Construction
Impacts to visual amenity at Iron Cove Link	LV19	Investigate vegetative and other screening measures along Victoria Road to improve the visual amenity of the streetscape and reduce impacts associated with the ventilation outlet and increased glare from the portals to residential dwellings to the north of Victoria Road.	Construction
	LV20	Provide a well-articulated, integrated car parking and landscape design for the bioretention facility in Manning Street that is place sensitive, and enhances the interface between the project and both King George Park and adjacent residences.	Construction
Impacts to visual amenity at St Peters interchange	LV21	The UDLP for the area adjoining Campbell Road motorway operations complex is to be consistent with the New M5 UDLP at St Peters.	Construction
Visual amenity impacts associated with design of ventilation outlets at Rozelle, Iron Cove Link and St Peters	LV22	Investigate measures during detailed design to reduce the height, bulk, scale and enhance the landscape setting of the ventilation outlets, subject to achieving desired ventilation outcomes, and in accordance with the design principles detailed in the M4-M5 Link Urban Design Report.	Construction

14 Social and economic

This chapter outlines the potential social and economic impacts associated with the M4-M5 Link project (the project). A detailed social and economic impact assessment has been undertaken for the project and is included in **Appendix P** (Technical working paper: Social and economic).

The Secretary of the NSW Department of Planning and Environment (DP&E) has issued environmental assessment requirements for the project. These are referred to as Secretary's Environmental Assessment Requirements (SEARs). **Table 14-1** sets outs these requirements and the associated desired performance outcomes that relate to social and economic matters, and identifies where they have been addressed in this environmental impact statement (EIS).

Table 14-1 SEARs – social and economic

Desired performance outcome	SEARs	Where addressed in the EIS
9. Social and economic, land use and property The project minimises adverse social and economic impacts and capitalises on opportunities potentially available to affected communities. The project minimises impacts to property and business and achieves appropriate integration with adjoining land uses, including maintenance of appropriate access to properties and community facilities, and minimisation of displacement of existing land use activities, dwellings and infrastructure.	1. The Proponent must assess social and economic impacts (of all phases of the project) in accordance with the current guidelines (including cumulative ongoing impacts of the proposal).	An assessment of the construction related impacts of the project on social and economic matters is provided in **section 14.3**. Operational impacts of the project are assessed in **section 14.4**. The relevant guidelines considered for the social and economic impact assessment are listed in **section 14.1.2**. Potential cumulative impacts of relevant projects are assessed in **Chapter 26** (Cumulative impacts).
	2. The Proponent must assess impacts from construction and operation on potentially affected properties (including Crown lands), businesses, recreational users and land and water users, including property acquisition/adjustments, access amenity and relevant statutory rights, and community severance and barrier impacts resulting from the project.	An assessment of the project's impact on property, businesses, the community and recreational users is provided **section 14.3** and **section 14.4**. Further assessment is provided in **Chapter 12** (Land use and property).
	3. The Proponent must identify opportunities for local centre street revitalisation improvements, pedestrian and cyclist access and connectivity and provision of community and social facilities.	An assessment of the opportunities the project provides for open space and community facilities is provided in **section 14.4**. Local centre street revitalisation improvements are identified in **Chapter 13** (Urban design and visual amenity), and active transport opportunities are outlined in **Chapter 8** (Traffic and transport) and **Appendix N** (Technical working paper: Active transport strategy).

Desired performance outcome	SEARs	Where addressed in the EIS
	4. The design and siting of project elements should be located in such a way that functional, contiguous areas of residual land are maximised. The design and siting must consider appropriate land use interfaces (ie White Bay) and the social and economic impacts of proposed land uses against alternate land uses.	Residual land is referred to as remaining project land in this EIS (refer to **Chapter 12** (Land use and property). Consideration of options and alternative uses for remaining project land is outlined in **Chapter 12** (Land use and property) and **Chapter 13** (Urban design and visual amenity).
	5. Where air quality allows, residual land must be designed to positively contribute to additional community uses, public recreation uses and/or affordable or social housing. Passively landscaped areas should not be the default use for residual land.	Design opportunities for remaining project land are described in **Chapter 13** (Urban design and visual amenity).
	6. The Proponent must assess potential impacts on utilities (including communications, electricity, gas, and water and sewerage) and the relocation of these utilities.	An assessment of the potential impacts on utilities is provided in **section 14.3.8**. Further detail is provided in **Appendix F** (Utilities Management Strategy).
	7. Where the project is predicted to impact on utilities the Proponent must undertake a utilities management strategy. The strategy must identify proposed management strategies, including relocation or adjustment of the utilities, and their estimated timing and duration. This strategy must be developed in consultation with the relevant utility owners or providers.	The Utilities Management Strategy for the project identifies proposed management strategies, including relocation or adjustment of the utilities, and their estimated timing and duration, and has been developed in consultation with the relevant utility owners or providers (refer to **Appendix F** (Utilities Management Strategy)).
	8. A draft Community Consultation Framework must be prepared identifying relevant stakeholders, procedures for distributing information and receiving/responding to feedback and procedures for resolving stakeholder and community complaints during construction and operation. Key issues that must be addressed in the draft Framework include, but are not limited to: (a) traffic management (including property access, pedestrian access); (b) landscaping/urban design matters; (c) construction activities including out of hours work, and (d) noise and vibration mitigation and management.	The draft Community Consultation Framework developed for the project is included in **Appendix G** (Draft Community Consultation Framework). Consultation activities undertaken for the project to date are outlined in **Chapter 7** (Consultation).

14.1 Assessment methodology

14.1.1 Overview

The key components of the social and economic assessment included:

- Desktop assessment including review of the social and economic impact assessments from the previous WestConnex projects to scope issues and identify the scale and magnitude of potential impacts
- Community and stakeholder consultation (including information sessions and business surveys)
- Definition of the study area (a description of the study area is provided in **section 14.1.4**)
- Development of a profile of the existing social and economic environment in the study area
- Identification and consultation with stakeholders who could be affected by the project
- Assessment of the potential construction, operation and cumulative impacts of the project on social and economic matters
- Identification of management measures for monitoring and managing the potential impacts of the project.

14.1.2 Guideline and policy framework

The social and economic impact assessment has been prepared to assess the impacts of the project in accordance with the *Environmental Impact Assessment Practice Note – Social and economic assessment* (EIA-N05) (Practice Note) (NSW Roads and Maritime Services (Roads and Maritime) 2014). The Practice Note guides the assessment level and process for social and economic impact assessments and outlines the requirements for establishing the social and economic baseline. In accordance with the Practice Note, the project requires a comprehensive assessment.

The assessment has also been undertaken with consideration of the following state and local council policies and plans:

- *NSW State Priorities* (NSW Government 2015)
- *State Infrastructure Strategy* (Infrastructure NSW 2012)
- *NSW Long Term Transport Master Plan* (Transport for NSW 2012)
- *NSW Freight and Ports Strategy* (Transport for NSW 2013b)
- *A Plan for Growing Sydney* (NSW Government 2014)
- *Draft Central District Plan* (Greater Sydney Commission 2016)
- *Parramatta Road Corridor Urban Transformation Strategy* (UrbanGrowth NSW 2016a)
- *The Bays Precinct Transformation Plan* (UrbanGrowth NSW 2015b)
- *Sustainable Sydney 2030 – Community Strategic Plan* (City of Sydney Council 2013)
- Inner West Council policies:
  - *Ashfield 2023 – Our Place, Our Future* (Ashfield Council 2014)
  - *Leichhardt 2025+ Community Strategic Plan* (Leichhardt Council 2013)
  - *Our Place, Our Vision – Marrickville Community Strategic Plan* (Marrickville Council 2013).

14.1.3 Desktop assessment

Additional data used to inform the social and economic assessment included:

- Australia Bureau of Statistics (ABS) (Census 2011)
- ABS (8165.0 Counts of Australian Businesses 2016)
- ABS (5220.0 Australian National Accounts 2016)

- DP&E Population and Dwelling Forecasts 2017
- Transport Performance and Analytics 2017
- Relevant NSW state, local government and agency policy and guidelines (see **section 14.1.2**)
- Outcomes of agency, community, business and stakeholder consultation
- Mapping of social and economic index for areas (SEIFA). The SEIFA is an advantage/disadvantage rating for household conditions within an area and is weighted one to 10, with 10 being the most advantaged
- Geographic information system (GIS) information on land uses as informed by relevant local environmental plans.

14.1.4 Study area

The study area for the social and economic impact assessment covers the project footprint and comprises the ABS geographic boundaries (referred to as Statistical Area Level 2s) (SA2s) outlined in **Table 14-2**.

Table 14-2 ABS boundaries defining the social and economic study area

Precinct	SA2 boundaries
Ashfield-Haberfield	Ashfield
	Five Dock–Abbotsford
	Burwood–Croydon
	Haberfield–Summer Hill
Leichhardt-Glebe	Leichhardt–Annandale
	Lilyfield–Rozelle
	Balmain
	Glebe–Forest Lodge
Alexandria-Erskineville	Sydenham–Tempe–St Peters
	Redfern–Chippendale
	Erskineville–Alexandria
	Newtown–Camperdown–Darlington
	Petersham–Stanmore

These boundaries have been extended to include the SA2 of any area within a 400 metre radius of the project footprint. Generally, direct and indirect social and economic impacts can be more explicitly felt within a 400 metre radius (a five to 10 minute walk) from the project. The study area is shown in **Figure 14-1**.

The baseline profile for the study area has been compared with data for the Greater Sydney metropolitan area.

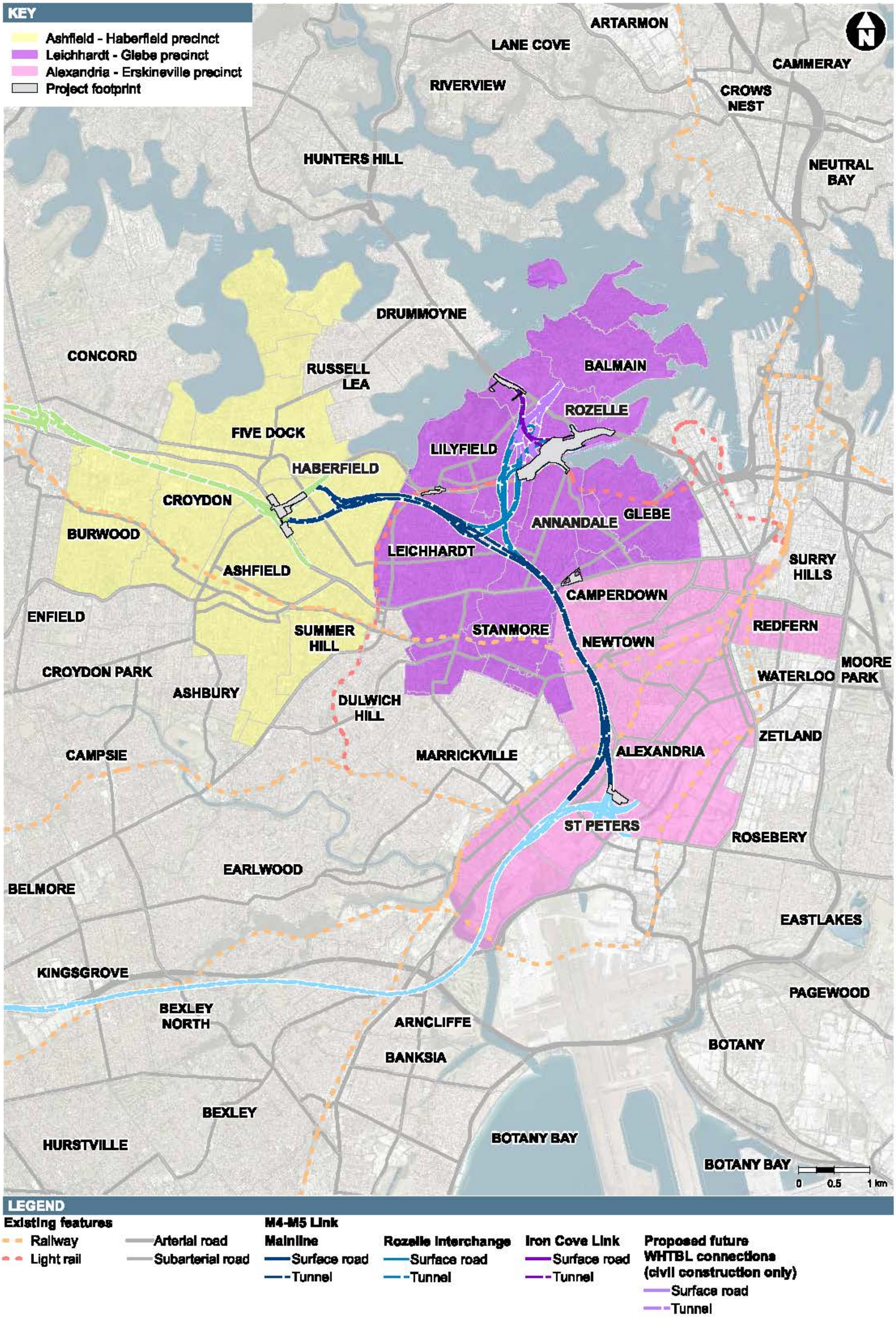


Figure 14-1 Study area for the social and economic impact assessment

14.1.5 Business surveys

The business surveys were conducted within 400 metres of the proposed construction ancillary facility sites at Rozelle, Lilyfield and Annandale over a two-week period in November 2016. Around 100 businesses participated in the survey, comprising local retailers, commercial operators and other businesses. The proposed construction sites at Haberfield and St Peters were not included in the survey as business impacts at these locations have previously been identified in the assessments for the M4 East and New M5 projects. The social and economic assessment has, however, considered these locations including with regard to the potential cumulative impacts of extended construction durations. This is discussed in **Chapter 26** (Cumulative impacts).

Information gathered as part of the business surveys was collated into a database and analysed. Survey questions generally related to the respondent's level of knowledge about the project, existing business access and delivery requirements, and perceptions and/or concerns regarding the construction and operation of the project. The survey questionnaire is included in Annexure A of **Appendix P** (Technical working paper: Social and economic).

14.1.6 Stakeholder consultation

The social and economic assessment has been informed by stakeholder and community consultation undertaken for the project including:

- Over 100 face-to-face business surveys
- Meetings were held with advocacy groups, local councils, elected representatives, government agencies, business groups, the freight industry, peak bodies and community members to seek input and feedback on key considerations influencing project design
- The online collaborative map was hosted on the WestConnex website to encourage community ideas and feedback
- Five community ideas sessions were held between 10 and 22 August 2016, to seek feedback and ideas and discuss the project process with the community
- Seven briefings were held with key stakeholders, including NRMA, Australian Logistics Council, Infrastructure Partnerships Australia, Greater Sydney Commission, and local, state and Commonwealth Government stakeholders
- Five community information sessions were held between May and June 2017 to confirm key information about the project’s concept design update and provide a forum for the community to provide feedback and ideas.

In addition, communication activities were specifically undertaken to inform the local community about the project, initial investigations and the assessment process. These included the distribution of postcards with key project facts, community update newsletters, notifications, community ideas sessions and community meetings.

Further details regarding consultation undertaken for the project (up to exhibition of the EIS) are provided in **Chapter 7** (Consultation).

14.1.7 Assessment approach

The social and economic impact assessment has assessed the direct and indirect impacts and benefits of the project with regard to:

- Property impacts, including changes to property access, acquisition, value, amenity, power and utilities and remaining project land use
- Social impacts, including amenity, community health, social infrastructure, local access and connectivity, heritage and visual character
- Business impacts and benefits, including passing trade, parking, servicing and deliveries, employment and recruitment, business access, connectivity and amenity
- Economic impacts, including construction expenditure and employment, economic benefit, freight and efficiency costs and road tolling.

Figure 14-2 outlines the assessment framework that was used to determine the significance of social and economic impacts.

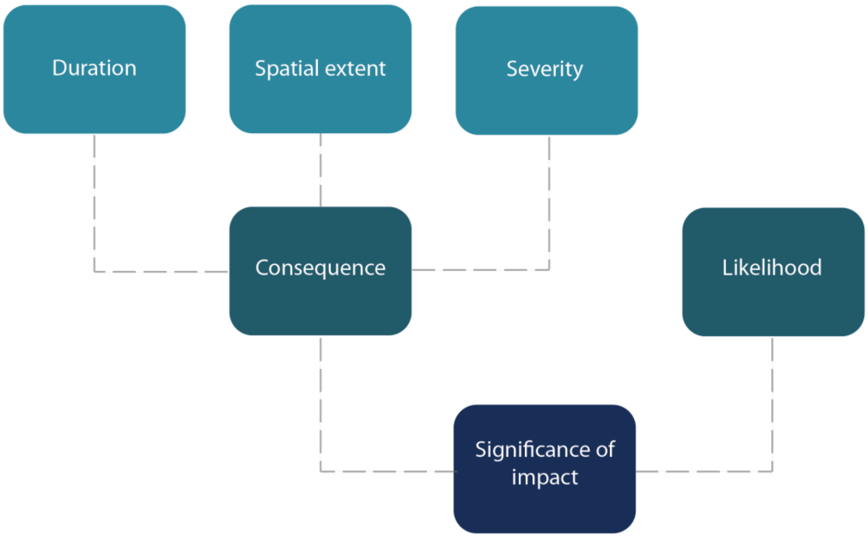


Figure 14-2 Assessment framework to determine the significance of social and economic impacts

Consequence refers to the degree of benefit or detriment associated with the impact and is assessed as neutral, slight, moderate or major. The following factors contribute to the determination of the overall consequence level:

- **Duration** – short term (less than six months), medium-short term (between six months and two years), medium term (between two and five years), medium-long term (between five and 10 years), or long term (more than 10 years)
- **Spatial extent** – locality, suburb, local government area or region
- **Severity of impact** – neutral, small, medium or large.

The likelihood of an impact is considered near certain, high, possible, low or rare.

The significance of an impact is determined from the consequence and likelihood and is assessed as positive, negative or neutral, as shown in **Table 14-3**. There terms are further defined in **Appendix P** (Technical working paper: Social and economic).

Table 14-3 Significance of social and economic impacts

		Consequence			
		Neutral	**Slight**	**Moderate**	**Major**
Likelihood	**Rare**	Negligible	Negligible	Minor	Moderate
	Low	Negligible	Negligible	Minor	Moderate
	Possible	Negligible	Minor	Moderate	Moderate
	High	Minor	Minor	Moderate	Major
	Near certain	Minor	Moderate	Major	Major

14.2 Existing environment

This section provides an overview of the social and economic characteristics of the study area with regard to precinct demographic profiles, community values, social infrastructure, business and transport services. Sensitive receivers identified in this section are indicative and not exhaustive.

Sensitive receivers and land zoning within 400 metres of construction ancillary facility sites are shown in **Figure 14-3** to **Figure 14-9**.

14.2.1 Demographic profile

This section provides an overview of the social and economic characteristics of the study area. This information has been sourced from the ABS Census 2011, Australian Statistics Business Indicators (ABS 2016) and Transport Performance and Analytics (TPA) (2011). **Table 14-4** summarises the demographic profile of the study area.

Table 14-4 Demographic information for study area precincts (ABS 2011 and TPA 2011)

Characteristics	Ashfield Haberfield precinct	Leichhardt Glebe precinct	Alexandria Erskineville precinct
Population by age	• A population of around 79,119 residents (in 2011) • A low proportion of residents were under the age of 15 years (15%) when compared to Greater Sydney (19%) • A high proportion of residents within the young working family of 15-44 years (47%) and older 75+ years (8%) age cohorts when compared to Greater Sydney (44% and 6% respectively).	• A population of around 68,800 residents (in 2011) • A low proportion of residents were under the age of 15 years (15%) when compared to Greater Sydney (19%) • A high proportion of residents within the young working family of 15-44 years (51%) groups when compared to Greater Sydney (44%).	• A population of around 77,973 residents (in 2011) • A younger age profile when compared to Greater Sydney (median age of 33 years compared to 36 years for Greater Sydney) • A lower proportion of residents were under the age of 15 years (10%) when compared to Greater Sydney (19%) • A higher proportion of residents within the young working family of 15-44 years (64%) group when compared to Greater Sydney (44%).
Unemployment and household conditions	• The unemployment level was 5.8% in 2011, which was slightly higher than the Greater Sydney region (5.7%) • A SEIFA index of 8 (slightly lower than the Greater Sydney index of 9) indicates lower household conditions than Greater Sydney. Both indexes are considered to be a high score, indicating a relative lack of disadvantage in general. For example, an area may have a high score if there are (among other things) few households with low incomes, few people with no qualifications and few people in low skilled occupations.	• The unemployment level was 4.5% in 2011, which was lower than in Greater Sydney (5.7%) • A SEIFA index of 9.5 (higher than the Greater Sydney index of 9) indicates higher household conditions than Greater Sydney.	• The unemployment level was 5% in 2011, which was lower than in Greater Sydney (5.7%) • A SEIFA index of 8.75 (lower than the Greater Sydney index of 9) indicates lower household conditions than Greater Sydney.

Characteristics	Ashfield Haberfield precinct	Leichhardt Glebe precinct	Alexandria Erskineville precinct
Cultural diversity	Around 44% of residents were born overseas and 46% of people spoke a language other than English. When compared to Greater Sydney, the number of people born overseas (40%) and the number of people who spoke a language other than English (38%) were both higher.	Around 30% of residents were born overseas and 17% of people spoke a language other than English. When compared to Greater Sydney, the number of people born overseas (40%) and the number of people who spoke a language other than English (38%) were both lower.	Around 38% of residents were born overseas and 29% of people spoke a language other than English. Greater Sydney recorded a lower proportion of people born overseas (40%) and a higher proportion of people who spoke a language other than English (38%).
Dwellings	In 2011, there were around 28,121 private dwellings, 47% of which were apartment style dwellings, which was higher than the Greater Sydney average (26%). There has likely been a sizeable increase in the number of apartments built in the inner and central city suburbs over recent years.	In 2011, there were around 28,710 private dwellings, 34% of which were apartment style dwellings, which was higher than the Greater Sydney average (26%). Townhouses were the primary form of housing, contributing 37% compared to Greater Sydney's 13%.	In 2011, there were around 32,643 private dwellings, 46% of which were apartment style dwellings, which was higher that the Greater Sydney average (26%).
Employment	In 2011, 65% of residents aged over 15 were employed. The top four employment industries were: • Health care and social assistance (12%) • Professional, scientific and technical services (11%) • Retail trade (9%) • Education and training (9%).	In 2011, 67% of residents aged over 15 were employed. The top four employment industries included: • Professional, scientific and technical services (17%) • Education and training (10%) • Health care and social assistance (10%) • Financial and insurance services (10%).	In 2011, 68% of residents aged over 15 were employed. The top four employment industries included: • Professional, scientific and technical services (15%) • Education and training (10%) • Health care and social assistance (9%) • Financial and insurance services (8%).
Journey to work	For employed residents within the precinct: • Around 47% drove to work in a car as either driver or passenger • Around 32% used public transport to get to work (via rail or bus) • Around 21% used other methods to get to work (including walking and cycling).	For employed residents within the precinct: • Around 43% drove to work in a car as either driver or passenger • Around 26% used public transport to get to work (via rail or bus) • Around 34% used other methods to get to work (including walking and cycling).	For employed residents within the precinct: • Around 31% drove to work in a car as either driver or passenger • Around 36% used public transport to get to work (via rail or bus) • Around 32% used other methods to get to work (including walking and cycling).

Characteristics	Ashfield Haberfield precinct	Leichhardt Glebe precinct	Alexandria Erskineville precinct
	For all workers travelling to jobs within the precinct: • Around 58% drove to work in a car as either driver or passenger • Around 19% used public transport to get to work (via rail or bus) • Around 23% used other methods to get to work (including walking and cycling).	For all workers travelling to jobs within the precinct: • Around 56% drove to work in a car as either driver or passenger • Around 16% used public transport to get to work (via rail or bus) • Around 28% used other methods to get to work (including walking and cycling).	For all workers travelling to jobs within the precinct: • Around 52% drove to work in a car as either driver or passenger • Around 25% used public transport to get to work (via rail or bus) • Around 24% used other methods to get to work (including walking and cycling).
Vehicle ownership	Of occupied private dwellings: • Around 44% had one registered motor vehicle garaged or parked at their address. Around 28% had two registered motor vehicles and 87% had three or more registered motor vehicles • Around 18% per cent did not have a vehicle.	Of occupied private dwellings: • Around 49% had one registered motor vehicle garaged or parked at their address. Around 24% had two registered motor vehicles and 4% had three or more registered motor vehicles • Around 19% did not have a vehicle.	Of occupied private dwellings: • Around 49% had one registered motor vehicle garaged or parked at their address. Around 16% had two registered motor vehicles and 3% had three or more registered motor vehicles • Around 29% did not have a vehicle.
Population and employment forecast	• The TPA forecasts that by 2036, the population would increase around 29% over its 2016 population of 83,308 to 111,067 residents • Employment is forecast to increase by around 28% with the workforce also expected to increase by 28% over the same period.	• The TPA forecasts that by 2036, the population would increase around 26% over its 2016 population of 76,174 to 95,808 residents • Employment is forecast to increase by around 22% with the workforce also expected to increase by 24% over the same period.	• The TPA forecasts that by 2036, the population would increase around 34% over its 2016 population of 89,975 to 120,520 residents • Employment is forecast to increase by around 31% with the workforce also expected to increase by 28% over the same period.

14.2.2 Community values

This section presents the community values and feedback gained from consultation undertaken for the project, as it relates to the social and economic impact assessment. Consultation activities undertaken for the project are summarised in **section 14.1.6** and detailed in **Chapter 7** (Consultation). Key issues and/or themes relevant to social and economic matters identified through consultation include:

- Property impacts, including acquisition, property value, and uncertainty around elements such as acquisition, construction damage etc
- Amenity impacts, including visual, noise and vibration, air quality and human health and heritage
- Access and connectivity impacts, including public transport, access and connectivity, congestion, parking, toll prices and active transport
- Business and industry, including access and connectivity, parking, visibility, revenue, amenity and notification
- Social infrastructure impacts
- Adequate notification of the project commencing.

A detailed list of all considerations raised is provided in **Appendix P** (Technical working paper: Social and economic).

Community values are those that are shared by residents and visitors about a particular area, or about the enhancement of quality of life or sense of place. Physical aspects, such as heritage items, social infrastructure or local features (such as public art and trees) are generally highly valued by communities. Intangible elements such as neighbourhood identity, community safety, health and wellbeing, and community cohesion are also highly valued by communities.

Neighbourhood identity and character relates to the features of a place or environment that generate a sense of ownership by the community and contribute to a person's appreciation of their surroundings. During community consultation, community values associated with neighbourhood identity included:

- Integration of public art
- Continued focus and improved access to educational facilities, including local schools, preschools and adult learning centres
- Protection and enhancement of heritage and valued views/vistas (ie city skyline and waterways)
- Retention of trees and vegetation for amenity.

Community safety, health and wellbeing are a key priority for communities within the study area. Community members indicated the importance of construction activities being undertaken in a manner that considers the health, safety and wellbeing of residents.

Community cohesion refers to the connections and relationships between individuals and their neighbourhoods. Levels of community cohesion and sense of belonging are said to be good where communities have access to a diverse range of local and regional infrastructure, barriers to movement are minimised and there are a variety of meeting places which encourage strong support networks.

14.2.3 Social infrastructure

Social infrastructure comprises social services or facilities that are used for the physical, social, cultural or intellectual development or welfare of the community. Social infrastructure often includes schools and libraries and the services, activities and programs that operate within these facilities. Open spaces, parks, recreation areas and sporting fields that support sport, recreational and leisure uses are also identified as social infrastructure.

Social infrastructure facilities generally operate at a local, district and/or regional level and are defined by the scale of the population catchment they serve. For example, a public primary school is generally intended to serve a local catchment and is usually within walking distance. However, a secondary school would generally serve a wider catchment of around three kilometres, and a university would generally cater for a significantly wider catchment (of up to 100 kilometres). Social infrastructure can often be classified as a sensitive receiver and may be directly affected by the project. This section identifies the social infrastructure within 400 metres of the construction ancillary facility sites.

The social infrastructure facilities outlined in this section are shown in **Figure 14-3** to **Figure 14-9**.

Educational facilities

There are a wide range of educational facilities in the study area, including childcare centres, primary schools, secondary schools, tertiary educational facilities and an indigenous school.

Childcare centres and primary schools mainly serve the local community. Secondary schools draw from a wider catchment as families are willing to travel further to enrol at schools with particular personal meaning, reputation or history. Tertiary facilities, such as the University of Sydney, draw from a vast catchment with students attending from interstate and overseas. The University of Sydney is located in the north of the Alexandria-Erskineville precinct and has over 54,000 students enrolled.

Table 14-5 identifies childcare and education facilities located within 400 metres of construction ancillary facility sites. Sensitive receivers identified in this section are indicative and not exhaustive.

Table 14-5 Education facilities within 400 metres of construction ancillary facility sites

Precinct	Construction site	Facility type	Facility name
Ashfield-Haberfield	Wattle Street civil and tunnel site (C1a) Haberfield civil and tunnel site (C2a)/Haberfield civil site (C2b) Northcote Street civil site (C3a) Parramatta Road West civil and tunnel site (C1b) Parramatta Road East civil site (C3b)	Childcare	• The Infants Home, Family Day Care • Chaya’s Family Day Care • Little VIPs Child Care Haberfield • St John’s Pre-school • Guardian Early Learning Centre • Goodstart Early Learning Centre • Nurjahan's Family Day Care • Greenwood Five Dock
		Primary school	• Haberfield Public School
Leichhardt-Glebe	Darley Road civil and tunnel site (C4)	Childcare	• Explore and Develop • Emmerick Street Community Preschool • Billy Kids Lilyfield Early Learning Centre • Zero Up Childcare • Only About Children Leichhardt Elswick St Campus • My Stepping Stone • St Columba's North Leichhardt Out of School Hours Care
		Primary school	• St Columba’s Primary School Leichhardt North • Orange Grove Public School
		Secondary College	• Sydney Secondary College Leichhardt

Precinct	Construction site	Facility type	Facility name
	Rozelle civil and tunnel site (C5) The Crescent civil site (C6) Victoria Road civil site (C7)	Childcare	• Rosebud Cottage Childcare Centre • Lilyfield Early Learning Centre • Hilda Booler Kindergarten • Balmain Cove Early Learning Centre
		Tertiary education	• Sydney Community College
	Iron Cove Link civil site (C8)	Childcare	• Rozelle Out of School Hours Care • St Thomas' Child Care Centre • Balmain Cove Early Learning Centre • Rozelle Child Care Centre
		Primary school	• Rozelle Public School
		Secondary school	• Sydney Secondary College Balmain Campus
		Tertiary education	• Sydney College of the Arts – The University of Sydney
Alexandria-Erskineville	Pyrmont Bridge Road tunnel site (C9)	Childcare	• Camperdown Child Care Centre • Camperdown Sunshine Kids • Explore and Develop Camperdown • Guardian Early Learning Centre • Peekaboo - Camperdown (Learning Centre) • Annandale Child Care Centre • Sunshine Bubs Kindergarten • JoJo's Family Day Care • Explore & Develop Annandale • Lucas Street Child Care Centre
		Primary school	• Annandale Public School • St Brendan’s Primary School • Bridge Road School
		Tertiary education	• Sydney Nursing School • The University of Sydney, Camperdown NSW
		University	• University of Sydney (located around 600 m east)
	Campbell Road civil and tunnel site (C10)	Childcare	• St Peters Community Preschool • Tribe Out of School Hours
		Primary School	• St Peters Public School

Health and emergency facilities

There are around 137 health facilities within the study area, including private and public hospitals, medical centres, general medical practices and fire, police and ambulance stations. **Table 14-6** identifies the health and emergency facilities located within 400 metres of construction ancillary facility sites. Sensitive receivers identified in this section are indicative and not exhaustive.

Table 14-6 Health and emergency facilities within 400 metres of construction ancillary facility sites

Precinct	Construction site	Facility type	Facility name
Leichhardt-Glebe	Iron Cove Link civil site (C8)	Medical centre	• Rozelle Medical Centre • Rozelle Total Health
Alexandria-Erskineville	Pyrmont Bridge Road tunnel site (C9)	Medical centre	• Community Mental Health Centre Camperdown • Missenden Medical Centre • Southern Radiology Centre • Therapies for Kids

Recreational facilities

There are a number of passive and active spaces in the study area in the form of parks, reserves, playgrounds, sporting fields, aquatic centres and bowling clubs. Bicycle and walking paths are also located alongside waterfronts and other natural waterways. Specialised sporting facilities include bowling clubs, tennis courts, golf courses, basketball courts, leisure centres and aquatic centres.

Table 14-7 identifies sporting and recreational facilities within 400 metres of construction ancillary facility sites. The facilities identified in **Table 14-7** are public only and do not include private facilities. Sensitive receivers identified in this section are indicative and not exhaustive.

Table 14-7 Sporting and recreational facilities within 400 metres of construction ancillary facility sites

Precinct	Construction site	Facility type	Facility name
Ashfield-Haberfield	Wattle Street civil and tunnel site (C1a) Haberfield civil and tunnel site (C2a) Northcote Street civil site (C3a) Parramatta Road West civil and tunnel site (C1b) Haberfield civil site (C2b) Parramatta Road East civil site (C3b)	Sports grounds	• Hammond Park
		Playgrounds	• Algie Playground • Livvi's Park Playground • Crocker Park Playground • Hammond Park Playground
		Parks/reserves	• Croker Park • Wadim Jegorow Reserve • Reg Coady Reserve • Hammond Park • Algie Park
		Sports ground	• Timbrell Park
Leichhardt-Glebe	Darley Road civil and tunnel site (C4)	Playground	• Richard Murden Reserve Playground
		Sports ground	• Blackmore Park

Precinct	Construction site	Facility type	Facility name
		Parks/reserves	• Richard Murden Reserve • Pioneers Memorial Park
	Rozelle civil and tunnel site (C5) The Crescent civil site (C6) Victoria Road civil site (C7)	Playground	• Easton Park Playground
		Sports grounds	• Easton Park
		Parks/reserves	• Easton Park • Federal Park • Cohen Park • Buruwan Park • O'Connor Reserve
	Iron Cove Link civil site (C8)	Playground	• Shields Playground • Bridgewater Park
		Parks/reserves	• King George Park • Callan Park • Bridgewater Park Playground
Alexandria-Erskineville	Pyrmont Bridge Road tunnel site (C9)	Playgrounds	• Camperdown Park Playground • O'Dea Reserve Playground
		Parks/reserves	• Douglas Grant Memorial Park • O'Dea Reserve
		Sports ground	• Camperdown Park
	Campbell Road civil and tunnel site (C10)	Sports ground	• Camdenville Park
		Playground	• Sydney Park Playground
		Parks/reserves	• Camdenville Park • Simpson Park
		Parks/reserves	• Sydney Park

Community facilities

Community centres, halls and places of worship for a variety of different faiths are located within the study area. These facilities provide opportunities for:

- Educational, recreational and health services and programs
- Community, cultural and social activities
- Places that build community connections and relationships
- Places that improve the inclusion of community members, especially within areas of high culturally and linguistically diverse communities.

Table 14-8 identifies the community facilities within 400 metres of construction ancillary facility sites. Sensitive receivers identified in this section are indicative and not exhaustive.

Table 14-8 Community facilities within 400 metres of construction ancillary facility sites

Precinct	Construction site	Facility type	Facility name
Ashfield-Haberfield	Wattle Street civil and tunnel site (C1a) Haberfield civil and tunnel site (C2a) Northcote Street civil site (C3a) Parramatta Road West civil and tunnel site (C1b) Haberfield civil site (C2b) Parramatta Road East civil site (C3b)	Place of worship	• Kingdom Hall of Jehovah's Witnesses • Anglican Church Sydney Diocese
Leichhardt-Glebe	Darley Road civil and tunnel site (C4)	Place of worship	• St Columba and the Holy Souls Catholic Church • St Gerasimos Greek Orthodox Church
		Community centre	• Lucan Care Community Centre
	Rozelle civil and tunnel site (C5) The Crescent civil site (C6) Victoria Road civil site (C7)	Community centre	• Lilyfield Community Centre
	Iron Cove Link civil site (C8)	Community centre	• Rozelle Neighbourhood Centre
		Place of worship	• Darling Street Anglican Church
Alexandria-Erskineville	Pyrmont Bridge Road tunnel site (C9)	Community centre	• Booler Community Centre
		Place of worship	• C3 Central City Church • St Joseph's Catholic Church
	Campbell Road civil and tunnel site (C10)	Place of worship	• St Peters Anglican Church

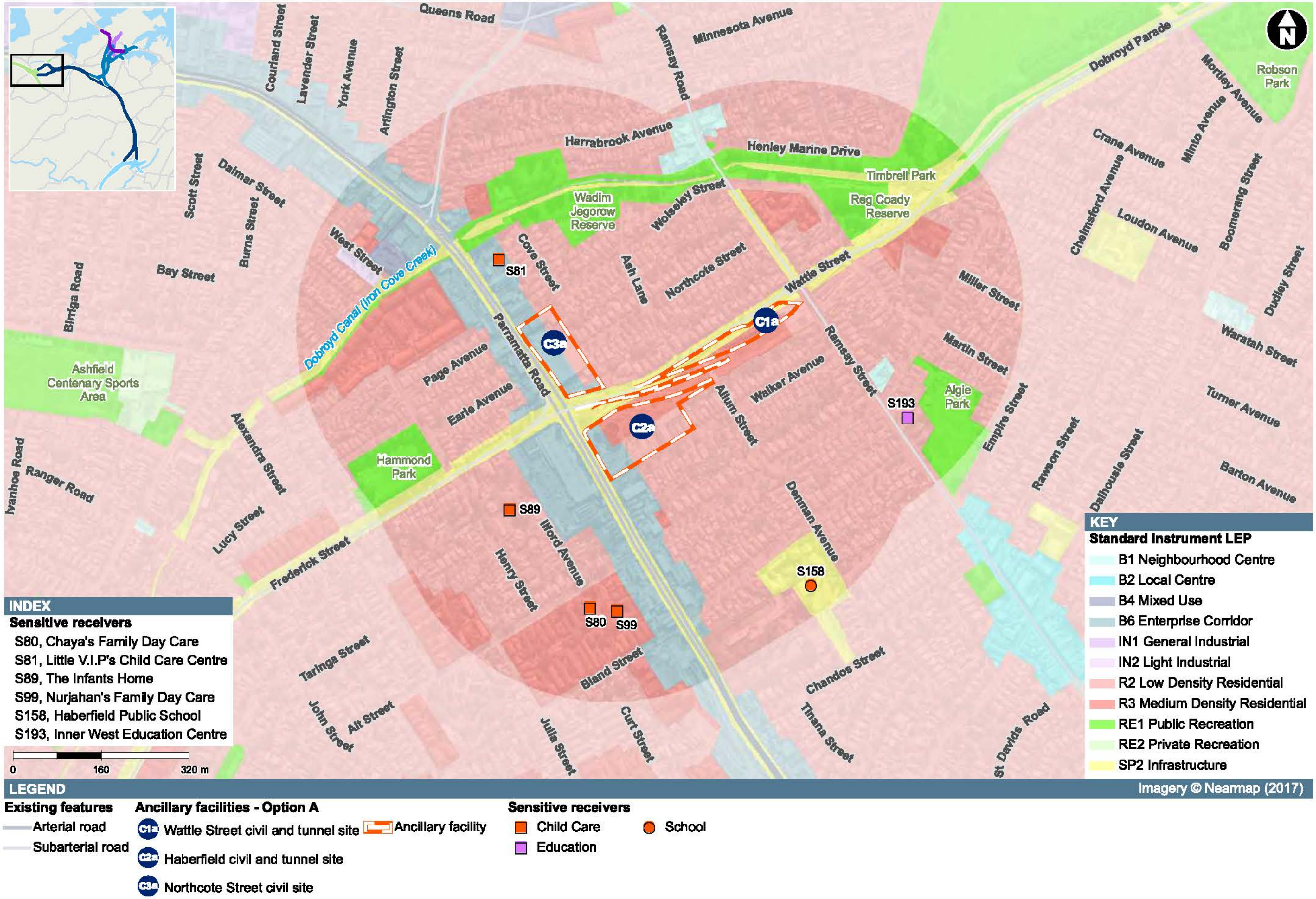


Figure 14-3 Sensitive receivers and land zoning around the Wattle Street civil and tunnel site (C1a), Haberfield civil and tunnel site (C2a) and Northcote Street civil site (C3a) – Option A

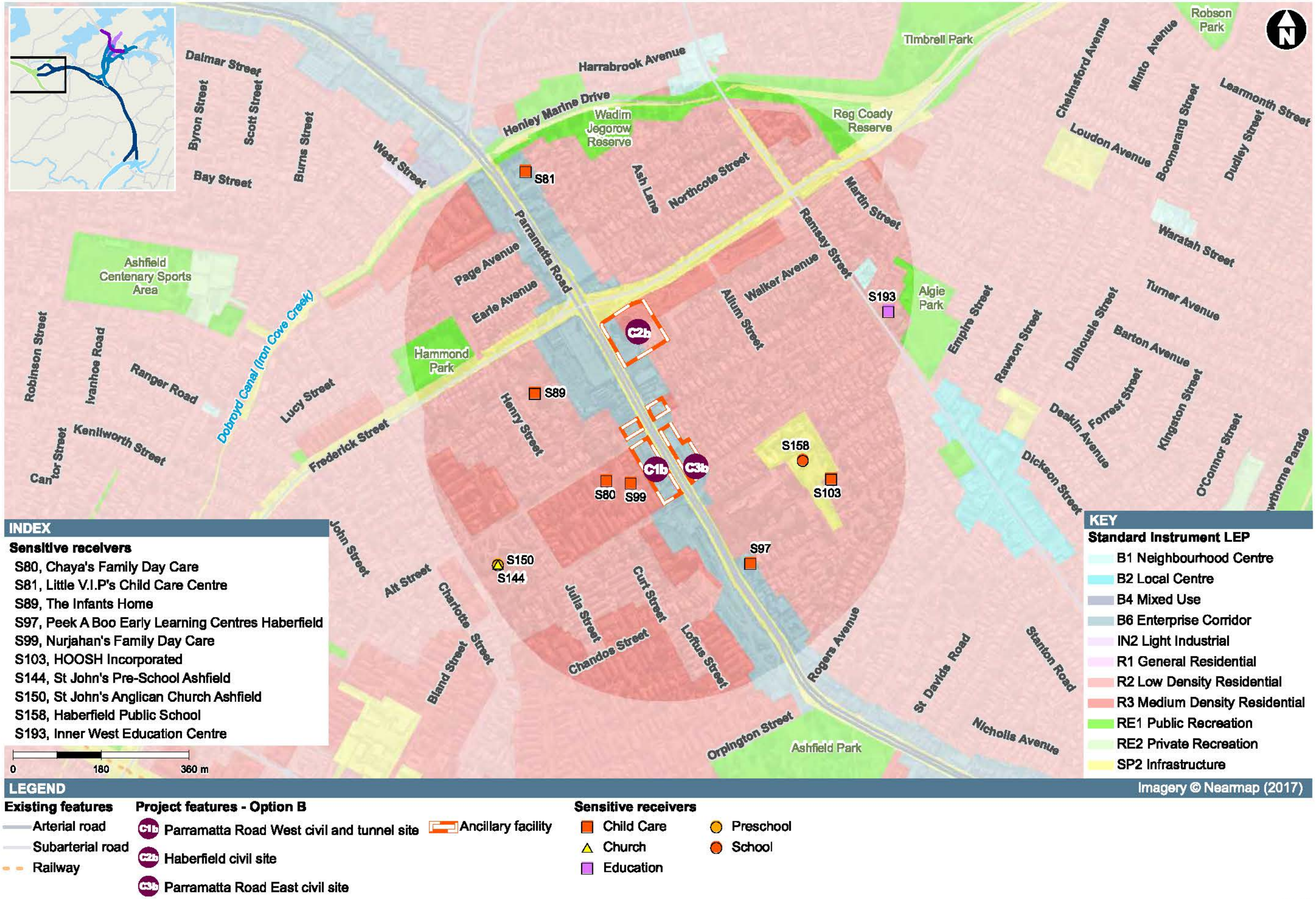


Figure 14-4 Sensitive receivers and land zoning around the Parramatta Road West civil and tunnel site (C1b), Haberfield civil site (C2b) and Parramatta Road East civil site (C3b) – Option B

Figure 14-5 Sensitive receivers and land zoning around the Darley Road civil and tunnel site (C4)

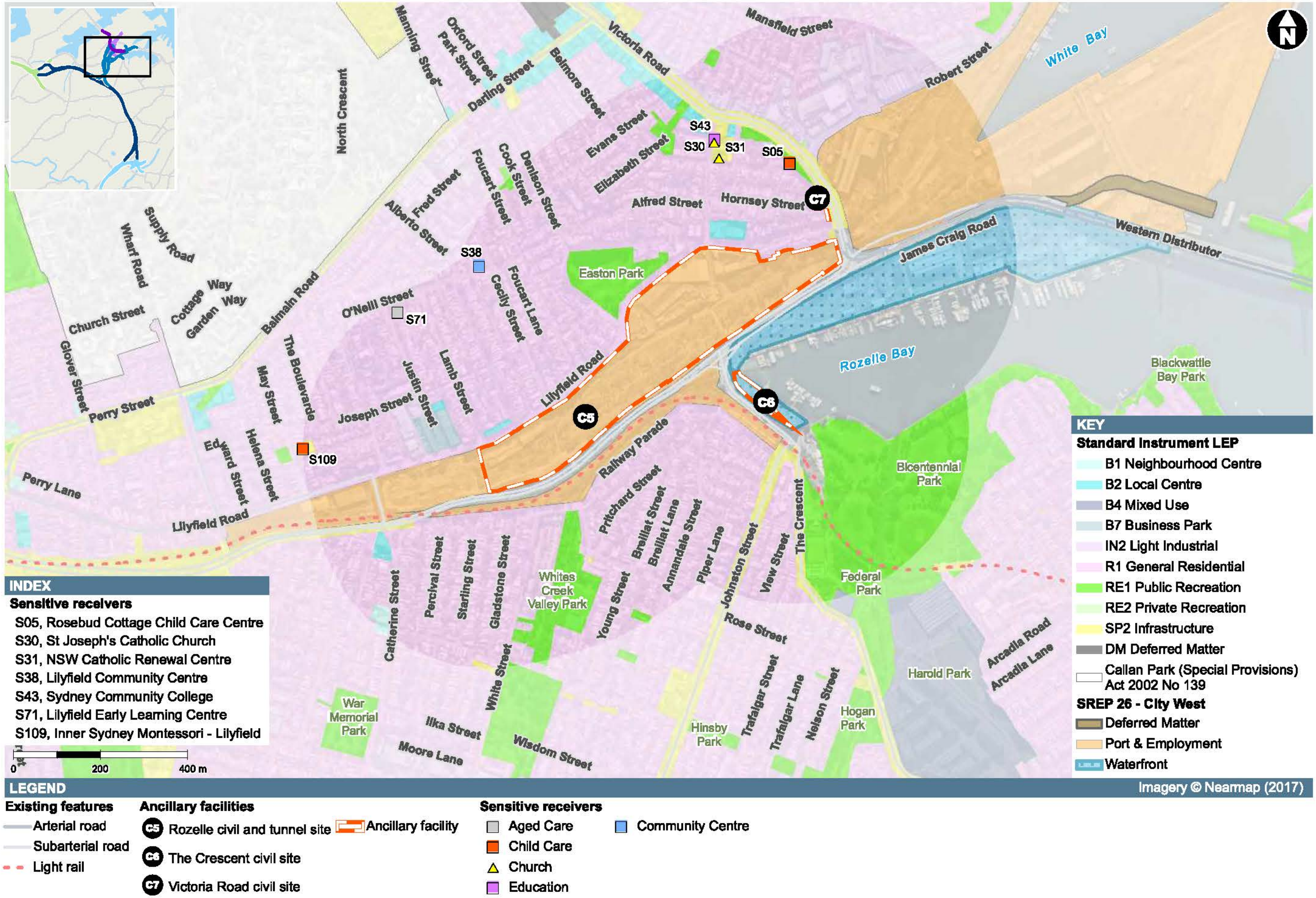


Figure 14-6 Sensitive receivers and land zoning around the Rozelle civil and tunnel site (C5), The Crescent civil site (C6) and Victoria Road civil site (C7)

Figure 14-7 Sensitive receivers and land zoning around the Iron Cove Link civil site (C8)

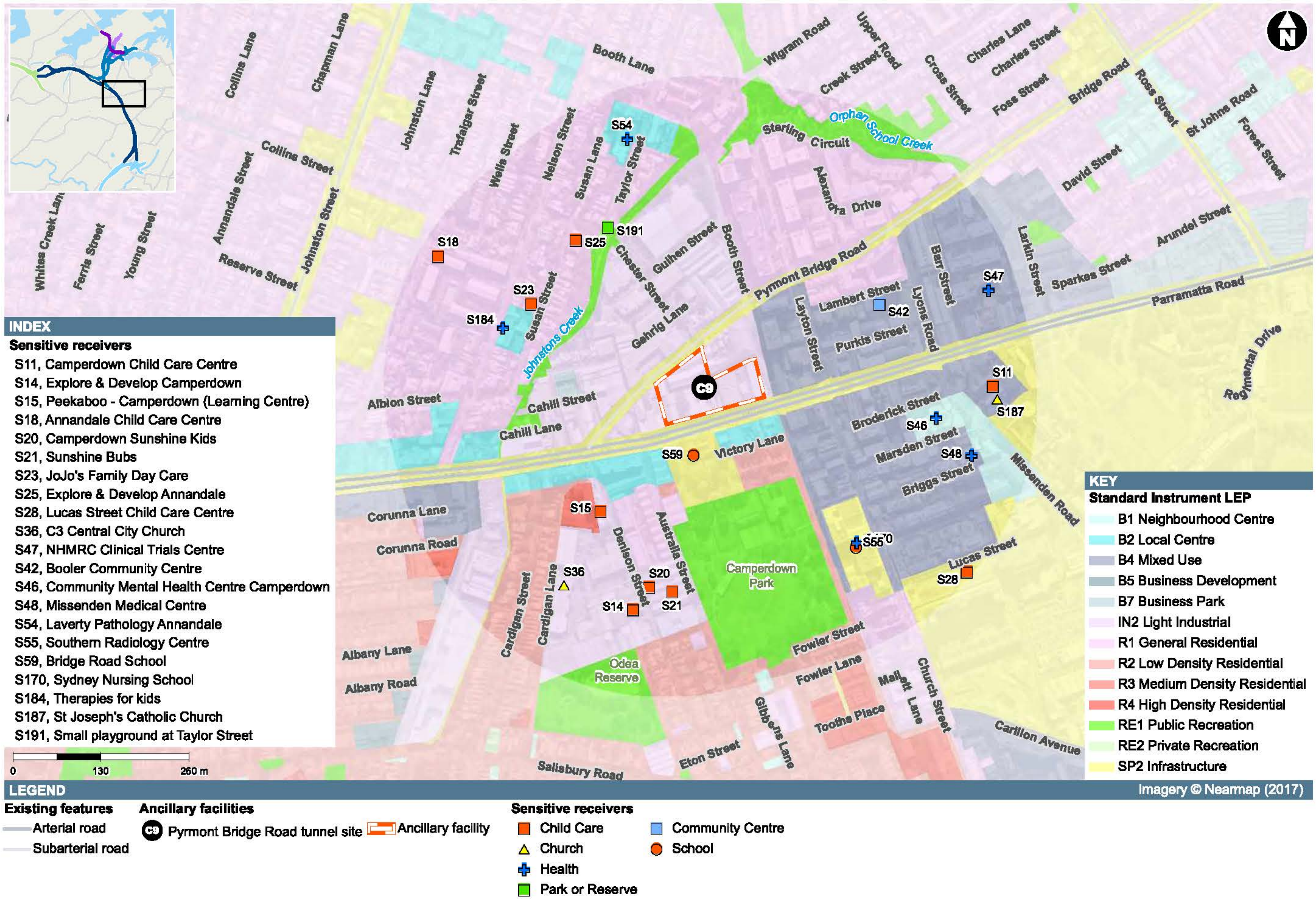


Figure 14-8 Sensitive receivers and land zoning around the Pyrmont Bridge Road tunnel site (C9)

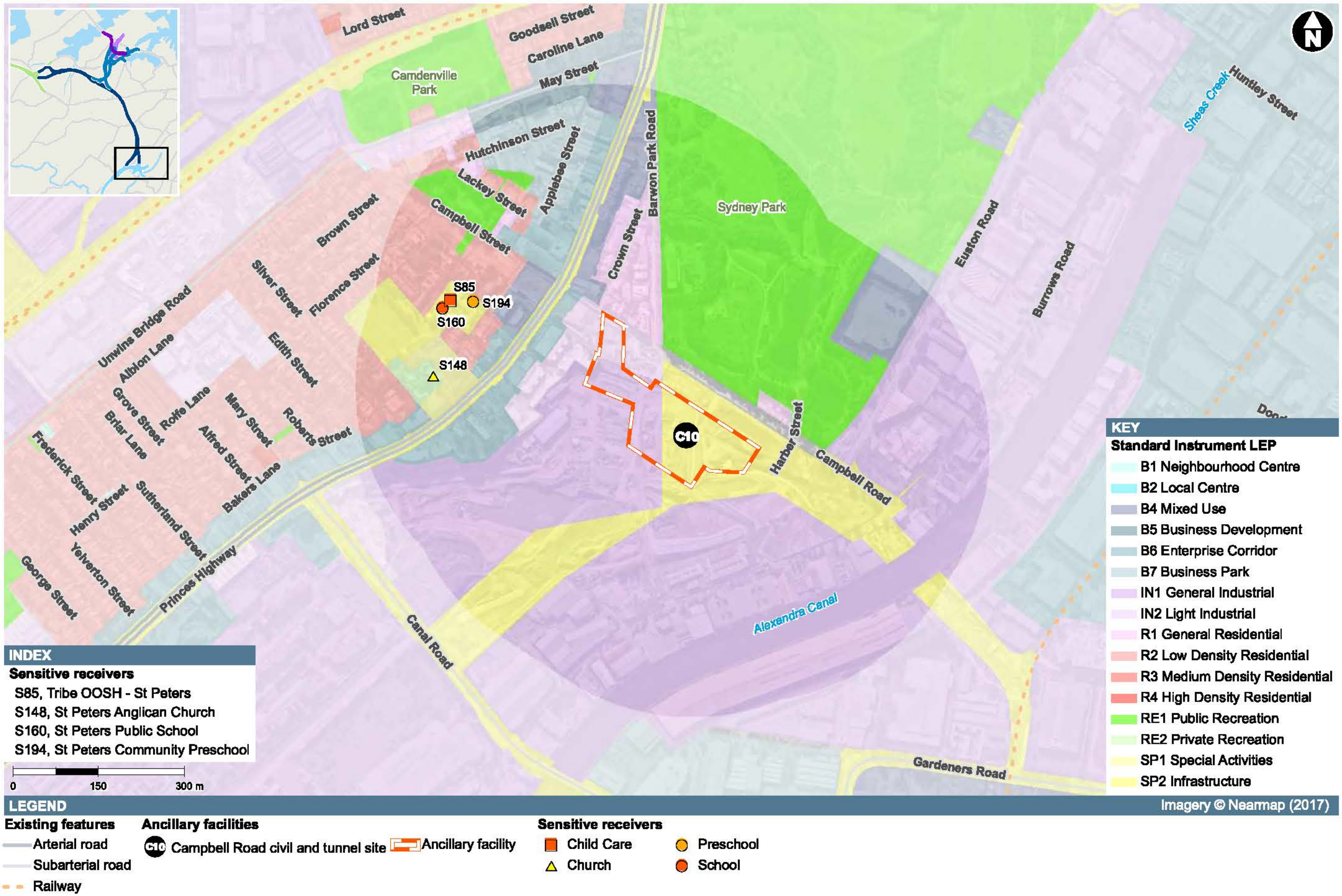


Figure 14-9 Sensitive receivers and land zoning around the Campbell Road civil and tunnel site (C10)

14.2.4 Employment centres

Strategic, district and local centres

In developing *Towards our Greater Sydney 2056* (Draft amendment to A Plan For Growing Sydney (NSW Government 2014)), The Greater Sydney Commission identified that some centres make a substantially greater contribution to the economy of Greater Sydney than others. On this basis, their draft District Plans have defined a hierarchy which includes three types of centres: strategic, district and local. These centres vary in terms of scale and contribution to Greater Sydney's job growth and productivity as well as service provision to local communities.

Local centres within the study area are generally clustered on the main transport routes (such as bus routes) and provide either a specialist service to the broader area or a convenience service for the local community. Rozelle local centre is the only local centre within close proximity to the project footprint.

Table 14-9 identifies the hierarchy of retail centres within the study area and provides an overview of some of the larger local centres in the study area. Other businesses and commercial areas within the study area are described in **Appendix P** (Technical working paper: Social and economic).

Table 14-9 Key retail centres in the study area

<table>
<tr><th>Centre hierarchy</th><th>Centre name</th><th>Description</th></tr>
<tr><td>Strategic
Strategic centres tend to support more than 20,000 jobs and have one or more of the following characteristics:
• A higher proportion of knowledge, economy jobs, generally associated with major hospitals, tertiary education institutions and/or standalone office development
• Existing or proposed major transport gateways that play a major role in supporting the increased economic activity.</td><td>Green Square-Mascot</td><td>Green Square-Mascot is located south of Sydney central business district (CBD) and is currently transitioning from former industrial lands to a new strategic centre. The centre is projected to grow as a new major retail, community, cultural and residential centre to support a projected population of 61,000 people living in Green Square by 2030.</td></tr>
<tr><td>District
District centres tend to support between 5,000 and 10,000 jobs and have one or more of the following characteristics:
• Over 50,000 square metres of floor space
• Presence of health and education facilities that serve the district and the local community
• Transport services.</td><td>Burwood</td><td>Burwood district centre is centred on Burwood Station and extends north and south along Burwood Road. Two shopping centres provide the bulk of retail floor space. Westfield Burwood is the larger of the two shopping centres housing a David Jones, Kmart, Target, Coles and Woolworths, with an additional 213 speciality stores. In 2016, the centre achieved a turnover of $481.8 million, ranking as 11th out of 91 similarly sized centres across Australia.

Burwood Plaza is located near Burwood Station and provides a Woolworths, Best and Less and Freshworld. Remaining retail provision within Burwood predominantly extends along Burwood Road and comprises speciality shopfront retailing.</td></tr>
<tr><td rowspan="2">Local
Local centres vary in size from a few shops on a corner to a vibrant main street. These are generally at a smaller scale than district centres and generally serve the local population.</td><td>King Street North, Newtown</td><td>The majority of this floor space consists of restaurants/cafes, entertainment, clothing and speciality stores. The diversity of speciality retail stores along King Street makes the strip a popular shopping destination with a vibrant lifestyle economy.</td></tr>
<tr><td>Broadway Shopping Centre, Glebe</td><td>Major tenants include Kmart, Hoyts, Target, Coles, ALDI and Harvey Norman, with a further 133 specialty stores. In 2015, Broadway recorded a turnover of $524.6 million, ranking the centre 32nd nationally out of 91 similar sized shopping centres in Australia.</td></tr>
</table>

Centre hierarchy	Centre name	Description
	Balmain town centre, Balmain	Balmain town centre includes a retail strip located along a one kilometres stretch of Darling Street from King Street to Queens Place. A Woolworths is also provided on the corner of Darling and Beattie Streets, anchoring the centre. Given Woolworths is the only major national supermarket in the Balmain Peninsula, the Balmain town centre serves a large area, capturing trade from the Balmain Peninsula and parts of Rozelle and Lilyfield, west of Victoria Road. The remainder of Balmain contains a mix of specialty retailing, personal services, restaurants and cafés. Balmain's vibrant restaurant and café culture, combined with an increasing range of clothing and apparel stores, also contributes to the success of the centre, especially on weekends. Balmain not only serves surrounding residents but has emerged as a destination shopping precinct.
	Norton Street, Leichhardt	Norton Street has a retail strip between Brenan Street and Parramatta Road, including Italian restaurants and cafés, an IGA supermarket, commercial shopfront premises (such as banks and real estate agents), a BWS bottle shop and other retail specialty stores. Norton Plaza is a neighbourhood shopping centre providing retail and commercial space. The Plaza is anchored by a Coles supermarket, surrounded by other specialty stores. The Italian Forum is located at the southern end of Norton Street and contains a number of restaurants, clothing stores, a travel agent, optometrist, hairdresser, beautician, bookshop, amongst others. The Italian Forum also includes a Woolworths, Target and ALDI.
	Rozelle retail strip, Rozelle	Rozelle retail strip extends along Victoria Road and Darling Street and comprises supermarkets, retail stores, speciality stores and professional businesses such as tax agents, financial services, real estate agents and lawyers.

Businesses

Business within the study area are generally clustered on the main transport routes (such as bus routes) and provide either a specialist service to the broader area or a convenience service for the local community. Business clusters considered in the social and economic assessment are listed in **Table 14-10**. Sensitive receivers identified in this section are indicative and not exhaustive.

Table 14-10 Business clusters within 400 metres of construction ancillary facilities

Construction site	Business cluster name	Business land zoning
Wattle Street civil and tunnel site (C1a) Haberfield civil and tunnel site (C2a) Northcote Street civil site (C3a) Parramatta Road West civil and tunnel site (C1b) Haberfield civil site (C2b) Parramatta Road East civil site (C3b)	Parramatta Road, Haberfield	B6 Enterprise Corridor
	Ramsay Road Convenience, Haberfield	B1 Neighbourhood Centre
Darley Road civil and tunnel site (C4)	Canal Road	SP1 Special activities: Canal Road arts precinct
	Norton Street	B2 Local centre
	State Transit	SP2 Infrastructure: transport depot
	Lilyfield Neighbourhood	B1 Neighbourhood Centre B2 Local Centre
Rozelle civil and tunnel site (C5) The Crescent civil site (C6) Victoria Road civil site (C7)	Catherine Street Convenience	B2 Local Centre
	Lilyfield Road	B1 Neighbourhood Centre B2 Local Centre
	Roberts Street	IN2 Light Industry
	James Craig Road	Unincorporated Sydney Foreshore Authority
	Chapman Road	B4 Mixed Use
	Victoria Road	B2 Local Centre IN20 Industrial Light Industry
Iron Cove Link civil site (C8)	Victoria Road	B2 Local Centre
	Darling Street	B2 Local Centre
	Crystal Street	IN2 Light Industrial
Pyrmont Bridge Road tunnel site (C9)	Annandale Camperdown	B1 Neighbourhood Centre B2 Local Centre B4 Mixed Use B7 Business Park IN2 Light Industrial

Construction site	Business cluster name	Business land zoning
Campbell Road civil and tunnel site (C10)	Princes Highway	B4 Mixed Use B6 Enterprise Corridor B7 Business Park IN2 Light Industrial
	Burrows Road Industrial	IN1 General Industrial
	Euston Road	B4 Mixed Use

Business clusters are described in detail in **Appendix P** (Technical working paper: Social and economic).

Industry Value Added

Industry Value Added (IVA) is a metric that measures economic contribution by calculating the total value of goods and services produced by an industry, minus the cost of goods and services used in the production process.

It is estimated that employment industries within the study area contributed around $9.6 billion to the total IVA of NSW as follows:

- Ashfield-Haberfield precinct contributed around $950 million IVA, comprising around 10 per cent of total IVA for the study area. Health care and social assistance, public administration and safety and rental, hiring and real estate services are the largest contributors to economic value, reflecting the presence of Sydney Private Hospital, Wesley Hospital and NSW Government offices, such as Family and Community Services and Housing NSW
- Leichhardt-Glebe precinct contributed around $2.6 billion IVA, comprising around 28 per cent of total IVA for the study area. Health care and social assistance and professional, scientific and technical services are among the largest generators of economic value, likely due to the Royal Prince Alfred Hospital and the University of Sydney
- Alexandria-Erskineville precinct contributed around $6 billion IVA, comprising around 62 per cent of total IVA for the study area. While transport, postal and warehousing information media and telecommunications are the two largest industries at the Australian Technology Park at Eveleigh, retail trade represents a much larger proportion of jobs across the precinct (but with a lower IVA), reflecting a relatively lower economic contribution.

14.2.5 Access and connectivity

A detailed description of the existing transport and traffic environment in the study area is provided in **Appendix H** (Technical working paper: Traffic and transport).

Road and freight network

Parramatta Road, Victoria Road, City West Link and King Street/Princes Highway are major arterial roads within the study area carrying significant volumes of traffic and providing access between the Sydney CBD and the west, southwest and northwest.

The road network in the study areas also services commercial and freight operators. The M4-M5 Link project forms part of the Urban National Land Transport Network for Sydney, which identifies major connections through urban areas to ports, airports and intermodal facilities. These connections are considered critical to support national and regional economic growth, development and connectivity. The M4-M5 Link project would provide a link between the M4 East and the New M5 motorways, to enable efficient movement of freight and commercial vehicles across Sydney to key metropolitan and regional markets.

Parramatta Road currently operates as a major commercial vehicle thoroughfare supporting the delivery of goods and services to major centres including Parramatta, Sydney Olympic Park and the Sydney CBD. City West Link, King Street/Princes Highway and Victoria Road are also main arterial roads within the study area used by commercial and heavy vehicles. Canal Road is close to the major industrial and port area around Sydney Airport, and subsequently supports a high number of commercial and heavy vehicle movements.

The *2014 State Infrastructure Strategy Update* (Infrastructure NSW 2014) identified that urban roads support about 278,000 heavy freight vehicle movements every day. Currently these movements have no alternative to urban roads because there is insufficient motorway connectivity between major centres and distribution areas, such as the Sydney Airport and Port Botany precinct.

Further information regarding freight movements and demand is included in **Chapter 4** (Project development and alternatives).

Public transport

Public transport modes across the study area include light rail, heavy rail, bus and ferry services. At the time of the 2011 census, rail transport was the primary mode of public transport across the study area, carrying around 19 per cent of residents.

Bus transportation was the second preferred mode of transport across the study area, carrying around 13 per cent of residents. Parramatta Road, Victoria Road and King Street are key bus corridors with a number of services operating both inbound and outbound from the Sydney CBD.

Less than one per cent of residents in the study area travel to work by ferry, likely because ferry services are only available in the Leichhardt-Glebe precinct. More detailed travel to work data is included in **Table 14-4**. Further details for public transport services in the study area are included in **Chapter 8** (Traffic and transport).

Connectivity

In 2011, walking was the most common form of active transport for commuters across the study area, with around eight per cent of residents walking to work. Around three per cent of commuters across the study area cycled to work.

There are a number of key active transport links in the study area. The Iron Cove walking and cycling path at Rozelle, Jubilee Park at Glebe, Richard Murden Reserve at Hawthorne Canal in Haberfield, Sydney Park at St Peters and the Johnstons Creek connection at Glebe, all provide separated cycleways for all levels of bicycle users. These parks and spaces are also popular with recreational walkers and provide connectivity through the inner west.

Highly valued active transport networks in the study area identified through community consultation include the Bay Run at Rozelle, Glebe foreshore, Anzac Bridge cycleway and the northern part of the Greenway (the active transport connection between Cooks River and Iron Cove) through Leichhardt. The shared path along Whites Creek to Buruwan Park at Annandale is used by cyclists and pedestrians. Shared pedestrian and cycle paths also run along both sides of Victoria Road, with important overpasses provided at the city end of Victoria Road and across City West Link to provide connection to the water.

14.3 Assessment of potential construction impacts

During construction of the project, construction works have the potential to affect the social and economic environment. These potential impacts are assessed in this section.

14.3.1 Demographic profile

Factors of the project’s construction that can influence or change the demographic profile of the study area include property acquisition and influx of construction workers resulting in more people being employed in the local area and choosing to live close to work, which has the potential to influence the demographic profile of the study area. Information on property acquisition as a result of the project is provided in **Chapter 12** (Land use and property). Properties to be acquired for the project include businesses and residential properties.

A small number of residential property acquisitions would be required in the Leichhardt-Glebe precinct along Victoria Road in Rozelle to facilitate the Iron Cove Link. No residential property acquisitions as a result of the project are proposed for the Ashfield-Haberfield precinct or the Alexandria-Erskineville precinct.

Given the overall number of residential property acquisitions required, this impact is not expected to affect the population and demography of the study area or precinct. The study area is projected to experience significant population growth over the next 20 years, partially as a result of urban renewal programs. Further assessment of the social and economic impacts of residential property acquisitions is included in **section 14.3.9**.

The construction workforce for the project would be expected to be sourced from across the broader Sydney region and is not expected to change the population and demography in the study area. As the project is located in the inner west and is relatively easily accessible, it is unlikely that construction workers would need to relocate to live in the study area. The presence of construction workers would have a minimal effect on local residential population and demographics.

Overall, the severity of the impact of the project on the demographic profile of the study area is expected to be neutral with the likelihood of change possible. Considering this, the overall impact of construction activities on the social and economic environment would be negligible.

14.3.2 Community values

Neighbourhood identity and character

As identified in **Appendix S** (Technical working paper: Biodiversity) of the EIS, vegetation removal would be required to facilitate construction, including the removal of street trees. Vegetation removal has the potential to expose residents, pedestrians and motorists to direct views of fencing and hoarding and other large elements of construction, reducing the amenity and character of affected environments.

As trees contribute to the identity of a neighbourhood, provide protection from the elements and provide intermittent or consistent screening and privacy, the clearing of trees is likely to be of concern to the community, particularly those where the visual amenity and landscape character of the area or property is altered due to a reduction in landscape screening.

Public art and monuments contribute to neighbourhood identity and character, holding sentimental value for the community. There are two items of public art within the project footprint – the statues of soldiers on the approaches of Anzac Bridge and the mural along The Crescent, between City West Link and Johnston Street. These items of public art would be retained and protected during construction and would not be impacted by the project.

Chapter 20 (Non-Aboriginal heritage) provides an assessment of the project on items of heritage significance. Overall, the project would have a moderate impact on non-Aboriginal heritage values. As heritage is of high value to communities within the study area, the loss of heritage items may diminish the sense of place and neighbourhood identity valued by the community. Environmental management measures would be implemented to reduce the loss of heritage, including photographic archival recordings and salvaging historic fabric and features. The social and economic impacts of a moderate heritage impact in the study area would be moderate negative.

An increase in construction activity in or around open space and recreation areas has the potential to reduce the amenity and accessibility of these areas. Key areas of open space in the study area include Easton Park, Blackmore Park, the Bay Run, King George Park, Sydney Park, the Glebe Foreshore parks and Buruwan Park at Whites Creek. During construction, a small area of King George Park (near Victoria Road) and Buruwan Park would be impacted. The impacts on social infrastructure have been assessed in **section 14.3.4**.

Overall, changes to community values would be medium-long term and reflect a moderate change to the existing environment. The likelihood of impacts occurring ranges from possible to near certain. As such, the overall impact upon the social and economic environment would be moderate negative.

Community safety, health and wellbeing

Construction impacts on community welfare include light spill, dust, traffic, noise and vibration. Those affected most by these impacts include residents and users who frequent areas closest to project footprint.

The human health risk assessment determined that without mitigation, extended elevated levels of noise, vibration and construction dust could result in adverse health effects across the community (refer to **Chapter 11** (Human health risk)). These health effects may include disturbance of sleep, reduced capacity for concentration, interference with speech and other activities, potential effects on cardiovascular health, annoyance and increased stress levels.

Increased levels of noise and vibration can affect human comfort and cause sleep deprivation if noise exceedances extend more than two consecutive nights. The potential for structural damage to properties as a result of vibration was also a concern for some residents and is considered likely to trigger higher levels of anxiety and stress, resulting in direct impacts on health and wellbeing.

Dust generation from construction activities was raised as a concern due to the potential impacts on the health of some sections of the community who may be more sensitive to changes in air quality. This includes people with pre-existing medical conditions such as asthma or respiratory difficulties, as well as children and the elderly. These impacts are likely to be relevant for works at the Pyrmont Bridge Road tunnel site (C9) in particular, where a number of educational receivers are located nearby, which may be affected by reduced amenity.

An increase in construction traffic and heavy vehicles within the study area may also affect the community's perception of safety around roads and active transport connections. This is most likely to occur in proximity to construction ancillary facilities, on local or arterial roads with higher traffic volumes than would normally be experienced, and along pedestrian and cyclist routes that have been temporarily diverted and may not accommodate the pre-existing level of lighting, casual surveillance or general activity. However, spoil haulage routes have been selected to avoid using local roads which would minimise heavy vehicle movements along these roads.

Traffic congestion and loss of residential on-street car parking has the potential to contribute to health impacts such as stress and anxiety, reduced air quality, increased noise, poor perception of amenity and safety concerns. On-street parking would be temporarily removed along a section of the northern side of Darley Road at Lilyfield for the Darley Road civil and tunnel site (C4), and areas around the Rozelle civil and tunnel site (C5) would likely experience the greatest competition and demand for on-street parking from the influx of construction workers. Elderly people, those with a disability or families with young children, who may have difficulty walking greater distances, would be particularly affected if they are required to park further away due to demand increases.

Measures to manage parking impacts would be addressed in a car parking strategy, which would be included in the Construction Traffic and Access Management Plan (CTAMP). This would be developed in consultation with local councils and stakeholders and would include the identification of areas where there are high levels of existing parking demand around the construction ancillary facilities (and other works sites) and identification of alternative car parking sites for use by the construction workforce.

As outlined above, management measures would be implemented to manage the construction impacts of light spill, dust, traffic, noise and vibration (refer to **Chapter 29** (Summary of environmental management measures)). Despite these measures, a small number of people may still experience adverse health impacts from these project related sources.

Construction of the project would directly affect values held by the community around community safety and health. Although the impacts would generally be confined to localities around construction ancillary facilities, they would be medium-long term and reflect a minor change to the existing environment. The likelihood of effects on health and safety is possible. As such, the overall impact upon the social and economic environment would be moderate negative.

Community cohesion

Infrastructure that creates a physical or psychological barrier between communities may produce a real or perceived barrier, reducing the capacity for community cohesion, including social and economic interaction. Community severance may lead to short or long term changes to people's behaviour patterns, affecting established community networks and an area's character and sense of place.

Existing physical and physiological barriers between communities in the study area include:

- Arterial roads including City West Link, Victoria Road, Parramatta Road and the Princes Highway that carry large volumes and high speed traffic, with priority generally given to motor vehicles over pedestrians and cyclists
- The Rozelle Rail Yards, which act as a significant physical barrier between the communities of Annandale, Rozelle and Lilyfield.

During construction, temporary changes to the road network, particularly along City West Link, Victoria Road, The Crescent, Lilyfield Road and Darley Road may contribute to the perception of further community severance and disconnection. Temporary road network changes would be short term and returned to their pre-construction layout. Access to properties would be generally be maintained at all times throughout construction. Where temporary impacts on existing property access are unavoidable as a result of construction activities (eg footpath and pavement works), consultation would be carried out with the landowner and/or tenant to provide equivalent standards of access.

The Bay Run around Iron Cove is a key active transport link in the study area. A small section of the Bay Run would be temporarily diverted during construction; however, access along the path would be maintained throughout construction.

Two pedestrian bridges across Victoria Road and City West Link, which are popular for both recreational and commuter pedestrian and cyclist traffic would also be removed by the project. The removal of these bridges, despite the presence of temporary alternatives during construction, may reduce community cohesion and perception of access to a place. These connections provide important access to Rozelle Bay and through to the Glebe Foreshore walkways. The project would provide new and improved north–south and east–west pedestrian and cyclist connections to replace these links.

The Crescent civil site (C6) would also impact pedestrian and cyclist connectivity to the Glebe Foreshore walkways for residents of Rozelle and Annandale. This reduced connectivity may deter people from participating in community activities or active transport, potentially reducing the connection to an environment and feeling of community cohesion.

While physical and psychological community severance would be increased during construction, these changes would result in only slight variation from existing conditions. Mitigation measures would be put in place during construction, including the transitioning of pedestrian and cyclist connections to alternative routes prior to the removal of the former. Impacts would generally be confined to suburbs around the project footprint, including the construction ancillary facilities and would extend for a medium-long term duration. The likelihood of effects on community cohesion is possible. As such, the overall impact upon the social and economic environment would be minor negative.

14.3.3 Amenity

Amenity refers to the pleasantness or attractiveness of a place or area. Changes to local amenity can affect the ability of a resident, a visitor or the community to enjoy or undertake activities within the local area. Construction of the project would temporarily change the amenity of the local area and affect community safety, health and wellbeing as well as community cohesion, particularly around or near construction ancillary facilities.

Local amenity would be impacted during construction by increased noise, vibration, dust, traffic movements and changes to visual amenity. Refer to **Chapter 10** (Noise and vibration), **Chapter 9** (Air quality), **Chapter 11** (Human health risk), **Chapter 8** (Traffic and transport) and **Chapter 13** (Urban design and visual amenity).

Some parts of the community would also experience construction fatigue associated with construction impacts from a variety of projects occurring over an extended period of time with few or no breaks between construction periods. Construction fatigue typically relates to traffic and access disruptions, noise and vibration, air quality and visual amenity and social and economic impacts from projects that have overlapping construction phases or are carried out back-to-back. Potential impacts associated with construction fatigue are assessed in **Chapter 26** (Cumulative impacts).

Overall, the impact of construction activities on the social and economic environment would be moderate negative. A summary of the streets that are likely to experience combined impacts of construction activity on a more regular basis is included in **Appendix P** (Technical working paper: Social and economic).

Noise and vibration

Construction would generate an exceedance of background noise levels at sensitive receivers surrounding all of the construction ancillary facilities, with the highest noise level exceedances predicted during pavement and infrastructure works. These works are generally of short-term duration (two weeks at each site) and intermittent, with some works required outside standard construction hours. The demolition of existing buildings, utility works, roadworks and use of laydown areas across the study area is also likely to generate noise exceedances and potentially disrupt night-time amenity. The following facilities are anticipated to experience noise exceedances:

- Kingdom Hall of Jehovah’s Witnesses at 12 Wattle Street, Haberfield
- The Infants Home at 17 Henry Street, Haberfield
- Yasmar training facility at 185 Parramatta Road, Haberfield
- Chaya’s Family Day Care at 12/111 Alt Street, Ashfield
- Nurjahan's Family Day Care at 12a/115 Alt Street, Ashfield
- Explore and Develop at 372 Norton Street, Lilyfield
- Billy Kids Learning at 64 Charles Street, Lilyfield
- Rosebud Cottage Child Care Centre at 5 Quirk Street, Rozelle
- Easton Park Playground at Lilyfield Road, Rozelle
- Rozelle Public School at 663 Darling Street, Rozelle.

Chapter 10 (Noise and vibration) identifies a number of management and mitigation measures to be implemented prior to or during construction that would reduce noise impacts on receivers as well as the number of potentially highly affected properties. These measures include increasing the height of site hoarding, upgrading acoustic shed performance, limiting the total sound power level of equipment operating within the acoustic sheds and providing respite periods to affected residents.

During the day, construction noise is expected to have a moderately negative impact on the social and economic environment, as there would be noticeable and substantial changes from the existing social and economic environment. The impact on night-time local amenity is anticipated to be major negative, with construction respite periods required. Ground-borne noise would also be generated from tunnelling, which would be progressive as the roadheader moves along the tunnel alignment (generally at a rate of about 20 to 25 metres per week), and from construction traffic, which is expected to have a negligible impact on local amenity as truck haulage routes are on arterial roads and not on local roads.

Where noise effects cannot be mitigated, there is potential for social and economic impacts including heightened annoyance, stress and sleep disturbance. These impacts would be particularly felt by people who work from home, shift workers, elderly residents or households with young children that are more dependent on quieter environments to rest and relax. As identified in **section 14.2**, health care and social assistance are among the top three industries of employment for residents in the study area. Given that the health care industry has a greater tendency to employ people under shift work arrangements, it is likely that there would be a higher number of shift workers in the study area who rely on a quieter environment to rest and recuperate.

Vibration impacts would be intermittent and short-term at any particular receiver. The severity of impact would be moderate resulting in a moderate change to the existing conditions. The likelihood and severity of impact would however dissipate the further the receiver is from the construction ancillary facility. With consideration of these factors, the overall impact on the social and economic environment would be minor negative.

Air quality

Construction activities such as demolition, earthworks and construction activities have the capacity to increase dust, air emissions and odour. This has the potential to affect local amenity due to the increase in dust in an environment.

Increased dust can adversely affect the function and operating costs of businesses. Nuisance dust generated from construction activities would commonly affect dwellings and sensitive premises that require a cleaner and/or sterilised environment (such as food manufacturers and processing manufacturers). Increased dust can also reduce the capacity of the community to enjoy the environment and can increase health risks for receivers, particularly those with respiratory and health issues such as asthma and allergies. The human health impacts of air quality are assessed in **section 14.4.3**.

Mitigation measures would be implemented to minimise the effects of construction dust on surrounding receivers, including minimising drop heights from machinery and using fine water sprays on dust generating equipment. These measures would be outlined in the Construction Air Quality Management Plan. Considering this, the residual impact of dust on local receivers is considered to be low (refer to **Chapter 9** (Air quality)).

Visual amenity

Construction of the project has the potential to affect visual amenity in the study area through activities including the removal of vegetation, installation of construction hoardings, installation of acoustic sheds, construction equipment and/or the presence of construction sites (including acoustic sheds, site offices and amenities). Additionally, view corridors to and from heritage items or areas, open space, water bodies or the city skyline may be affected by temporary construction facilities and permanent fixed facilities that are being constructed (refer to **Chapter 13** (Urban design and visual amenity)).

Visual impacts have the potential to affect the appeal of external and internal living spaces and reduce the overall amenity of an environment. Residential properties that have the amenity of their living and entertaining spaces reduced may be less inclined to entertain or interact with other household members as the appeal or privacy has declined. The removal of trees and the introduction of construction ancillary facilities could also reduce the privacy of some properties and reduce screening of construction activities.

Visual impacts on local amenity would be medium-long term in nature. The severity of impact on individual receivers would vary depending on the proximity from the construction ancillary facility. The severity of impact would be confined to locality level, while construction effects would result in a moderate change to existing conditions. The overall impact on the social economic environment would be moderate negative.

14.3.4 Social infrastructure

Changes in access and amenity for some social infrastructure facilities are anticipated during construction. Construction ancillary facilities and activities may affect the amenity of nearby social infrastructure, resulting in increased noise, dust and construction traffic, or changes in visual amenity (ie presence of construction machinery or clearing of vegetation).

Changes in amenity can affect how users interact with or enjoy an environment or their ability to participate and concentrate. Changes in access to social infrastructure can also affect the operation and function of social infrastructure facilities or services, reducing accessibility for operators, visitors and service providers. A reduction in the convenience of social infrastructure access may also deter users and potentially impact on community participation levels, which would have an indirect impact on community values. Social infrastructure users exposed to multiple construction activities may also be more susceptible to construction fatigue, which may have direct social and economic consequences.

Social infrastructure facilities that would be most indirectly affected during construction would include the receivers nearby construction ancillary facilities, including:

- Kingdom Hall of Jehovah’s Witnesses at 12 Wattle Street, Haberfield

- Timbrell Park at Henley Marine Drive, Five Dock
- The Infants Home at 17 Henry Street, Haberfield
- Yasmar training facility
- Chaya's Family Day Care at 12/111 Alt Street, Ashfield
- Nurjahan's Family Day Care at 12a/115 Alt Street Ashfield
- Haberfield Public School at 24-26 Denman Avenue, Haberfield
- Explore and Develop at 372 Norton Street, Lilyfield
- Billy Kids Learning at 64 Charles St, Lilyfield
- Rosebud Cottage Child Care Centre at 5 Quirk Street, Rozelle
- Easton Park at Lilyfield Road, Rozelle
- Glebe Foreshore Parks at Chapman Road, Glebe
- Rozelle Public School at 663 Darling St, Rozelle
- Rozelle Out of School Hour Care at 663 Darling St, Rozelle
- King George Park at Manning Street, Rozelle
- Bridge Road School at 127 Parramatta Road, Camperdown
- Sydney Park at St Peters.

Further detail on specific impacts at each of the receivers identified above is included in **Appendix P** (Technical working paper: Social and economic). During construction measures to manage the impacts on social infrastructure would be included in the Social Infrastructure Plan, including:

- Measures that will be delivered as part of the project to improve community connectivity in areas affected by the project, including pedestrian and cyclist access
- Community and social facilities, for example open space, that will be delivered or enhanced as part of the project
- Community initiatives and programs that will receive support as part of the project, including the manner in which support will be provided.

Considering this, the overall impact on the social and economic environment is likely to be a moderate negative.

14.3.5 Business and industry

Businesses across the study area may be affected during construction by temporary changes in passing trade, access and travel time (for employees, customers, deliveries and/or servicing), parking, serving and deliveries and amenity. Dependent on the nature of the business, the actual impact on business revenue would vary. These impacts would be an inconvenience for businesses affected although they would be temporary in nature. Potential impacts on specific individual businesses and commercial areas are included in **Appendix P** (Technical working paper: Social and economic).

Passing trade

Passing trade refers to customers who choose to visit a business because they see it when walking or driving, not because they planned to go there.

During construction, vehicle and pedestrian flows along current routes would change, which may influence the level of passing trade. Some businesses could benefit as passing trade is redirected towards their business, while others might be disadvantaged as traffic is diverted away or they are otherwise affected by indirect impacts (eg from noise, dust, reduces visibility, parking availability). The majority of business clusters outlined in **Table 14-10** that offer retail and convenience services would experience an increase in construction workers in the area, which may generate increased passing trade. This would be particularly beneficial for the smaller local business clusters such as Ramsay

Street Convenience, Lilyfield Neighbourhood, Norton Street North, Catherine Street Convenience, Victoria Road and Darling Street. Increased passing trade would generate increased business revenue, directly benefiting the social and economic environment. It is unlikely that any centre would experience a noticeable loss in passing trade due to construction.

Access and travel time

Businesses may be affected by temporary traffic changes, such as congestion or diversions, which may impact access to workplaces or servicing areas. The traffic and transport assessment identified that road network performance would be affected during construction, with a number of temporary road closures, increased construction traffic and an expected worsening of intersection performance at some intersections (refer to **Chapter 8** (Traffic and transport)). These changes would likely affect employee and customer travel time and the efficiency of services and deliveries.

A number of business clusters identified in **Table 14-10** would experience a potential decline in road network efficiency. Specialised retailers may experience a greater decline in their customer base, as clients seek to avoid traffic delays, travelling instead to more accessible business centres that offer similar products. Business clusters including Chapman Road, Annandale, Camperdown and Roberts Street may be more affected by these changes. Although employee travel time may slightly increase, there is adequate provision of public transport in most locations around the business clusters that offer alternative commuting options. Although there would be minimal direct access impacts, a reduction in the efficiency of the road network overall, may result in minor adverse effects on this business cluster.

Parking

The removal of parking or increased demand and competition for car parking would impact nearby businesses' deliveries and/or services and parking convenience for workers and customers. Reduced parking can influence customers to use an alternative service or visit a different business.

Changes to parking accessibility as a result of the project would occur around the Darley Road civil and tunnel site (C4), Rozelle civil and tunnel site (C5), Iron Cove Link civil site (C8) and Pyrmont Bridge Road tunnel site (C9). Business clusters identified in **Table 14-10** that may experience increased competition for car parking include Parramatta Road Haberfield, Canal Road, Lilyfield Road, James Craig Road, Victoria Road, Annandale Camperdown and Euston Road may. As the majority of these business clusters would have their own private parking, it is unlikely that a reduced supply in car parking would have a noticeable impact on employee or customer access.

Servicing and deliveries

Businesses rely on deliveries and dispatch of goods to support the sale of products and/or services, as well as relying on services from other businesses such as refuse collection. These activities may sometimes be required multiple times per day.

Temporary changes to the existing road network, including street closures, the relocation and/or removal of car parking and/or loading zones along street frontages, and the location of construction ancillary facilities could collectively restrict or reduce servicing, delivery and dispatch opportunities. This can detrimentally affect businesses resulting in time and vehicle related costs and lost revenue for businesses.

All of the business clusters identified in **Table 14-10** would be dependent on servicing, deliveries and dispatch as part of normal business operation. The construction of the project, is however, not anticipated to remove loading zones or parking that would affect the business clusters. Although the efficiency and condition of access routes may alter, such as for businesses along Lilyfield Road, James Craig Road and potentially Roberts Street it is unlikely that this would have a substantial impact on business revenue, overheads or productivity.

Amenity

Construction of the project would affect the amenity of an environment, including for people visiting or working at local businesses in the study area. This would be as a result of increased noise, vibration and dust, or reduced visual outlook and business visibility. Changes to amenity can affect business ambience, productivity, functionality and exposure.

Businesses that rely on the external ambient environment to some degree, such as beauty salons, restaurants or cafes, may experience a decline in customers due to negative customer experiences from reduced amenity. Customers could be encouraged to travel to more amenable locations that offer similar services. This change in consumer behaviour would directly affect business viability as trade and customer expenditure would reduce.

Increased dust during construction may result in increased operating costs (including cleaning and maintenance costs), reduced hygiene (associated with food preparation) or increased instances of respiratory issues for employees or customers.

The visual appeal of an environment can be important to businesses that rely on customer attraction to the pleasantness and quality of an environment, such as retail, personal service providers, cafes and restaurants. These businesses are more dependent on access to natural light and clear sightlines of the street to enhance the attraction of their business. This is particularly important for businesses that provide outdoor dining. Reduced visual amenity may result in a reduction in customer sales and repeat clients, affecting business revenue in both the short and long term.

Businesses that rely on storefront exposure to attract customers may be affected by reduced visibility from the presence of construction machinery and materials (such as construction hoardings). This has the potential to directly affect business revenue and turnover as customers do not see the business, or are less inclined to enter due to reduced amenity or safety concerns. A change in pedestrian or vehicle routes and traffic volumes can also affect the exposure of businesses to potential customers.

Business clusters that have higher dependency on amenity to attract and retain customers would be more susceptible to changes in amenity as a result of construction activity. The business cluster of Annandale-Camperdown is the only business cluster that is more sensitive to amenity impacts such as noise, vibration and dust, that has a heightened risk of being affected.

14.3.6 Access and connectivity

Road network

Construction impacts on the local and arterial road network have the capacity to influence the performance of the broader road network, both within the study area and within a wider area. Construction of the project would increase traffic congestion, commuter travel time, the accessibility of local areas and the efficiency of freight, commercial vehicle and public transport movements. Detailed impacts on the road network are outlined in **Chapter 8** (Traffic and transport).

These changes have the potential to increase peak spreading or result in modal shifts for commuters. Traffic delays can also affect freight and commercial vehicle transport efficiency, commuter travel times and general access and connectivity to surrounding areas or employment centres. Increased traffic congestion can also reduce the amenity of an environment, with idling vehicles generating noise and emissions in a particular area. This can have impacts on human health and business amenity. These increases in traffic volumes may also reduce roadside safety, particularly in areas of high pedestrian and cyclist traffic such as near schools, child care centres, aged care facilities and near public transport stops. This would particularly be the case at Alt Street at Ashfield due to the proximity of Haberfield Public School and the Parramatta Road East civil site (C3b) and along Parramatta Road due to the proximity of Bridge Road School to the Pyrmont Bridge Road tunnel site (C9).

Increased intersection delays and traffic congestion have the capacity to increase stress and anxiety for road users; reduce access to residences, social infrastructure and businesses; increase air and noise pollution; and increase the costs and reduce the efficiency of the freight network. Generally, intersections in the study area are unlikely to experience substantial increases in average delays, with construction having a negligible impact on the road network (refer to **Chapter 8** (Traffic and transport)).

In most instances, modifications to the road network would be temporary with local roads reinstated upon completion of construction. These local roads carry lower volumes of primarily local residential traffic. While properties along these roads may experience a marginal increase in travel time, the variance from what is currently experienced is unlikely to be substantial and would result in a minor negative impact on the social and economic environment.

Construction impacts on major road networks would increase traffic congestion, travel time, the accessibility of local areas and the efficiency of freight, commercial vehicles and public transport movements. Arterial road impacts are expected on City West Link, The Crescent, Victoria Road and Parramatta Road. Detailed traffic management plans would be required which would include measures to manage the additional volumes of heavy vehicles travelling along arterial roads.

To reduce traffic and amenity impacts on local roads, spoil haulage routes would operate on arterial roads including Parramatta Road, M4 East tunnels, City West Link, Pyrmont Bridge Road, Campbell Street and the Princes Highway. The implementation of the CTAMP would assist in reducing the impacts associated with changes and alterations to the road network. However, inefficiencies would still be experienced by road users. The construction impacts have the capacity to affect a large number of people and businesses both locally and regionally. Although the effects would be temporary, a noticeable and substantial change from the existing environment is anticipated. As such, the effect on the social and economic environment is a moderate negative.

Overall, construction impacts would occur for a medium-long duration and would potentially affect the efficiency of road networks across the broader region. This reflects a moderate change from the existing road network condition, with impacts having a high likelihood of occurring. The overall impact on access and connectivity with regard to the social and economic environment would be moderate negative.

Public transport

Temporary impacts on existing bus services would occur during construction (refer to **Chapter 8** (Traffic and transport)). Bus customers near construction ancillary facilities may experience a reduction in amenity while waiting for buses and increased travel times due to potential traffic congestion. The temporary or permanent relocation of bus stops would also potentially increase the distance bus patrons are required to walk. Impacts on bus services and the broader public transport network are likely to be minor and would be managed in consultation with bus service providers. Any changes to bus services would be undertaken in consultation with the bus service provider, with relevant information being communicated to bus users.

Heavy rail or light rail services would not be directly impacted during construction; however passenger access to stations (including the Leichhardt North light rail stop and Rozelle Bay light rail stop) may be temporarily affected by temporary traffic changes and congestion arising from the presence of construction works. Surrounding amenity would also be impacted. In both cases, access to light rail stops would be retained at all times, although some local diversions of pedestrian movements may be required.

Active transport

Changes to the existing pedestrian and cyclist network have the potential to affect commuter departure times, travel durations, movement patterns and accessibility. Activities that would impact the active transport network include the removal of the Victoria Road and City West Link pedestrian bridges, and the temporary closure of a section of the Victoria Road shared path on the southern side of the westbound carriageway.

During consultation, all of these connections were identified as important for commuter links or enabling public access to waterways. Subsequently, the loss of these connections would have an adverse effect on commuter connectivity, local amenity and community values. Proposed alterations to these links are outlined in **Chapter 8** (Traffic and transport).

Generally, these diversions do not result in significant changes from the existing pedestrian and cyclist network connections. There are two instances where the alternative active transport route would present new difficulties for users. This includes proposed diversions on the southern side of Victoria Road and the connection between Whites Creek and Rozelle Bay (via Johnston Street), which would extend the travel distance and require users to navigate more difficult terrain. This may present difficulties for cyclists or pedestrians with reduced mobility.

The introduction of temporary signalised crossings, delays due to construction vehicles turning in and out of construction sites, or extended travel routes may increase pedestrian wait times and increase journey to work times for active transport commuters. While the opportunity to walk or cycle in the study area would be maintained, the alterations and changes may detract from the experience of the pedestrian and cyclist environment and potentially deter people from enjoying an active lifestyle or feeling connected with their community. Depending on the length and terrain of alternative routes, people may be more inclined to take a shorter, less safe option, than detouring along a recommended detour route. At the extreme, this may increase the chance of pedestrian and cyclists conflicts with vehicles or may encourage people to break road rules.

Around eight per cent of the population in the study area walk to work, while around three per cent cycle. Temporary changes to commuter oriented networks would therefore only impact a small proportion of the population. Some of these changes, however, would affect popular recreational pedestrian and cyclist paths at Rozelle and Glebe that are heavily used by both locals and visitors. Generally, the alternatives proposed for these recreational paths do not noticeably increase the difficulty or distance of these routes.

To reduce the impact on pedestrian and cyclist connections, a strategy for the maintenance of pedestrian and cyclist access during construction, and information regarding alternative travel routes, would be prepared during detailed design. Measures would form part of the CTAMP and would include:

- Specifications around the standards of pedestrian and cyclist environments (around construction sites and on alternative routes)
- Provisions that ensure the maintenance of access for all levels of mobility
- Information regarding alternative travel routes including the difficulty of terrain, the additional distances and the duration of time detours would be in place
- Construction signage clearly identifying the detour route and locations for alternative crossings.

Any changes to pedestrian and cyclist routes would ensure safety and maintenance of access for all levels of mobility, while minimising detour distances. During construction, all efforts would be made to minimise disruption to pedestrian and cyclists and to maintain network legibility by transferring from the existing infrastructure to the new infrastructure as soon as possible.

Parking

During construction, around 20 on-street parking spaces would be lost from the northern carriageway of Darley Road between Francis Street and Charles Street in Leichhardt. The removal of these parking spaces would reduce the availability of on-street parking for light rail commuters and would increase demand for parking on other nearby streets. Should construction workers also utilise on-street parking, the demand for parking in this area would increase further. Local residents would then be competing with both regular commuters and the construction workers for parking. A similar scenario may occur at the Rozelle Bay light rail stop, which is in close proximity to The Crescent civil site.

Residential streets, in close proximity to construction ancillary facilities which are not constrained by parking time limits, would likely experience an increase in construction worker parking. Elderly people, those with a disability or families with young children, who may have difficulty walking greater distances, would be particularly affected if they are required to park further away.

A detailed car parking strategy would form part of the CTAMP and would be developed in consultation with local councils and affected stakeholders adjacent to project sites. The above mentioned plan would reduce the extent of the impact on the socio-economic environment.

14.3.7 Economy

Expenditure and employment

Construction activity can benefit the economy by injecting economic stimulus benefits into the local, regional and state economies. The economic benefits of construction include:

- Increased expenditure at local and regional businesses through purchases by construction workers
- Direct employment through on-site construction activities

- Direct expenditure associated with on-site construction activities
- Indirect employment and expenditure through the provision of goods and services required for construction.

The number of direct and indirect jobs generated as a result of the proposed five-year construction period has been estimated based on the following assumptions:

- A base year of 2018 for the start of construction
- A five-year construction period (from 2018 to 2023)
- The project opening to traffic in 2023 (noting that the mainline tunnels would be operational and open to the public by 2022).

Direct jobs are defined as those relating to the project's development throughout construction, commissioning, operation and management of the facility and would include on-site labour, supervision, professional services and project managers. Indirect jobs are defined as jobs that support the project through the provision of goods and services such as off-site manufacturing and equipment hire (within Australia).

Based on a five-year construction period, 14,378 direct job years would be created from 2018 to 2023, which is equivalent to 2,876 jobs a year. Furthermore, around 42,351 indirect (off-site) job years would be generated, equivalent to 8,470 jobs a year based on the project period. Construction of the project would significantly increase the employment opportunities across the study area, and is considered to have a major positive impact on the social and economic environment.

As a commitment of the project, the WestConnex Training Academy has been established. As outlined in the WestConnex Sustainability Strategy, the WestConnex program of works aims to deliver 500 apprenticeships/traineeships during the life of the WestConnex project. A portion of this number would be trained on the M4-M5 Link project. In addition to offering new opportunities for employment, the WestConnex Training Academy is providing training in tunnelling to people who have transferrable skills from other industries, like the natural resources sector. This would allow people with experience from other sectors, like mining and heavy industry, to join the workforce. The WestConnex Sustainability Strategy also incorporates initiatives to improve Aboriginal and Torres Strait Islander participation in construction and provides opportunities to Aboriginal and Torres Strait Islander enterprises.

Construction of the project would significantly increase the employment opportunities across the study area. Construction would create medium-long to long term job opportunities and economic benefit to the region. There is a high likelihood of these benefits occurring with potential significant consequence on the social and economic environment. As such, the overall impact upon the social and economic environment would be major positive.

Value add

The construction industry contributes around 7.7 per cent of total gross domestic product (GDP) to the Australian economy. In calculating the flow-on economic benefits of a project, it is common to employ economic multipliers. Multipliers refer to the level of additional economic activity generated by a source industry. There are two types of multipliers:

- Production induced, comprising:
  - First round effects (all outputs and employment required to produce the inputs for construction)
  - Industrial support effect (induced extra output and employment from all industries to support the production of the first round effect)
- Consumption induced, which relates to the demand for additional goods and services due to increased spending of wages and/or salaries across all industries.

Consumption induced effects comprise the increase in output required to satisfy the additional demand generated by the increased wages and salaries resulting from all increased output (ie direct and indirect employment).

The estimated construction costs of the project, ABS multipliers and industry knowledge have been analysed to determine that construction of the project would generate a further $5.8 billion of activity in production induced effects and $7.7 billion in consumption induced effects. Total economic activity generated by the construction of the project would be around $19.7 billion. Further detail is included in **Appendix P** (Technical working paper: Social and economic).

Overall, construction of the project would produce a long-term economic benefit to the region. There is a high likelihood of these benefits occurring with potential moderate consequence on the social and economic environment. As such, the overall impact on the social and economic environment would be moderate positive.

14.3.8 Utilities

Communities and businesses are dependent on public utilities, particularly the supply of electricity and water, for the operation of electronics, industrial production and daily activities such as showering, drinking water and cooking. The disruption of these services for short periods of time may cause some inconvenience to daily life and business operation, consequently affecting economic productivity and the routines of individuals.

During construction, public utilities and services may be disrupted while they are temporarily or permanently relocated, or for safety reasons. Disruptions for safety reasons could arise when construction activities involve relocating power lines or operating machinery close to power lines. Such disruptions may result in an economic loss for a business and could affect business viability if disruptions continue for extended periods. This may also affect employees who may experience an economic loss if employment is temporarily placed at risk. Residents would also feel these disruptions as they create inconvenience, require a change in routine and have the capacity to reduce the productivity of individuals and increase household costs.

A Utilities Management Strategy has been prepared for the project (refer to **Appendix F** (Utilities Management Strategy)). In accordance with the strategy, existing utility services would be avoided or protected wherever possible. Utility relocations and adjustments would still be required both inside and outside the project footprint. In most instances, impacts on utilities would be temporary, and would be effectively managed by the measures outlined in **Appendix F** (Utilities Management Strategy). When disruptions to the local community are required, the local community who may be affected would be given prior notification of the works, at least five days prior to the works commencing.

Extended utility outages are unlikely; however short-term outages to facilitate utility works are likely. The consequence on the social and economic environment would generally be limited to a locality or suburb, be short term and have only a slight effect on the existing condition. The overall impact on the social and economic environment from planned utility outages would be a minor negative.

14.3.9 Property acquisition

The nature of direct property impacts, including details of property acquisitions, temporary occupation of land and settlement and subsidence impacts are detailed in **Chapter 12** (Land use and property). This section identifies the socio-economic consequence of these direct property acquisitions on residential properties, businesses and social infrastructure.

Residential

The project has been designed to be a predominantly sub-surface motorway. To facilitate surface works for the project, the acquisition of residential properties is required.

Acquisition and subsequent relocation of households and businesses due to property acquisition can disrupt social networks and affect health and wellbeing due to raised levels of stress and anxiety. Purchasing and moving houses can be one of the most significant events in a person’s life. Similarly, finding appropriate rental property within restricted timeframes can also be stressful for households who rent. The duration of this process can potentially be extended due to the high demand for rental housing in inner western Sydney.

Both a house and a workplace/study location are central to most people’s daily routine, with the location of these influencing their travel patterns, and social, community and commercial interactions.

When an individual is required to relocate, their daily routine would be affected with new routines and social interactions generally taking a while to re-establish. This feeling of disconnect may not be isolated to people moving away from a location. Those people left behind, if they had strong social connections to the person leaving, may also be affected by the change.

The property acquisition process and the subsequent need to relocate can also elevate health risks, causing stress and anxiety. This can particularly affect vulnerable households, such as the elderly, those suffering illness or a disability, or those that speak English as a second language.

Uncertainty around the acquisition process can also heighten stress and anxiety across the broader community. Speculative media coverage or misinterpretation of project information can cause some members of the community to unnecessarily worry about their property being acquired. This speculation and uncertainty can also influence a person's economic decision to purchase or sell in an area due to perceived changes in the local property market.

Property acquisition presents the potential for major adverse social and economic impacts upon individuals and households. These impacts may be reduced and/or managed through the application of a process of consultation and compensation that is designed to be equitable to existing property owners. As the process may be emotionally and physically taxing and requires a permanent change, the overall social and economic impact upon affected individuals is expected to be major.

Impacts associated with property acquisition are being managed through a property acquisition support service that provides the following:

- Affected households would have access to a counselling service that assist people through the property acquisition process and, where necessary, providing referrals to more specialised experts
- A property acquisition factsheet that outlines the process and provides further information for concerned residents is to be prepared and made available online and in hard copy at project information centres
- An independent service is to be provided to vulnerable households (eg elderly, those suffering an illness) to assist with relocation. Assistance could include, finding a suitable house for relocation (purchase or rent), arranging removalists, disconnecting services and attending appointments with solicitors or other representatives
- A community relations support toll-free telephone line is to be established to respond to any community concerns or requests for translation services.

All acquisition required for the project is being undertaken in accordance with the *Land Acquisition (Just Terms Compensation) Act 1991* (NSW), the *Land Acquisition Information Guide* (NSW Government 2014) and the land acquisition reforms announced by the NSW Government in 2016 (2016 reform).

The 2016 reform was triggered by a review of the existing acquisition process, which demonstrated that although the legislative framework for land acquisitions was sound, there was more work to be done to ensure that a stressful and complex situation is made as easy as possible. The reformed position on land acquisitions strikes a more effective balance between the property rights of landowners and the public good derived from essential public infrastructure. Additional information about the 2016 reform, including changes that were introduced, is included in **Appendix P** (Technical working paper: Social and economic).

The reformed acquisition process has been and would continue to be implemented as part of the project. The impact of residential property acquisition will be managed by the implementation of a detailed consultation and advice process, as per the 2016 reform. The impact of residential property acquisition is expected to be moderate negative.

Businesses

As well as residential property acquisitions, the project would also require the acquisition of business premises in the study area. These businesses comprise commercial and industrial properties and likely serve a local to district trade. Impacts of acquisition and the associated relocation of businesses can result in:

- Disruptions to business operation
- Loss of revenue
- Relocation and re-establishment costs
- Employee training expenses for new employees
- Trade catchment alterations
- Business closure.

Businesses required to close or relocate due to the project are mostly light industrial or specialty services, all likely to service a district trade area and employ a small number of workers. It is therefore likely that these businesses would need to relocate to another trade catchment, resulting in noticeable relocation and establishment costs with a loss in trade and business revenue during this period.

The relocation and subsequent loss of local businesses due to property acquisition would also disrupt the character of business areas and affect the productivity of the local economy. The impact on the character of these areas may be temporary, where the opportunity exists for businesses be return and re-establish in the same location following construction. This would most likely be seen around the Darley Road civil and tunnel site (C4), Pyrmont Bridge Road tunnel site (C9) and along Parramatta Road, which would retain opportunity for the land to be redeveloped post construction, consistent with the current land zoning.

Communities can develop strong ties to a business and its employees, particularly local businesses. Changes to these businesses can cause disruptions to routine, social networks and economic productivity.

The area where a business relocates to may also have different locational attributes, such as reduced passing trade or business visibility, which could result in a loss of revenue or the requirement to relocate again to maintain viability.

Although the acquisition process is likely to be a noticeable change for individual businesses directly affected by the project, the compensation process should help to alleviate the severity of impact on individual business interests. In regards to the broader social and economic environment, the business closures are anticipated have a slight effect on the existing condition, with the economy expected to normalise and business expected to be re-established in a short-medium term. The spatial extent of impact would generally be confined to a suburb level. The likelihood of these changes occurring is near certain. Considering this, the overall impact of construction activities on the social and economic environment is moderate negative.

Social infrastructure

Direct impacts on the following social infrastructure facilities would occur during construction:

- Loss of Buruwan Park to facilitate the new alignment of The Crescent. Buruwan Park is a passive open space area that is predominantly used by pedestrians and cyclists using the active transport link through to Rozelle Bay. The park currently has poor surveillance with evidence of anti-social behaviour in the form of graffiti on the walls. The park has no formalised outdoor furniture and has limited grass area. Due to other parks being in close proximity (such as Easton Park, Jubilee Park, Bicentennial Park) and the creation of the new open space at the Rozelle Rail Yards (upon completion of construction), the loss of this park would have minimal impact
- King George Park:
  - Loss of a small portion of the park adjacent to Byrnes Street to facilitate the Iron Cove Link portals
  - Loss of part of the informal area of the car park at Manning Street (within King George Park) to formalise the car park and provide a bioretention facility. The park is heavily utilised by local residents and visitors from the broader area due to its high amenity value and park facilities. The park also contains a section of the Bay Run, which is a highly valued pedestrian and cyclist connection. The Bay Run would be temporarily diverted; however access would be maintained during construction.

14.4 Assessment of potential operational impacts

The operation of the project has the potential to positively and negatively affect residents, businesses, road users, users of social infrastructure and the wider community in the study area. An assessment of potential social and economic impacts within the study area during operation of the project is provided in this section. Further information is provided in **Appendix P** (Technical working paper: Social and economic).

14.4.1 Demographic profile

Given the number of residential property acquisitions required, this impact is not expected to affect the population and demography of the study area or precinct. The study area is projected to experience significant population growth over the next 20 years as a result of urban renewal programs.

14.4.2 Community values

Community safety, health and wellbeing

Residents living on Clubb Street at Rozelle would have their access affected by the closure of the intersection with Victoria Road, turning Clubb Street into a cul-de-sac. Although direct access from Victoria Road would be reduced, community safety is likely to increase as vehicles would no longer be able to turn left into and out of Clubb Street.

In total, the project would result in the loss of around 26 unrestricted on-street parking spaces from Byrnes Street, Clubb Street, Toelle Street and Callan Street at Rozelle. Loss of parking availability can affect residents, social infrastructure providers and businesses in terms of daily routines, level of activity, passing trade or business operations. Reduced street parking can also deter visitors from accessing a business or community facility due to an increase in travel time and lack of convenience, and can impair convenience and accessibility for residents accessing their properties and visitors accessing properties. This impact would potentially impact businesses along the southern side of Victoria Road.

The removal of these parking spaces at Rozelle is considered to result in a small, but measureable, change to the existing conditions, affecting a small number of local residents. This would have minor social and economic impacts.

Community cohesion

Elements of the project that could affect community severance include local road closures (Clubb Street at Rozelle), the widening of Victoria Road near the eastern side of Iron Cove Bridge, increased accessibility to active and public transport routes, and changes to existing traffic volumes on arterial roads. Community severance can lead to short or long term changes to people's behaviour patterns, affecting established community networks and an area's character and sense of place.

The project would deliver new and enhanced areas of open space at the Rozelle Rail Yards, the Glebe Foreshore and a network of active transport connections, which has the potential to increase social connectivity and community cohesion by providing increased opportunities for the community to meet and interact.

The Rozelle Rail Yards currently act as a significant physical barrier between the communities of Annandale, Rozelle and Lilyfield. The project would transform this area providing a net increase in public open space with a network of active transport links, which would improve community cohesion and better connect the communities of Annandale, Rozelle and Lilyfield and improve connections between Bicentennial Park, the Rozelle Rail Yards and beyond to Easton Park.

The widening of Victoria Road at the eastern abutment of Iron Cove Bridge has the ability to exacerbate the existing barrier effect between the communities of Rozelle and Balmain already created by Victoria Road. The improved pedestrian and cyclist accessibility between Toelle Street and Terry Streets would assist in alleviating this impact. The siting of Iron Cove Link portals would also reduce this impact, allowing a direct link between these streets that would provide a pedestrian crossing over the two northbound lanes before another signalised crossing over the two southbound lanes of Victoria Road. The closure of Clubb Street is unlikely to cause community severance, given the other through roads in the immediate surrounding area (Toelle Street and Callan Street).

It is expected that around 2,000 heavy vehicles would be removed from Parramatta Road and reduced traffic is anticipated on sections of major arterial roads, including City West Link, Parramatta Road, Victoria Road, King Street, the Princes Highway, Southern Cross Drive and Sydenham Road (refer to **Chapter 8** (Traffic and transport)). This forecast in the reduction in traffic may lead to increased use of these streets for residents, visitors and businesses.

The operation of the project is expected to increase community cohesion and for a large number of local residents and businesses across the study area and therefore has a moderate positive impact on the social and economic environment.

14.4.3 Amenity

The project would improve general amenity within the study area by reducing the volume of traffic on surface roads, which would be displaced into the mainline tunnels. This would subsequently reduce current levels of noise and vibration, air pollution from vehicle emissions, traffic movements and congestion. In addition, the project provides opportunities for:

- Creation of open space at Rozelle Rail Yards and Iron Cove for community and recreational use
- New and improved active transport links, connecting currently disconnected communities and improving community cohesion
- Potential future urban revitalisation along existing arterial roads, particularly along Victoria Road at Rozelle and Parramatta Road east of Haberfield.

Noise and vibration

During operation, traffic related noise in the study area is generally expected to decrease as a result of traffic being displaced from surface roads into the mainline tunnels. This would have a moderate positive impact, resulting in a noticeable and substantial positive change in the existing environment. This impact would be long-term and would affect a large number of people.

Significant reductions in noise are identified along sections of Victoria Road at Rozelle where the project is forecast to significantly reduce traffic numbers. As this area is generally occupied by businesses, positive effects are likely to include increased amenity and ambiance which could increase the number of visitors and passing trade. This is considered a moderate positive impact, resulting in a noticeable and substantial positive change in the existing environment, and has the potential to affect a large number of people working, visiting and living in these locations.

Increases in noise are identified in areas of the study area such parts of Johnston Street where traffic volumes are expected to increase, and in Iron Cove to the south of Victoria Road (Byrne Street, Clubb Street, Toelle Street, Callan Street and Springside Street) where noise shielding from the front row of buildings would be removed due to property acquisitions and subsequent demolition.

Residents would be more susceptible to health impacts associated with increased noise, such as general annoyance (eg having to keep windows closed), sleep disturbance and interference with household activities (eg eating outdoors). This is considered a moderate negative impact on the social and economic environment for residents who are currently shielded from traffic noise.

Open space areas are also particularly sensitive to changes in noise levels. King George Park is predicted to experience a noticeable increase in noise levels, particularly the eastern end closest to Victoria Road. Although the existing background noise levels are high and dominated by existing road traffic noise, the increased noise levels may affect a person’s desire use the park in the future. People would be less likely to gather for picnics and other outdoor activities if it is believed to be less healthy and unattractive where there may be interference with normal speech levels.

To minimise the impact of elevated noise levels in the study area, management measures would be implemented, such as low noise pavement and noise barriers. In addition, at-property acoustic treatment would be considered where noise exceedances are still predicted (refer to **Chapter 10** (Noise and vibration).

No vibration impacts are expected during operation of the project (refer to **Chapter 10** (Noise and vibration)).

Air quality

The project is expected to result in an overall reduction in total pollutant levels in the community and a redistribution of emissions to the tunnels as there would be less vehicles using surface roads. For much of the community this would result in no change or a small improvement to existing conditions, resulting in a negligible impact. Changes in air quality related health incidents would be too small to measure and therefore the impact on their occurrence is expected to be negligible.

Changes to air quality both inside and outside the tunnels would also have an unobservable impact on human health or local amenity. Therefore, air quality impacts associated with the operation of the project are considered negligible (refer to **Chapter 11** (Human health risk)).

Planning controls would need to be developed in the vicinity of St Peters to ensure future developments at heights of 10 metres or higher are not adversely impacted by emissions from the ventilation outlets. Development of planning controls would need to be supported by detailed modelling addressing relevant pollutants and averaging periods (refer to **Chapter 9** (Air quality)).

Visual amenity

The operation of the project would result in changes to local visual amenity due to the presence of new and enhanced infrastructure, landscaping and urban design features.

The suburbs of Lilyfield and Rozelle would experience the most noticeable change in visual amenity from the transformation of the Rozelle Rail Yards. During operation, permanent infrastructure would be located in the Rozelle Rail Yards, including ventilation and water treatment facilities, comprising three, thirty-five metre ventilation outlets. This area would be landscaped and rehabilitated in to be consistent with the Urban Design and Landscape Plan (UDLP), however the visual character of the immediate area would change. Within The Bays Precinct, there are number of existing prominent buildings and structures including the White Bay Power Station, the large grain silos which are located on the northern side of Anzac Bridge and Anzac Bridge itself. Over the next 20 or so years, the area surrounding the Rozelle Rail Yards is expected to change as The Bays Precinct is subject to urban renewal which would result in changes to the urban landscape. This would affect local residents in the suburbs of Rozelle and Lilyfield and therefore would have a moderate negative impact on the social and economic environment.

Design options have been considered to minimise the visual impacts of prominent infrastructure. A landscape and visual impact mitigation strategy would be developed for the project to avoid, reduce and manage identified potential landscape and visual impacts during operation. This would include:

- Street tree planting for screening, shade and canopy
- High quality finishes to buildings and ventilation facilities to facilitate long term durability and minimal maintenance
- Improvement of active transport links to reduce reliance on local roads for short journeys.

In addition, the project would deliver open space, providing opportunities for recreational and community land uses. The open space at the Rozelle Rail Yards would include active transport links that would connect the communities of Annandale and Lilyfield and improve community cohesion by delivering an area where communities can come together and enjoy community space. While the project would introduce new infrastructure elements that would reduce amenity, the overall change in land use at Rozelle Rail Yards is considered to have an overall positive impact on amenity at Rozelle.

14.4.4 Business and industry

Access and parking

Overall, the road, active transport and public transport network would improve during operation of the project. Increased accessibility and connectivity has the potential to reduce delivery time, increase delivery reliability and reduce transport costs.

The largest reduction in traffic is expected along Victoria Road, which would potentially benefit businesses along Victoria Road and Darling Street through general improved amenity and improved delivery and dispatch movements. The reduction in traffic may activate the commercial areas by allowing more passing trade and foot traffic, however may reduce passing trade. There are no permanent impacts on on-street parking near business and commercial areas proposed as part of the project.

Amenity

Changes to amenity can affect businesses that are heavily dependent on passing trade. Reduced amenity may also result in customers travelling to competing business centres for goods and services. This change in consumer behaviour can have a long-term impact on business and local economic viability.

Traffic volumes on local surface roads in the study area are projected to reduce. This reduction potentially improves environmental amenity by reducing congestion, noise and air pollution. This may increase pedestrian and cyclist activity in the area, which may lead to an increase in trade and business revenue. This would be particularly true for the commercial areas along Parramatta Road, Victoria Road and Darling Street.

As a result, the project is expected to have a positive impact on existing business amenity, which would lead to a moderate positive impact on the broader social and economic environment. Potential impacts on specific individual businesses and commercial areas are included in **Appendix P** (Technical working paper: Social and economic).

14.4.5 Access and connectivity

Permanent changes to the existing road, public transport and active transport networks could potentially impact access and connectivity for residents, business owners and visitors. This section assesses the potential access and connectivity impacts during operation of the project.

Road network

Road intersection and network performance is forecast to improve across the overall road network, largely due to the redirection of vehicles from surface roads into the mainline tunnels. This would have a positive effect for those travelling to or from western Sydney, with significant improvements predicted at the Wattle Street interchange in both the AM and PM peak periods. This would have a major positive social and economic impact, reducing travel times for a large number of people living or working in western Sydney.

Reduced network performance is forecast at the Rozelle interchange in both the AM and PM peak periods, and at the St Peters interchange in the PM peak period. This would have an adverse impact on residents living in the inner west, increasing travel times and cost.

Overall, the project is forecast to improve travel times, reduce congestion, reduce travel costs and reduce traffic related mental and physical health benefits. The improvements to the network are considered a major positive benefit to the social and economic environment. Changes to local roads are unlikely to affect the broader road network. However, these changes would directly affect accessibility for local residents, businesses and visitors.

Public transport

Improvements to public transport would contribute to a number of direct and indirect social and health benefits such as reduced stress and accessibility. As people often choose to shop, visit and spend their time at the most convenient and accessible locations, changes to public transport travel time may benefit businesses and social infrastructure within the study area.

Both travel time savings and delays across the public transport network are considered minor and are unlikely to deter a person from using public transport, or to have any significant impact on a person’s quality of life. Therefore, the changes to the public transport network are considered to have a negligible impact on the social and economic environment. Details of changes to public transport as a result of the project are outlined in **Chapter 8** (Traffic and transport).

Active transport

Social and economic benefits from active transport networks include enhanced connectivity, increased opportunities for social interaction and community cohesion, reduced car dependency, reduced cost of travel and the promotion of more active lifestyles, resulting in community health benefits.

The project would improve connectivity and safety and contribute to the active transport network. Cyclist and pedestrian paths delivered by the project would create safe links that have reasonable grades and are separated from vehicular traffic. Two key pedestrian bridges would be replaced at Victoria Road and City West Link, maintaining existing active transport access at Rozelle.

The project would also address poor active transport connectivity in the study area, including along Victoria Road and the Rozelle Rail Yards at Rozelle. **Table 14-11** identifies the active transport infrastructure that would be delivered as part of the project. The project would contribute 3,800 metres to the existing active transport network in the study area. This enhancement is considered a major positive impact, as it would result in a noticeable, long-term change to the social and economic environment, benefiting a large number of people.

Table 14-11 Active transport being delivered as part of the project

Route	Feature	Approx. length	Benefits
Rozelle Rail Yards Link Links the Bay Run, The Bays Precinct and the Greenway in the west to Anzac Bridge and Sydney CBD in the east	Underpass	150 m	• Provides the junction connecting Rozelle Rail Yards and Victoria Road to The Bays Precinct • Provides north–south connectivity between Glebe and Annandale with Rozelle and Balmain • Provides a connection from the inner west to The Bays Precinct via the Rozelle Rail Yards • Removes the need for an at-grade crossing at City West Link • Connects to the Rozelle Bay light rail stop
	Shared path	1 km	• Provides the link between Victoria Road and Lilyfield Road across the Rozelle Rail Yards
Victoria Road - Iron Cove Link Links the northern suburbs of Drummoyne, Russell Lea and Chiswick to The Bays Precinct and the Sydney CBD	Separated cycleway	250 m	• Provides a separated cycleway and footpath on the western side of Victoria Road along the extent of the M4-M5 Link works • Connects the eastern side of the Rozelle Rail Yards along Victoria Road to the intersection of Robert Street • Connects the existing retail centres on Darling Street and Victoria Road, as well as social infrastructure and active and passive recreation facilities
	Separated cycleway	450 m	• Links the intersection of Springside Street to Iron Cove Bridge and the Bay Run

Route	Feature	Approx. length	Benefits
	Bridge	200 m	• Connects Victoria Road to The Crescent over Rozelle Rail Yards • Connects to Rozelle Bay light rail stop • Removes the conflict between pedestrians and cyclists with traffic on City West Link • Removes the need for an at-grade crossing at City West Link and increases pedestrian safety • Provides north–south connectivity between Glebe and Annandale with Rozelle and Balmain
	Shared path	400 m	• Connects Victoria Road to the Crescent
	Shared path	500 m	• Connects The Crescent to the James Craig Road existing active transport network
Whites Creek Link Links Parramatta Road to the Rozelle Rail Yards and Callan Park	Bridge	200 m	• Links the intersection of Brenan Street and Railway Parade with City West Link and Rozelle Rail Yards • Links residential communities in Annandale and Lilyfield • Addresses connectivity from Whites Creek to the Rozelle Rail Yards, crossing the light rail line and City West Link
Johnstons Creek Valley Link Extends the existing Johnstons Creek pathway to connect Glebe Foreshore to Parramatta Road	Bridge and shared path	300 m	• Connects Easton Park to The Crescent through the Rozelle Rail Yards • Addresses connectivity from Johnstons Creek to Rozelle Rail Yards • Links Glebe Foreshore and parklands to the Rozelle Rail Yards and Parramatta Road and The Bays Precinct
	Shared path	500 m	• Provides a suitable cycling space for the connection along The Crescent into Jubilee Park and linking to the existing Glebe Foreshore • Provides connectivity and links to an existing and proposed off-road active transport network

14.4.6 Economy

Freight and efficiency costs

The freight industry is an important part of the NSW economy as an enabler of economic activity, contributing an estimated $58 billion to NSW State Gross Product (SGP) in 2011 (Transport for NSW 2011). An objective of the M4-M5 Link project is to encourage heavy and commercial vehicle movements into the tunnel, increasing efficiencies and reducing freight costs through increased travel speeds and reliability and reduced travel distances.

Commercial vehicle movements are generally oriented around the major commercial/industrial centres of Port Botany and Sydney Airport. **Appendix H** (Technical working paper: Traffic and transport) determined that the project would result in substantial potential benefits for freight and commercial vehicle movements. Improvements in the efficiency and reliability of these transport networks would likely result in increased productivity, reduced costs and broader economic benefits for these workforces.

Reductions in freight or heavy vehicle traffic movements along surface roads in the study area, particularly Parramatta Road, City West Link, Victoria Road, King Georges Road and the existing M5 East Motorway, have the potential to improve the amenity of the environment, which in turn benefits residential communities, visitors and businesses.

Employment connectivity

Over 25 per cent of all Sydney jobs are located in the Global Economic Corridor, which extends from Norwest Business Park in the north through to the Sydney CBD and on to Port Botany and Sydney Airport in the south (A Plan for Growing Sydney 2014). Western Sydney is expected to deliver strong job growth over the next 20 years, however employment in the eastern part of Sydney would also continue to grow. This means that people from western Sydney would continue to travel eastwards for employment opportunities. WestConnex would improve existing transport connections to the Global Economic Corridor and the eastern part of Sydney, as well as facilitating the growth of Parramatta. It is estimated that using WestConnex, motorists would save around 40 minutes on a typical journey from Parramatta to Sydney Airport (WestConnex Updated Strategic Business Case 2015). In addition, the reduction of traffic on surface roads would improve the road network and allow for enhanced public transport services, including buses.

For commuters, the project would lead to a more reliable road network, reducing commuting time and lowering vehicle operating costs. For the residents of western Sydney, in particular, this would result in a major positive impact on the social and economic environment.

Road tolling

The M4-M5 Link (excluding the Iron Cove Link) would be tolled. The direct impacts of a tolling system include the management of congestion, which has an impact on economic productivity, and social elements such as stress, time with family and friends, cost and environmental amenity.

The use of a toll road may increase the cost of living for individuals and can exacerbate social inequality. Generally, higher income earners are more capable of absorbing the cost of tolls than lower income households, whereas lower income households are more likely to travel longer distances and avoid tolls due to affordability constraints (Mokonyama 2012).

ABS 2011 Census data on taxable personal incomes highlight that areas of western Sydney, including Bankstown, Blacktown, Parramatta, Fairfield and Liverpool, are in the lowest 20 per cent of Sydney’s income receivers (Phillip O’Neill 2013). This may mean that despite the introduction of the tolled section of the M4-M5 Link, a proportion of the Greater Sydney population may not be able to afford to benefit from the increased efficiency and travel times that the project could offer. However, given the benefits of the project for users it is likely that there would be minimal economic variance between using a toll free road versus using a tolled road. This would result in improvements to the existing conditions resulting in a minor positive impact on the social and economic environment.

An impact of implementing a tolled road is the potential for increased congestion on surrounding roads as a consequence of motorists changing travel patterns to avoid being charged by the new toll. Once the project is operational, there would likely be a period during which drivers would trial both existing, toll-free routes and the new, tolled M4-M5 Link, before deciding on a regular route. Congestion in peak periods on the existing, toll-free surface roads may provide an incentive to use the new, tolled road.

This would result in improvements to the existing situation, resulting in a moderate positive impact on the social and economic environment.

14.4.7 Future land use

Land required for the construction of the project that is not required for permanent operational infrastructure, and that would not be subject to the UDLP has been termed remaining project land. This land would consist of:

- Land that would be retained by Roads and Maritime for future (separate) road infrastructure projects
- Land that would be considered for separate future development (residual land).

The potential future use of this land would be identified in the Residual Land Management Plan (RLMP) that would be prepared for the project. A summary of the potential future uses of land required for construction and not required for permanent operational infrastructure is included in **Chapter 12** (Land use and property). These areas would be confirmed following detailed design. A description of how remaining project land would be managed following the project is provided in **Table 14-12**.

In considering the potential future use of remaining project land, regard would be given to identifying opportunities to deliver outcomes that support and connect existing neighbourhoods, complement and stimulate local economies, and provide opportunities for growth across existing and future local industries. The project would not rezone or consolidate remaining project land and therefore there would be no changes to land use zoning for future development, including around the Rozelle Rail Yards.

Table 14-12 Future land use following the project

Location	Feature
Wattle Street interchange surface works	The land remaining at Wattle Street at Haberfield would be rehabilitated and landscaped to be consistent with the RLMP and the UDLP for the M4 East project. The current use as construction sites would be consistent with the future use as transport infrastructure and as such would have negligible impact on future land use. This would result in a neutral impact on the social and economic environment.
Parramatta Road West and East civil and tunnel sites	These construction ancillary facilities would change the land use from commercial to construction infrastructure during construction. Following construction, these sites would be rehabilitated to be consistent the UDLP developed for the project. In determining the future use of this site, consideration would be given to the Parramatta Road Urban Transformation Strategy (UrbanGrowth NSW 2016). Future potential use of the site would be outlined in the RLMP developed for the project.
Darley Road surface works	The project would change the existing land use at the site as it would comprise permanent operational infrastructure (Darley Road motorway operations complex (MOC1)). However this site is adjacent to existing transport infrastructure for the Inner West Light Rail line and the Leichhardt North light rail stop and as such, this change would be consistent with surrounding transport infrastructure land uses. Upon operation the remaining land would continue to be zoned B2 Local Centre and any future use would be subject to a separate assessment and determination in accordance with the relevant planning controls. The project would not have long term impacts on future use of the site and as such, would have a negligible impact on the social and economic environment.
Rozelle surface works	This area is currently a disused industrial and transport infrastructure site and inaccessible to the public. The project would deliver new open space at the Rozelle Rail Yards, as well as new and enhanced active transport links for the community and permanent operational and transport infrastructure. The Rozelle Rail Yards are identified as a Precinct under The Bays Transformation Plan (UrbanGrowth NSW 2015). Open space and active transport links are identified as land uses for this precinct in the Plan, as well as an area for mixed housing and employment uses. The project would deliver open space in this area, and not preclude further development in accordance with The Bays Transformation Plan. The project on operation would continue to provide transport infrastructure. However, on operation the site would be accessible to and useable by the public resulting in a moderate positive impact on the existing social and economic environment.

Location	Feature
The Crescent and Whites Creek surface works	The use of The Crescent civil site (C6) would be temporary and would not permanently change the existing land use. During operation, the site would be reinstated. The realignment of The Crescent would result in the permanent loss of Buruwan Park, which would have a moderate to high impact on the local community. Notwithstanding, delivery of new open space within the Rozelle Rail Yards and new pedestrian and cyclist bridges is considered to be a beneficial outcome for the community and as such, the loss of Buruwan Park is considered to be minor in a regional context. Active transport connections to the Rozelle Bay light rail stop and to Railway Parade would be maintained. For much of the surrounding communities these future land use opportunities would improve the existing environment, resulting in a moderate positive impact on the social and economic environment
Victoria Road and Anzac Bridge approaches	The reconstruction of Victoria Road would result in the permanent loss of a small number of commercial buildings located on the western side of Victoria Road. The potential future redevelopment of this land for commercial uses in accordance with the existing land zoning would be lost. The design of the approaches to and from Anzac Bridge includes the delivery of new and enhanced active transport connections, which would allow future connections into the future redevelopment areas of the White Bay Power Station and the wider Bays Transformation Precinct. While the permanent loss of a small number of commercial properties on the western side of Victoria Road would be a moderate negative impact on the existing social and economic environment, the social infrastructure benefits arising from the project would provide a moderate positive impact for the wider community.
Iron Cove Link surface works	This area would change from residential and commercial land use to transport infrastructure, mainly from the acquisition of properties south of Victoria Road to the permanent operational infrastructure. This would result in moderate negative impact on the existing local social and economic environment. The bioretention facility adjacent to Manning Street within King George Park would be unlikely to impeded redevelopment of this land as the existing zoning limits the potential for redevelopment (RE1 Public Recreation). The project would not have long term negative impacts on future use of this area in King George Park and would have a minor positive impact on the social and economic environment due to the improvement to the existing informal carpark.
Pyrmont Bridge Road tunnel site	The Pyrmont Bridge Road tunnel site (C9) would be located on land currently used by commercial and industrial uses. The land use zoning would remain unchanged (currently IN1 Light Industrial). Any future development on the site would be subject to approval by the relevant consent authority. When considering future use of this site, consideration would be given to the *Parramatta Road Urban Transformation Strategy* (NSW Government 2016). Future potential use of the site would be outlined in the RLMP for the project.
St Peters interchange surface works	The Campbell Road civil and tunnel site (C10) is currently being used by the New M5 project. Following construction by the M4-M5 Link project, this site would be landscaped to be consistent with the UDLP's for the New M5 and M4-M5 Link projects.

14.5 Environmental management measures

Environmental management measures relating to social and economic impacts during construction and operation are provided in **Table 14-13**. Additional mitigation and management measures relevant to social and economic matters are also described in the following sections of this EIS:

- Traffic management and safety, access and parking management measures in **Chapter 8** (Traffic and transport)
- Air quality management measures in **Chapter 9** (Air quality)
- Noise and vibration management measures in **Chapter 10** (Noise and vibration)
- Human health risk management measures in **Chapter 11** (Human health risk)
- Urban design and visual amenity management measures in **Chapter 13** (Urban design and visual amenity).

Table 14-13 Environmental management measures – social and economic

Impact	No.	Environmental management measure	Timing
Construction			
Impacts on businesses	SE1	A Business Management Plan will be prepared and will include: • Identification of businesses that have the potential to be adversely affected by construction activities that will occur as part of the project • Management measures that will be implemented to maintain appropriate vehicular and pedestrian access during business hours and visibility of the business to potential customers during construction, including alternative arrangements for times when access and visibility cannot be maintained. These will be determined in consultation with the owners of the identified businesses.	Construction
Changes to community access and connectivity	SE2	A Community Communication Strategy will be prepared that details: • Procedures and mechanisms that will be implemented in response to the key social impacts identified for the project • Property acquisition support services that will be provided • Procedures and mechanisms to communicate to project stakeholders (including affected communities), the access and connectivity enhancements and new community and social facilities that will be delivered as part of the project through the Social Infrastructure Plan and to update stakeholders on delivery progress • Procedures and mechanisms that will be used to engage with affected business owners to identify potential access, parking, business visibility and other impacts to develop measures to address potential impacts on a case by case basis.	Construction
Property acquisition	SE3	Property acquisition will continue to be undertaken in accordance with the *Land Acquisition Information Guide* (Roads and Maritime 2014), the *Land Acquisition (Just Terms Compensation) Act 1991* (NSW) and the land acquisition reforms announced by the NSW Government in 2016 (NSW Government 2016). A property acquisition factsheet that outlines the process and provides further information for concerned residents will continue to be made available online and in hard copy at project information centres.	Construction
	SE4	Affected households will continue to have access to a counselling service that assists people through the property	Construction

Impact	No.	Environmental management measure	Timing
		acquisition process.	
	SE5	An independent service will continue to be provided to vulnerable households (eg elderly, those suffering an illness) to assist with relocation. Assistance could include finding a suitable house for relocation, arranging removalists, disconnecting services and attending appointments with solicitors or other representatives.	Construction
	SE6	A community relations support toll-free telephone line will be operated to respond to any community concerns or requests for translation services.	Construction
Operation			
Impacts on social infrastructure and facilities	OSE7	A Social Infrastructure Plan will be prepared that details: • Measures that will be delivered as part of the project to improve community connectivity in areas affected by the project, including pedestrian and cyclist access • Community and social facilities, for example open space, that will be delivered or enhanced as part of the project • Community initiatives and programs that will receive support as part of the project, including the manner in which support will be provided. The Social Infrastructure Plan will be prepared by a suitably qualified and experienced person in consultation with the community and relevant councils and implemented as part of the project.	Construction and operation

15 Soil and water quality

This chapter describes the environmental values relating to soil and water quality and identifies the potential impacts on these values as a result of the construction and operation of the M4-M5 Link (the project). A surface water and flooding assessment has been carried out for the project and is included in **Appendix Q** (Technical working paper: Surface water and flooding). The surface water component of that assessment has informed this chapter. The flooding component of that assessment is addressed in **Chapter 17** (Flooding and drainage).

The Secretary of the NSW Department of Planning and Environment (DP&E) has issued environmental assessment requirements for the project. These are referred to as Secretary's Environmental Assessment Requirements (SEARs). **Table 15-1** sets outs the requirements and the associated desired performance outcomes that relate to soil and water quality, and identifies where those requirements have been addressed in this environmental impact statement (EIS).

Table 15-1 SEARs – Soil and water quality

Desired performance outcome	SEARs	Where addressed in the EIS
10. Water – Hydrology The environmental values of nearby, connected and affected water sources, groundwater and dependent ecological systems including estuarine and marine water (if applicable) are maintained (where values are achieved) or improved and maintained (where values are not achieved)	1. The Proponent must describe (and map) the existing hydrological regime for any surface and groundwater resource (including reliance by users and for ecological purposes) likely to be impacted by the project, including stream orders, as per the FBA.	The stream order for each waterway within the study area (as required by the Framework for Biodiversity Assessment (FBA) (NSW Office of Environment and Heritage (OEH) 2014a)) is identified in **Table 15-8**. The hydrological regime for each waterway is described in **Chapter 17** (Flooding and drainage). A description of the FBA methodology is provided in **Chapter 18** (Biodiversity). The hydrological regime for groundwater is considered in **Chapter 19** (Groundwater).
	2. The Proponent must prepare a detailed water balance for ground and surface water including the proposed intake and discharge locations, volume, frequency and duration for both the construction and operational phases of the project.	A surface water balance for construction and operation is provided in **Chapter 17** (Flooding and drainage). Refer to **Chapter 19** (Groundwater) for groundwater inflow predictions.

Desired performance outcome	SEARs	Where addressed in the EIS
	3. The Proponent must assess (and model if appropriate) the impact of the construction and operation of the project and any ancillary facilities (both built elements and discharges) on surface and groundwater hydrology in accordance with the current guidelines, including: (a) natural processes within rivers, wetlands, estuaries, marine waters and floodplains that affect the health of the fluvial, riparian, estuarine or marine system and landscape health (such as modified discharge volumes, durations and velocities), aquatic connectivity and access to habitat for spawning and refuge;	Scour and impacts on geomorphology are discussed in **section 15.3.2** and **15.4.2**. Hydrological impacts and impacts on natural processes are included in **Chapter 17** (Flooding and drainage).
	(d) direct or indirect increases in erosion, siltation, destruction of riparian vegetation or a reduction in the stability of river banks or watercourses;	Potential impacts on surface water with regard to erosion, siltation, and bank stability are assessed in **section 15.3.1** and **section 15.4.1**. An assessment of the potential impacts of the project on groundwater is included in **Chapter 19** (Groundwater).
	5. The assessment must include details of proposed surface and groundwater monitoring.	A description of surface water monitoring undertaken to inform this EIS, and requirements for operational monitoring are provided in **section 15.1.2** and **section 15.4.2** respectively. Proposed surface water monitoring locations are shown in **Figure 15-2**. Proposed groundwater monitoring locations are provided in **Chapter 19** (Groundwater).

Desired performance outcome	SEARs	Where addressed in the EIS
11. Water – Quality The project is designed, constructed and operated to protect the NSW Water Quality Objectives where they are currently being achieved, and contribute towards achievement of the Water Quality Objectives over time where they are currently not being achieved, including downstream of the project to the extent of the project impact including estuarine and marine waters (if applicable)	1. The Proponent must: (a) state the ambient NSW Water Quality Objectives (NSW WQO) and environmental values for the receiving waters relevant to the project, including the indicators and associated trigger values or criteria for the identified environmental values;	A list of the ambient NSW Water Quality Objectives (NSW WQO) for receiving waters within the study area is included in **section 15.1.4**. Specific indicators and associated trigger values for the identified environmental values are included in **Appendix Q** (Technical working paper: Surface water and flooding).
	(b) identify and estimate the quality and quantity of all pollutants that may be introduced into the water cycle by source and discharge point and describe the nature and degree of impact that any discharge(s) may have on the receiving environment, including consideration of all pollutants that pose a risk of non-trivial harm to human health and the environment;	Potential pollutants of concern are identified in **section 15.3.2**, **section 15.4.2** and **Appendix Q** (Technical working paper: Surface water and flooding). An assessment of the potential for construction to introduce pollutants into receiving waterways is provided in **section 15.3.2**. The outcomes of modelling using the Model for Urban Stormwater Improvement Conceptualisation (MUSIC) are provided in **section 15.4.2**.
	(c) identify the rainfall event that the water quality protection measures will be designed to cope with;	**Section 15.3.2** outlines water quality protection measures to be adopted during construction and states the rainfall event that construction sediment basins would be designed for. Discussion and justification for the design of operational management measures based on pollutant load reduction (rather than a rainfall event) are provided in **section 15.4.2**.
	(d) assess the significance of any identified impacts including consideration of the relevant ambient water quality outcomes;	The significance of identified impacts on ambient water quality outcomes is assessed in **section 15.3.2** and **section 15.4.2**.

Desired performance outcome	SEARs	Where addressed in the EIS
	(e) demonstrate how construction and operation of the project will, to the extent that the project can influence, ensure that: • where the NSW WQOs for receiving waters are currently being met they will continue to be protected, and • where the NSW WQOs are not currently being met, activities will not worsen water quality and, where reasonably practical, work toward their achievement over time;	Discussion of whether the NSW WQOs would continue to be met, during construction and operation of the project is provided in **section 15.3.2** and **section 15.4.2** respectively. Management measures to be adopted to ensure that water quality requirements for the project are met are provided in **section 15.5**.
	(f) justify, if required, why the WQOs cannot be maintained or achieved over time;	The ability of the project to meet the NSW WQOs is discussed in **section 15.3.2** and **section 15.4.2**.
	(g) demonstrate that all practical measures to avoid or minimise water pollution and protect human health and the environment from harm are investigated and implemented;	Practical management measures to be adopted for the project are provided in **section 15.5**. Management measures to ensure the protection of human health are outlined in **Chapter 11** (Human health risk).
	(h) identify sensitive receiving environments (which may include estuarine and marine waters downstream) and develop a strategy to avoid or minimise impacts on these environments; and	Sensitive receiving environments are identified and described in **section 15.2.2**. Management measures to avoid (or minimise) impacts are provided in **section 15.5**.
	(i) identify proposed monitoring locations, monitoring frequency and indicators of surface and groundwater quality.	Proposed monitoring locations are shown in **Figure 15-2**. Further details, including monitoring frequency and indicators are provided in **Appendix Q** (Technical working paper: Surface water and flooding). The proposed monitoring locations, monitoring frequency and indicators of groundwater quality are outlined in **Chapter 19** (Groundwater).

Desired performance outcome	SEARs	Where addressed in the EIS
	2. The assessment should consider the results of any current water quality studies, as available, in the project catchment.	Water quality studies considered for this assessment are listed in **section 15.1.6** and further information is provided in **Appendix Q** (Technical working paper: Surface water and flooding).
12. Flooding The project minimises adverse impacts on existing flooding characteristic	1. The Proponent must assess and (model where required) the impacts on flood behaviour during construction and operation for a full range of flood events up to the probable maximum flood (taking into account sea level rise and storm intensity due to climate change) including: (g) downstream velocity and scour potential;	An assessment of flood behaviour during construction and operation is provided in **Chapter 17** (Flooding and drainage). Downstream velocities and scour potential are also considered in **Chapter 17** (Flooding and drainage). The potential for scour to occur during construction and operation of the project is also outlined in **section 15.3.2** and **section 15.4.2** respectively.
Construction and operation of the project avoids or minimises the risk of, and adverse impacts from, infrastructure flooding, flooding hazards, or dam failure**.**	(j) whether there will be direct or indirect increase in erosion, siltation, destruction of riparian vegetation or a reduction in the stability of river banks or watercourses; and	Potential impacts that could increase erosion and siltation are assessed in **section 15.3.2** and **section 15.4.2**. Potential impacts on riparian vegetation are assessed in **Chapter 18** (Biodiversity).
13. Soils The environmental values of land, including soils, subsoils and landforms, are protected.	1. The Proponent must verify the risk of acid sulfate soils (Class 1, 2, 3 or 4 on the Acid Sulfate Soil Risk Map) within the area likely to be impacted by, the project.	The risk of acid sulfate soils is verified in **section 15.2.1**.
Risks arising from the disturbance and excavation of land and disposal of soil are minimised, including disturbance to acid sulfate soils and site contamination	2. The Proponent must assess the impact of the project on acid sulfate soils (including impacts of acidic runoff off-site) in accordance with the current guidelines and detail the mitigation measures proposed to minimise potential impacts.	An assessment of the impact of the project on acid sulfate soils is provided in **section 15.3.1**. Mitigation measures recommended to minimise these impacts are outlined in **section 15.5**.

Desired performance outcome	SEARs	Where addressed in the EIS
	3. The Proponent must assess whether the land is likely to be contaminated and identify if remediation of the land is required, having regard to the ecological and human health risks posed by the contamination in the context of past, existing and likely (or potential) future land uses. Where assessment and/or remediation is required, the Proponent must document how the assessment and/or remediation would be undertaken in accordance with current guidelines.	Qualitative assessment of the potential contamination risks, and the need for land remediation, is provided in **Chapter 16** (Contamination). Ecological and human health risks posed by contamination are assessed in **Chapter 11** (Human health risk).
	4. The Proponent must assess whether salinity is likely to be an issue and, if so, determine the presence, extent and severity of soil salinity within the project area.	An assessment of the potential for salinity to be present, and the associated impacts, is provided in **section 15.2.1** and **section 15.3.1**.
	5. The Proponent must assess the impacts of the project on soil salinity and how it may affect groundwater resources and hydrology.	An assessment of potential project impacts on soil salinity, including how it may affect hydrology, is provided in **section 15.3.1**. The impacts of soil salinity on groundwater resources are assessed in **Chapter 19** (Groundwater).
	6. The Proponent must assess the impacts on soil and land resources (including erosion risk or hazard). Particular attention must be given to soil erosion and sediment transport consistent with the practices and principles in the current guidelines.	An assessment of the project's impact on soil and land resources, with particular emphasis on soil erosion and sediment transport, is provided in **section 15.3.1**.
	7. The Proponent must assess the impact of any disturbance of contaminated groundwater and the tunnels should be carefully designed so as to not exacerbate mobilisation of contaminated groundwater and/or prevent contaminated groundwater flow.	An assessment of contaminated groundwater impacts and a description of how the tunnel has been designed so as to not exacerbate mobilisation of contaminated groundwater and/or prevent contaminated groundwater flow is provided in **Chapter 16** (Contamination).

15.1 Assessment methodology

15.1.1 Soils

The methodology for the assessment of potential impacts of the project on soils included:

- Review of the geological context, soil landscapes, and acid sulfate soils within the study area, including consideration of:

- Regional geology, as described in the Geological Survey of NSW 1:100,000 scale Sydney Map Sheet 9130 (1983)
- Soil landscapes and characteristics, determined from the Soil Landscapes of the Sydney 1:100,000 Sheet 9130 (1989)
- Acid sulfate soil mapping, obtained from Australian Soils Resource Information System and NSW Department of Land and Water Conservation (DLWC) to determine areas of higher probability

- Review of the geotechnical investigations carried out for the project
- Identification and assessment of construction and operational activities that may result in erosion or the exposure of acid sulfate soils
- Assessment of erosion risk or hazard and the potential for soil sediment mobilisation
- Assessment of soil stability and the associated potential for subsidence and settlement
- Assessment of the potential for soil salinity to be present within the project footprint and identification of associated environmental impacts
- Identification of environmental management measures, including the type of controls and design criteria required to mitigate potential impacts.

15.1.2 Water quality

The methodology for the assessment of potential impacts of the project on water quality included the following:

- Identification of a surface water assessment study area and the relevant NSW Water Quality Objectives (NSW WQOs) and environmental values for the receiving waters of the project
- Desktop review and analysis of existing information to identify potential sensitive receiving environments, characterise the existing environment and identify potential issues
- Review of existing policies and guidelines applicable to the management of water quality during construction
- Field assessment to understand and assess the existing features and condition of the water quality assessment study area (including implementation of a baseline surface water monitoring program)
- Model for Urban Stormwater Improvement Conceptualisation (MUSIC) modelling to assess the performance of the operational water quality treatment measures against pollutant reduction targets (see **section 15.1.4**)
- Assessment of construction activities that could mobilise sediments and other pollutants into the surface water environment
- Assessment of the quality and volume of proposed discharges of construction wastewater
- Assessment of potential impacts of the project during construction and operation with regard to flooding, drainage, water supply and water quality, and in accordance with the relevant requirements of the SEARs
- Identification of environmental management measures to mitigate potential impacts.

The methodology for the surface water quality assessment is presented in further detail in the following sections and in **Appendix Q** (Technical working paper: Surface water and flooding). **Chapter 17** (Flooding and drainage) includes an assessment of the potential impact the project may have on flood dispersion and drainage.

15.1.3 Study area

The study area for the soil and water quality assessment is located within the Sydney Harbour and Parramatta River and Cooks River catchments and is shown in **Figure 15-1**. This area comprises the project footprint and includes areas where potential impacts could occur as a result of construction or operation of the project.

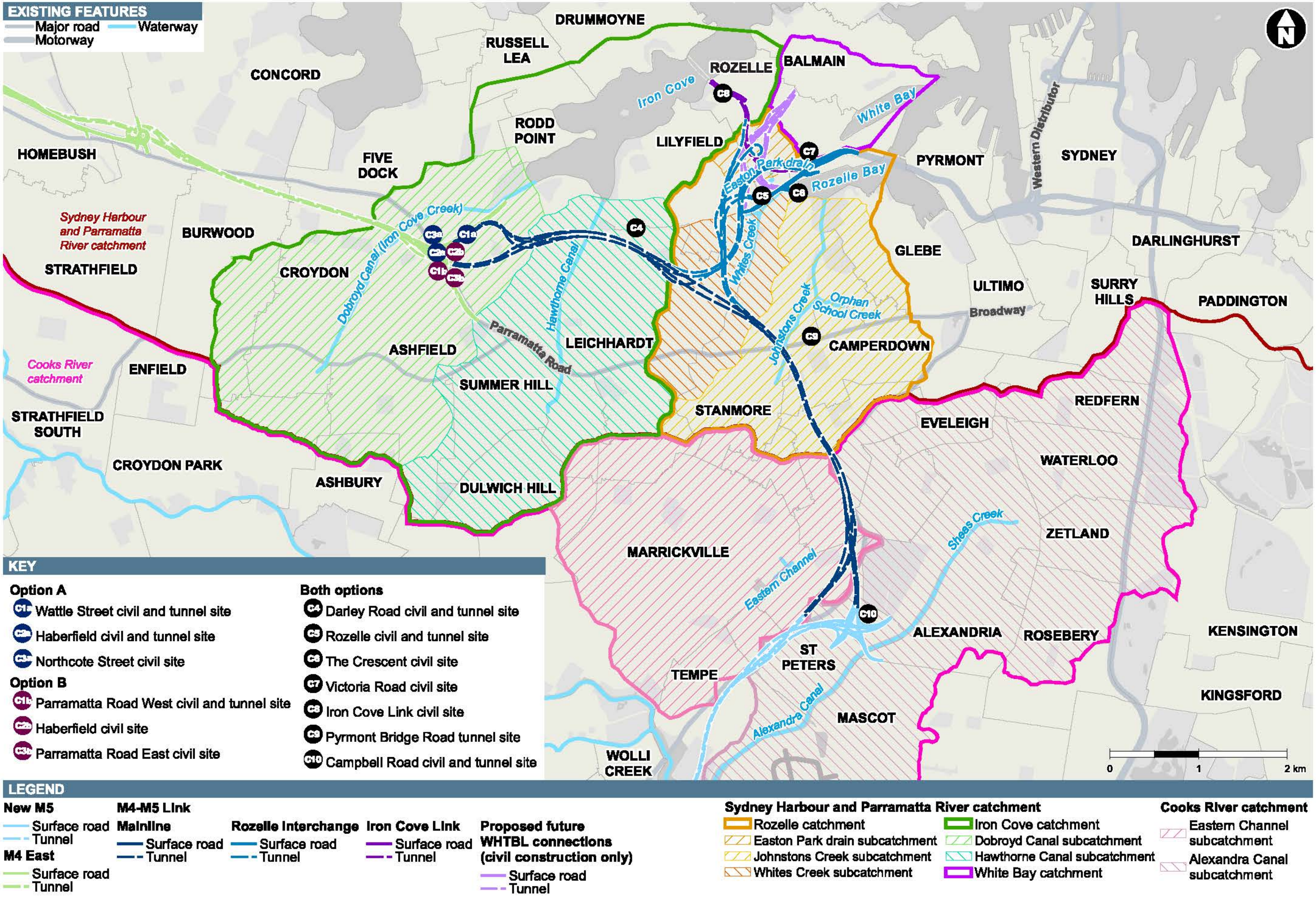


Figure 15-1 Soil and surface water quality assessment study area

15.1.4 Legislative and policy framework

Relevant legislation

The *Water Act 1912* (NSW) and the *Water Management Act 2000* (NSW) (WM Act) are the two key pieces of legislation for the management of water in NSW and contain provisions for the licensing of water access and use. The *Water Act 1912* (NSW) is being progressively phased out and replaced by the WM Act, but its provisions remain in force in respect of areas of NSW where water sharing plans under the WM Act have not yet been made.

The aims of the WM Act are to provide for the sustainable and integrated management of the State's water sources for the benefit of both present and future generations. The WM Act implicitly recognises the need to allocate and provide water for the environmental health of our rivers and groundwater systems, while also providing licence holders with more secure access to water and greater opportunities to trade water through the separation of water licences from land.

The WM Act enables the State's water resources to be managed under water sharing plans, which establish the rules for the sharing of water in a particular water source between water users and the environment, and rules for the trading of water in a particular water source.

The project is located within an area covered by the Water Sharing Plan for the Greater Metropolitan Region Unregulated River Water Sources (NSW Department of Primary Industries (DPI) 2011). This plan applies to surface water sources and includes rules for protecting the environment, water extraction, managing licence holders' water accounts, and water trading within the plan area. The Greater Metropolitan Region Groundwater Source Water Sharing Plan DPI (2011) is also relevant to the project and is further discussed in **Chapter 19** (Groundwater).

Relevant guidelines

Soil

The impact assessment of the project on soils has been prepared in accordance with the following key relevant guidelines and policies:

- *Managing Urban Stormwater: Soils and Construction Volume 1* (Landcom 2004) and Volume 2 (NSW Department of Environment and Climate Change (DECC) 2008)
- *Soil and Landscape Issues in Environmental Impact Assessment* (DLWC 2000)
- *Urban and regional salinity – guidance given in the Local Government Salinity Initiative booklets* (including Site Investigations for Urban Salinity) (DLWC 2002)
- *Landslide risk management guidelines* (Australian Geomechanics Society 2007).

Water quality

The water quality assessment has been prepared in accordance with the following key relevant guidelines and policies:

- *Australian and New Zealand Guidelines for Fresh and Marine Water Quality* (Australian and New Zealand Environment and Conservation Council (ANZECC)/ Agriculture and Resource Management Council of Australia and New Zealand (ARMCANZ) 2000)
- NSW Water Quality and River Flow Objectives *(*NSW Department of Environment, Climate Change and Water (DECCW) 2006)
- Sydney Harbour Water Quality Improvement Plan (Sydney Metropolitan Catchment Management Authority (SMCMA) 2010)
- Botany Bay and Catchment Water Quality Improvement Plan (SMCMA) (2011).

Further detail on relevant water quality policies and guidelines is included in **Appendix Q** (Technical working paper: Surface water and flooding).

15.1.5 Design criteria

Project water quality objectives

Water quality treatment design for the project would take into account the ambient NSW WQOs that apply to the Sydney Harbour and Parramatta River catchment water quality objectives. The NSW WQOs aim to maintain or improve water quality in the Sydney Harbour and Parramatta River catchment. Discharge from the Campbell Road civil and tunnel site (C10) would be treated at the treatment facility being built by the New M5 project, eventually draining to Alexandra Canal and Cooks River.

The following mean annual pollutant load reduction targets would be adopted as part of the water quality treatment design for the project, where practicable:

- 85 per cent reduction in the mean annual load of Total Suspended Solids (TSS)
- 65 per cent reduction in the mean annual load of Total Phosphorous (TP)
- 45 per cent reduction in the mean annual load of Total Nitrogen (TN)
- 90 per cent reduction in the mean annual load of Gross Pollutants (GP) more than five millimetres in diameter.

The surface water quality assessment for the project has been based on an indicative design for stormwater treatment measures. The type and design of specific stormwater treatment measures would be further refined as part of the detailed design process, including confirmation of performance with modelling, if required. Further detail is provided in **Appendix Q** (Technical working paper: Surface water and flooding).

NSW Water Quality and River Flow Objectives

The ambient NSW Water Quality and River Flow Objectives (DECCW 2006) are consistent with the agreed national framework of the ANZECC Water Quality Guidelines and are 'primarily aimed at maintaining and improving water quality, for the purposes of supporting aquatic ecosystems, recreation and where applicable, water supply, and the production of aquatic foods suitable for consumption and aquaculture activities' (DECCW 2006).

The NSW Water Quality and River Flow Objectives have been developed for the Cooks River catchment and the Sydney Harbour and Parramatta River catchment. The classifications of receiving waterways in the study area are provided in **Table 15-2**. The water quality and river flow objectives for catchments and waterways relevant to the project are summarised in **Table 15-3**.

Appendix Q (Technical working paper: Surface water and flooding) provides further detail on the ambient NSW Water Quality and River Flow Objectives and environmental values for the relevant receiving waters, including specific indicators and associated trigger values for the identified environmental values.

Table 15-2 Receiving waterway catchment and classification

Catchment	Receiving waterway within study area	Classification of waterway in accordance with NSW Water Quality and River Flow Objectives
Sydney Harbour and Parramatta River	Dobroyd Canal (Iron Cove Creek)	Waterways affected by urban development
	Hawthorne Canal	Waterways affected by urban development
	Whites Creek	Waterways affected by urban development
	Easton Park drain	Waterways affected by urban development
	Johnstons Creek	Waterways affected by urban development

Catchment	Receiving waterway within study area	Classification of waterway in accordance with NSW Water Quality and River Flow Objectives
	Rozelle Bay	Lower estuary
	Iron Cove	Upper estuary
Cooks River	Alexandra Canal	Waterways affected by urban development Estuaries

Table 15-3 NSW water quality and river flow objectives relevant to the project

Objective	Description	Applicable catchment(s)/waterways
Water quality objectives		
Protect aquatic ecosystems	Ecological condition of waterways and their riparian zone	• Waterways affected by urban development in the Sydney Harbour and Parramatta River catchment • Upper estuary in the Sydney Harbour and Parramatta River catchment • Lower estuary in the Sydney Harbour and Parramatta River catchment • Estuaries in the Cooks River catchment
Protect visual amenity	Aesthetic qualities of waters	• Waterways affected by urban development in the Sydney Harbour and Parramatta River catchment • Upper estuary in the Sydney Harbour and Parramatta River catchment • Lower estuary in the Sydney Harbour and Parramatta River catchment • Estuaries in the Cooks River catchment
Protect secondary contact recreation	Water quality suitable for activities, such as boating and wading	• Waterways affected by urban development in the Sydney Harbour and Parramatta River catchment • Upper estuary in the Sydney Harbour and Parramatta River catchment • Lower estuary in the Sydney Harbour and Parramatta River catchment • Estuaries in the Cooks River catchment – for achievement within five years
Protect primary contact recreation	Water quality for activities, such as swimming	• Waterways affected by urban development in the Sydney Harbour and Parramatta River catchment – for achievement in 10 years or more • Upper estuary in the Sydney Harbour and Parramatta River catchment • Lower estuary in the Sydney Harbour and Parramatta River catchment • Estuaries in the Cooks River catchment – for achievement in 10 years or more

Objective	Description	Applicable catchment(s)/waterways
Aquatic foods (to be cooked before eating)	Water quality suitable for production of aquatic foods for human consumption, and aquaculture activities	• Upper estuary in the Sydney Harbour and Parramatta River catchment • Lower estuary in the Sydney Harbour and Parramatta River catchment • Estuaries in the Cooks River catchment – for achievement in 5 to 10 years
River flow objectives		
Protect pools in dry times	Protect natural water levels in pools of creeks, rivers and wetlands during periods of no flows	• Urban waterways in the Sydney Harbour and Parramatta River catchment
Protect natural low flows	Manage water extraction and storage to allow sufficient low flows to avoid stress on aquatic plants and animals	• Urban waterways in the Sydney Harbour and Parramatta River catchment
Protect important rises in water levels	Protect or restore a proportion of moderate flows and high flows	• Estuaries in the Cooks River catchment
Maintain wetland and floodplain inundation	Maintain or restore the natural inundation patterns and distribution or floodwaters supporting natural wetland and floodplain ecosystems	• Waterways affected by urban development in the Sydney Harbour and Parramatta River catchment • Upper estuary in the Sydney Harbour and Parramatta River catchment • Lower estuary in the Sydney Harbour and Parramatta River catchment
Mimic natural drying in temporary waterways	Mimic the natural frequency, duration and seasonal nature of drying periods in naturally temporary waterways	• Waterways affected by urban development in the Sydney Harbour and Parramatta River catchment
Maintain natural flow variability	Maintain or mimic natural flow variability in all streams	• Waterways affected by urban development in the Sydney Harbour and Parramatta River catchment • Estuaries in the Cooks River catchment
Maintain natural rates of change in water levels	Maintain rates of rise and fall of river heights within natural bounds	• Waterways affected by urban development in the Sydney Harbour and Parramatta River catchment • Estuaries in the Cooks River catchment
Manage groundwater for ecosystems	Maintain groundwater within natural levels and variability that are critical to surface flows and ecosystems	• Upper estuary in the Sydney Harbour and Parramatta River catchment

Objective	Description	Applicable catchment(s)/waterways
Minimise effects of weirs and other structures	Minimise the impact of instream structures	• Waterways affected by urban development in the Sydney Harbour and Parramatta River catchment • Upper estuary in the Sydney Harbour and Parramatta River catchment • Lower estuary in the Sydney Harbour and Parramatta River catchment • Estuaries in the Cooks River catchment
Maintain or rehabilitate estuarine processes and habitats	Maintain or rehabilitate estuarine processes and habitats	• Upper estuary in the Sydney Harbour and Parramatta River catchment • Lower estuary in the Sydney Harbour and Parramatta River catchment • Estuaries in the Cooks River catchment

15.1.6 Desktop assessment

The desktop assessment involved a review of the existing surface water environment across the study area, including:

- Information obtained from geotechnical investigations and assessments carried out as part of the project
- Information and previous studies relevant to surface water within the study area including those prepared for the M4 East EIS and the New M5 EIS
- Other technical working papers prepared to inform this EIS including **Appendix T** (Technical working paper: Groundwater), **Appendix R** (Technical working paper: Contamination), **Appendix S** (Technical working paper: Biodiversity) and the review of environmental factors (REF) for site management works at the Rozelle Rail Yards (NSW Roads and Maritime Services (Roads and Maritime) 2016)
- Data relevant to the existing surface water conditions in the study area from sources including the Inner West Council and the City of Sydney Council, Sydney Motorway Corporation and NSW Government agencies including UrbanGrowth NSW, Sydney Water, Roads and Maritime and Transport for NSW (in respect of the Central Business District (CBD) and South East Light Rail)
- Water quality monitoring data collected for the M4 East and New M5 projects (CPB Samsung John Holland Joint Venture 2016a).

15.1.7 Field assessment

A baseline surface water monitoring program has been implemented since 2016 to establish existing surface water quality conditions and to provide a baseline for assessment of water quality during and after implementation of the project. The program was implemented to:

- Evaluate the existing surface water quality at key locations in the study area
- Identify potential pathways of pollutants to surface water receivers
- Monitor and assess the surface water quality in the study area to form a baseline of environmental conditions, to measure the environmental performance of the project during the construction and operation of the project.

Table 15-4 summarises the field assessments undertaken during 2016. These included a visual assessment of the relevant waterways, assessment of the current state of surface water receivers and potential pathways to the receivers.

Table 15-4 Summary of surface water field assessments

Date	Location	Waterways assessed
May 2016	St Peters, Rozelle Rail Yards, Wattle Street, Darley Road	Dobroyd Canal (Iron Cove Creek), Hawthorne Canal, Easton Park drain, Whites Creek, Rozelle Bay, Johnstons Creek, Alexandra Canal
July 2016	Rozelle Rail Yards	Whites Creek, Easton Park drain, Rozelle Bay
September 2016	Rozelle Rail Yards and Victoria Road	Whites Creek, Easton Park drain, Rozelle Bay, Iron Cove

Water quality monitoring locations are located upstream and downstream of construction ancillary facilities, as shown in **Figure 15-2** and listed in **Table 15-5**. Further detail is provided in **Appendix Q** (Technical working paper: Surface water and flooding). These sites were chosen to provide general characterisation of the waterways. For operational monitoring, these locations may need to be adjusted to better suit the final construction ancillary facility locations selected to support construction as determined during detailed design. **Figure 15-2** also includes water quality monitoring locations for data collected for the M4 East and the New M5 projects.

MUSIC modelling was carried out to assess potential impacts on receiving waters during operation associated with pollutant loads generated from runoff and the performance of the project's water treatment systems. Details of the MUSIC modelling are included in **Appendix Q** (Technical working paper: Surface water and flooding).

Discharges of treated tunnel water were quantitatively assessed for potential impacts during construction to Hawthorne Canal, Dobroyd Canal (Iron Cove Creek), Rozelle Bay and Johnstons Creek and during operation to Hawthorne Canal and Rozelle Bay (see **section 15.3.2** and **15.4.2** and **Appendix Q** (Technical working paper: Surface water and flooding)).

Table 15-5 Surface water sampling locations

Sample ID	Sample location	Waterway
SW01	Whites Creek outlet at City West Link/The Crescent, Rozelle	Rozelle Bay (downstream)
SW02	Whites Creek Valley Park, Railway Parade, Annandale	Whites Creek (downstream)
SW03	Smith Park pedestrian bridge, Neilson Lane, Annandale	Johnstons Creek (downstream)
SW04	Adjacent to playground, Chester Street, Annandale (non-tidal, ie not influenced by the ocean tides)	Johnstons Creek (downstream)
SW05	Hawthorne Canal Reserve, Canal Road, Leichhardt	Hawthorne Canal (upstream)
SW06	Canal Road (between City West Link and Lilyfield Road) Lilyfield	Hawthorne Canal (downstream)
SW07	Adjacent to 88-90 Lilyfield Road, Lilyfield	Easton Park drain (downstream)
SW08	Pedestrian bridge between Timbrell Park and Reg Coady Reserve, Dobroyd Parade, Haberfield	Dobroyd Canal (Iron Cove Creek) (downstream)
SW09	West of Ramsay Road bridge at Dobroyd Parade, Haberfield	Dobroyd Canal (Iron Cove Creek) (upstream)
SW10	South side of Huntley Street, Alexandria	Sheas Creek (upstream)
SW11	Under Iron Cove Bridge, Rozelle	Iron Cove (downstream)

Sample ID	Sample location	Waterway
SW12	King George Park, Rozelle	Iron Cove (downstream)
SW14	Cruikshank Street, Stanmore	Johnstons Creek (upstream)

Note:

SW13 was monitored as part of the contamination assessment (refer to **Appendix R** (Technical working paper: Contamination)) and is not relevant to the surface water assessment

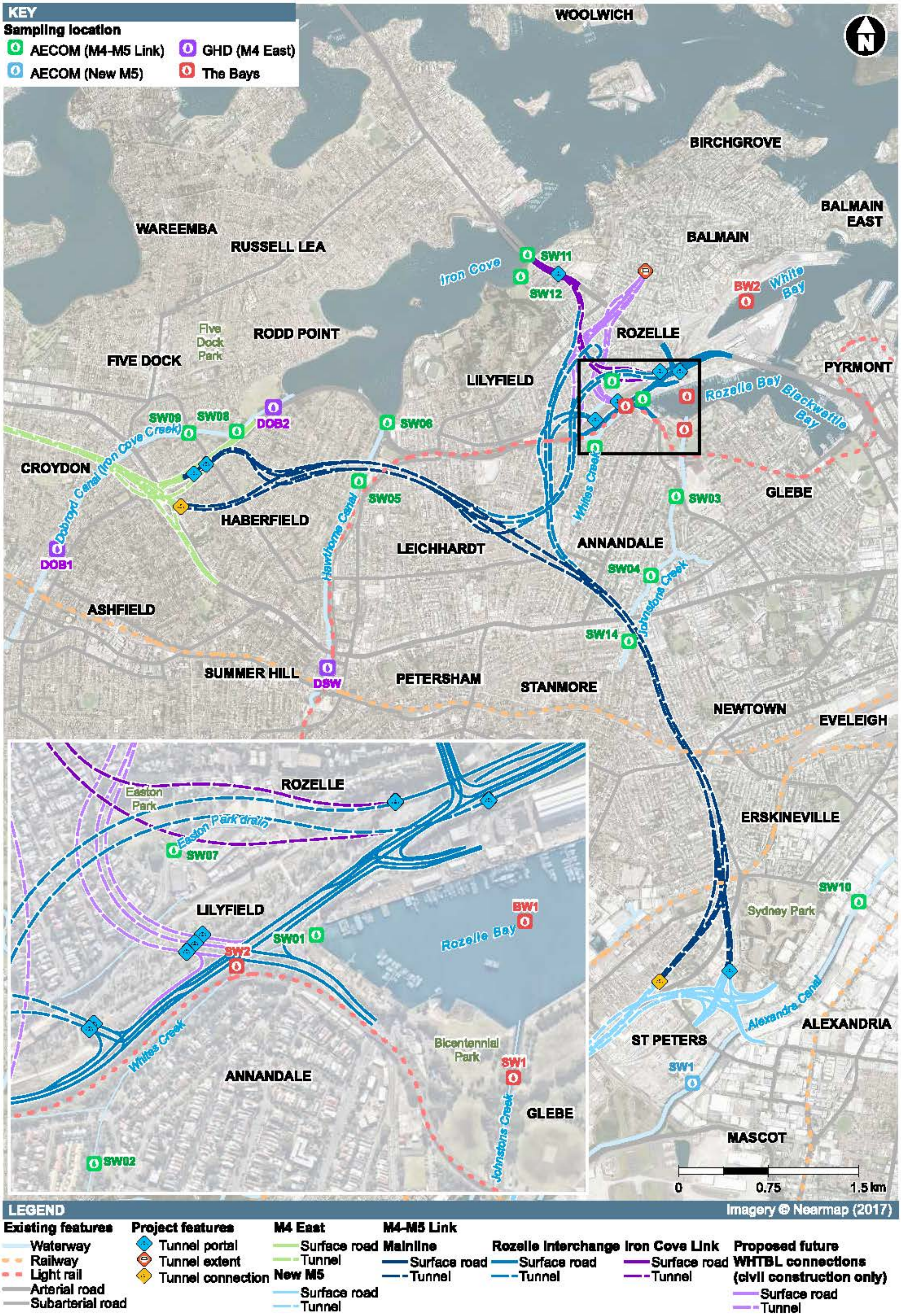


Figure 15-2 Surface water quality data locations

15.2 Existing environment

15.2.1 Soils

Topography and geolog

The project is located in the Sydney Basin and is predominantly underlain by Ashfield Shale and Hawkesbury Sandstone, which outcrop in topographically high areas. In lower lying areas such as Rozelle Bay and White Bay, the bedrock is overlain by fill and alluvium. The thickness of the alluvium is variable and can be up to 20 metres deep in the palaeochannels under Hawthorne Canal and Johnstons Creek. The alluvium comprised clay, silt, sand, gravel or similar unconsolidated detrital material, deposited during comparatively recent geologic time by a stream or other body of running water. Fill materials are typically uncontrolled anthropogenic deposits.

The landform of the study area is relatively flat and low-lying, with gentle undulating hills ranging between 30 metres and 40 metres above Australian Height Datum (AHD).

Soil landscapes

The Soil Landscapes of the Sydney 1:100,000 Sheet 9130 (NSW Department of Conservation and Land Management 1989) indicates that the project footprint is underlain by four soil landscapes. These are shown in **Figure 15-3**. Characteristics of the soil landscapes, as well as their potential for erosion, are summarised in **Table 15-6**.

Table 15-6 Soil landscape characteristics and erosion potential

Soil landscape	Characteristics	Erosion/mass movement potential
Residual Blacktown	• Occurs on gently undulating rises on Wianamatta Group Shales • Poorly drained	No appreciable erosion occurs on this landscape as most of the surface is covered by buildings, structures, roads etc
Erosional Gymea	• Occurs on undulating to rolling rises and low hills on Hawkesbury Sandstone • Localised steep slopes • High soil erosion hazard	The soil is generally stabilised by urban infrastructure across the study area, despite the majority of remnant vegetation having been removed
Colluvial Hawkesbury	• Occurs on rugged, rolling to very steep hills on Hawkesbury Sandstone • Extreme soil erosion and mass movement hazard	The ground surface is generally stabilised by urban infrastructure across the study area
Disturbed Terrain	• Terrain extensively disturbed by human activity, including complete disturbance, removal or burial of soil • Variable relief and slopes	Erosion hazard varies according to site characteristics including slope, aspect and exposure. The ground surface within the study area is generally stabilised by urban infrastructure

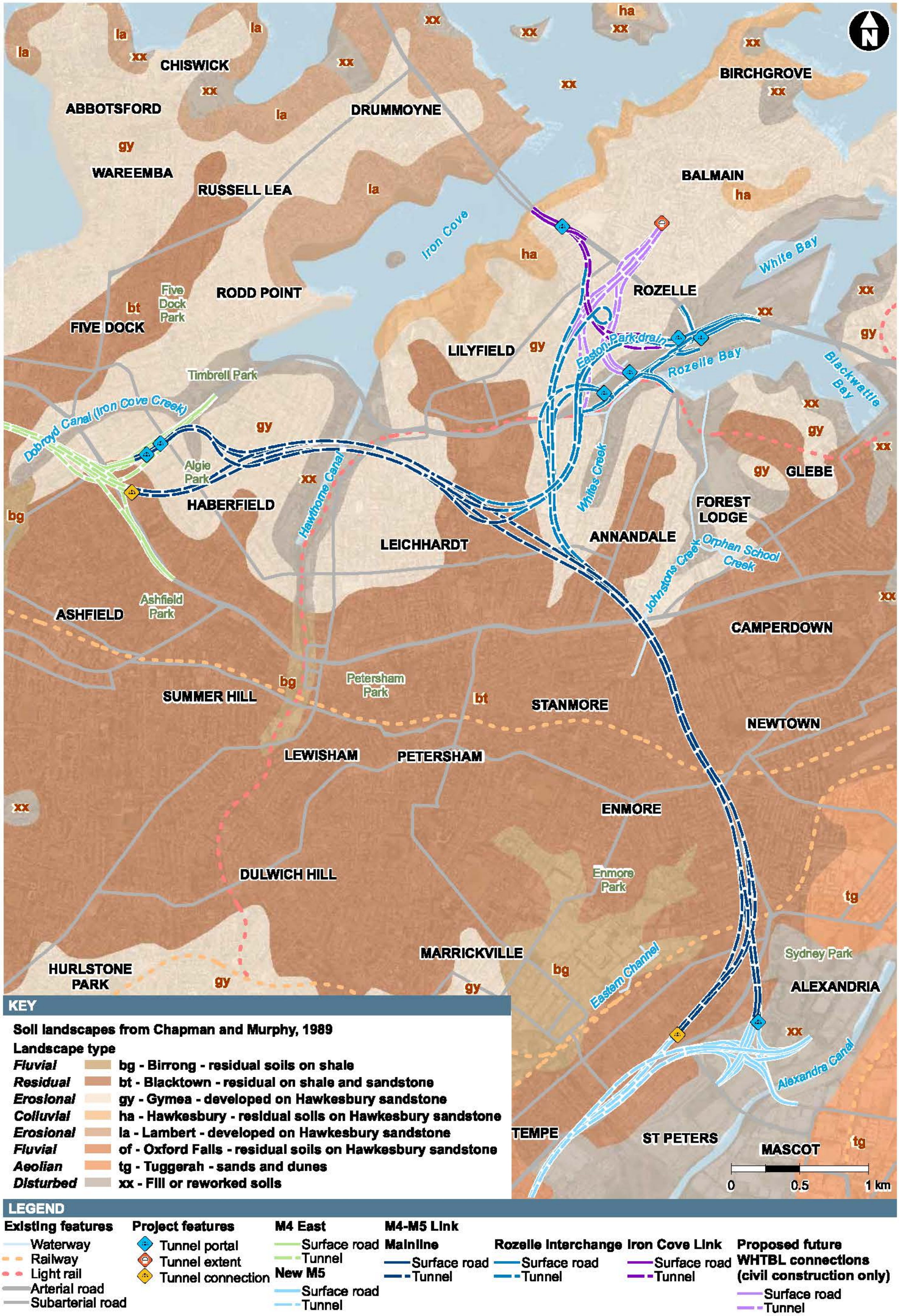


Figure 15-3 Soil landscapes within the study area

Soil salinity

Salinity refers to the salt content of soil. Saline soils form part of the natural landscape of the Sydney Harbour and Parramatta River catchment, particularly within or adjacent to estuarine environments where the natural salt content of tidal waterways is transported to adjacent soils. This may occur adjacent to tidal waterways within the study area, around the concrete canals (Whites Creek, Hawthorne Canal and Alexandra Canal) and Rozelle Bay.

The risk of salinity can be increased by clearing vegetation, irrigation or other activities that can lead to a rise in the groundwater table. The project footprint does not affect land known to be naturally saline, based on a review of the Salinity Potential in Western Sydney Map (NSW Department of Infrastructure, Planning and Natural Resources 2002).

Acid sulfate soils

Acid sulfate soils are naturally occurring soils that contain iron sulfides which, when exposed to the air, can oxidise to form sulfuric acid. Sulfuric acid formed from acid sulfate soils can pose a risk to the environment if not appropriately managed. Potential acid sulfate soils are generally waterlogged soils, rich in pyrite that have not been oxidised.

Disturbance of acid sulfate soils and/or potential acid sulfate soils can result in adverse impacts on surface and groundwater quality, flora and fauna, and degradation of habitats.

In NSW, land is classified based on the likelihood of acid sulfate soils being present in particular areas and at certain depths. In accordance with the *Guidelines for the Use of Acid Sulfate Soils Risk Maps* (DLWC 1998), there are five classifications:

- Class 1: Acid sulfate soils are likely to be found on and below the natural ground surface. Any works would trigger the requirement for assessment and may require management
- Class 2: Acid sulfate soils are likely to be found below the natural ground surface. Any works beneath the natural ground surface, or works which are likely to lower the water table, would trigger the requirement for assessment and may require management
- Class 3: Acid sulfate soils are likely to be found more than one metre below the natural ground surface. Any works that extend beyond one metre below the natural ground surface, or works which are likely to lower water table beyond one metre below the natural ground surface, would trigger the requirement for assessment and may require management
- Class 4: Acid sulfate soils are likely to be found more than two metres below the natural ground surface. Any works that extend beyond two metres below the natural ground surface, or works which are likely to lower the water table beyond two metres below the natural ground surface, would trigger the requirement for assessment and may require management
- Class 5: Acid sulfate soils are not typically found in Class 5 areas. Areas classified as Class 5 are located within 500 metres on adjacent Class 1, 2, 3 or 4 land. Works in a Class 5 area that are likely to lower the water table below one metre AHD on adjacent Class 1, 2, 3 or 4 land would trigger the requirement for assessment and may require management.

The acid sulfate soil risk across the project footprint is shown in **Figure 15-4**. Areas identified as containing acid sulfate soils (or potential acid sulfate soils) within the project footprint were identified include:

- Rozelle civil and tunnel site (C5) – mapped as Class 1, 3 and 5 acid sulfate soil risk. Potential acid sulfate soils have been detected within the alluvial sediments across the Rozelle Rail Yards
- The Crescent civil site (C6) – mapped as Class 1 and 3 acid sulfate soil risk
- Surface works at Rozelle near Rozelle Bay
- Bioretention facility at Manning Street – southern part of the site mapped as Class 2 acid sulfate soil risk
- Campbell Road civil and tunnel site (C10) – mapped as Class 3 and 5 acid sulfate soil risk.

Acid sulfate soils within the areas listed above have been identified as contaminants of concern (refer to **Appendix R** (Technical working paper: Contamination)). Further assessment of potential impacts associated with acid sulfate soils and other sources of contamination is provided in **Chapter 16** (Contamination).

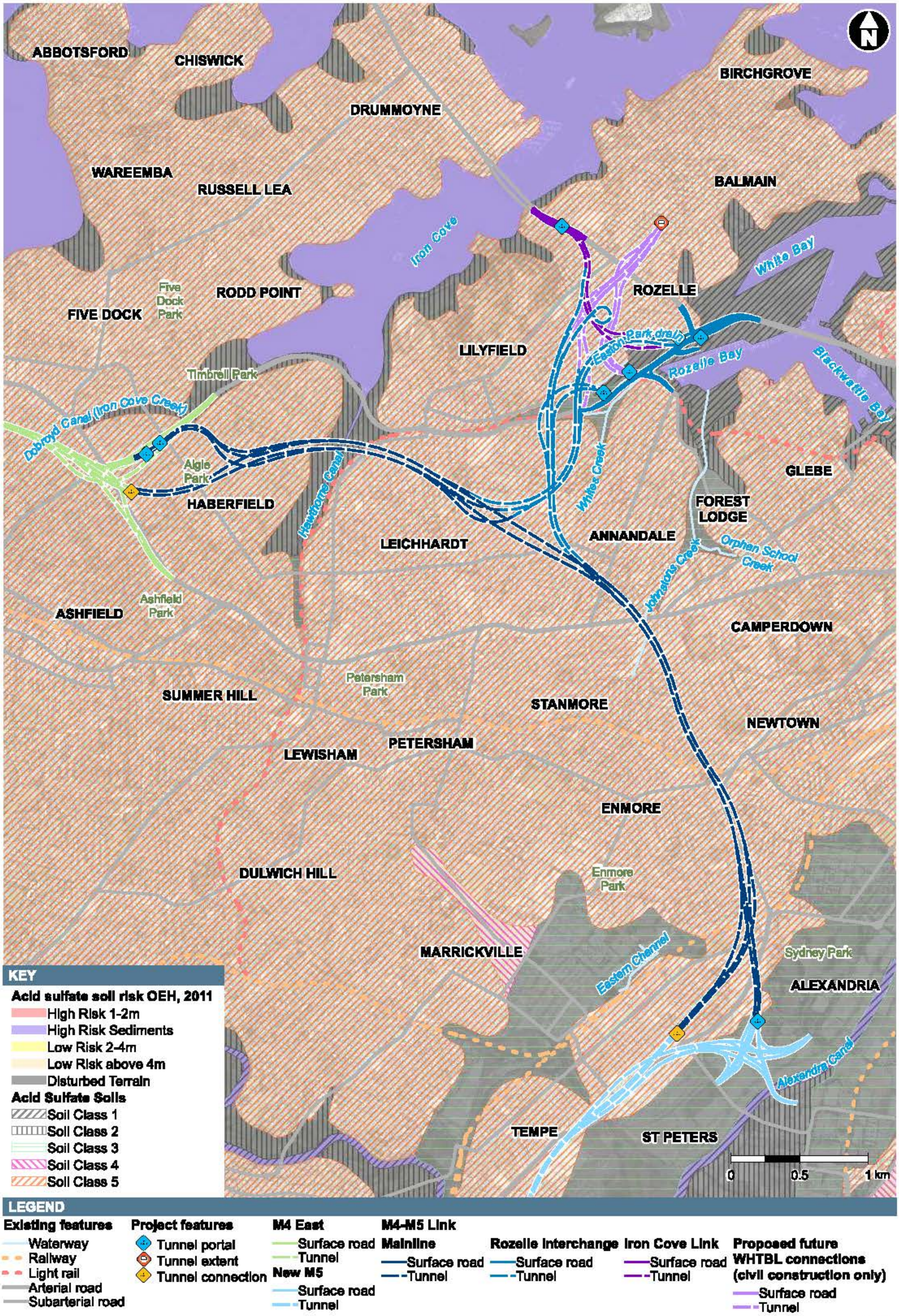


Figure 15-4 Acid sulfate soil risk areas within the study area

15.2.2 Water quality

Catchments and waterways

Table 15-7 outlines the sub-catchments which form part of the larger Sydney Harbour and Parramatta River and Cooks River catchments as relevant to the project. These sub-catchments, including the relevant project activities, are shown in **Figure 15-1**.

Table 15-7 Sub-catchments relevant to the project

Catchment	Sub-catchment	Project components
Sydney Harbour and Parramatta River catchment	Dobroyd Canal (Iron Cove Creek)	Wattle Street interchange and associated construction ancillary facilities at Haberfield/Ashfield (C1a, C2a/C2b, C3a, C1b and C3b)
	Hawthorne Canal	Darley Road civil and tunnel site (C4) and associated water treatment facility
	Whites Creek	Rozelle interchange, surrounding roads and associated construction ancillary facilities and works (C5, C6 and C7)
	Easton Park drain	Rozelle interchange and associated construction ancillary facilities (C5, C6 and C7)
	Rozelle Bay	Rozelle interchange, surrounding roads and associated construction ancillary facilities (C5, C6 and C7)
	White Bay	Victoria Road surface runoff
	Iron Cove	Iron Cove Link civil site (C8), surface works and water treatment facility
	Johnstons Creek	Pyrmont Bridge Road tunnel site (C9)
Cooks River catchment	Alexandra Canal	St Peters interchange and Campbell Road civil and tunnel site (C10)

The majority of the project footprint is located within the Sydney Harbour and Parramatta River catchment, the main tributary of which is the Parramatta River. The southern portion of the project footprint is located within the Cooks River catchment, which discharges into Botany Bay at Mascot. The waterways and associated catchments within the study area are shown in **Figure 15-1**.

Key waterways within the Sydney Harbour and Parramatta River catchment and the parts of the project relevant to those waterways are outlined in **Table 15-8** and described in detail in **Appendix Q** (Technical working paper: Surface water and flooding).

Table 15-8 Summary description of key waterways within the study area

Waterway	Description	Project components
Dobroyd Canal (Iron Cove Creek)	Dobroyd Canal (Iron Cove Creek) drains parts of the inner western suburbs of Ashfield, Burwood, Haberfield, Croydon, Drummoyne and Canterbury and discharges into Iron Cove (Cardno Lawson Treloar 2008). Dobroyd Canal (Iron Cove Creek) is a 1st order stream and is mapped as Key Fish Habitat downstream of Ramsay Street, Haberfield.	Dobroyd Canal (Iron Cove Creek) runs parallel to the Wattle Street interchange and the proposed tunnel portal of the M4-M5 Link. The Wattle Street civil and tunnel site (C1a), Haberfield civil and tunnel site (C2a)/ Haberfield civil site (C2b), Northcote Street civil site (C3a), Parramatta Road West civil and tunnel site (C1b) and Parramatta Road East civil site (C3b) are located within the Dobroyd Canal (Iron Cove Creek)catchment. The Wattle Street interchange and remaining project land at construction ancillary facilities

Waterway	Description	Project components
		at Haberfield and Ashfield would drain to Dobroyd Canal (Iron Cove Creek) during operation.
Hawthorne Canal	Hawthorne Canal starts at Lewisham and flows into Iron Cove at Dobroyd Point. It was originally a natural waterway known as Long Cove Creek but has since been straightened and given artificial banks. The channel is generally constructed from unreinforced concrete with the base of the channel comprising paved brick for a section upstream of Parramatta Road. Hawthorne Canal is a 1st order stream and is mapped as Key Fish Habitat downstream around Marion Street, Leichhardt.	The mainline tunnel alignment crosses beneath Hawthorne Canal adjacent to Hawthorne Parade, around 300 metres upstream of Iron Cove. The proposed operational water treatment facility at Darley Road at Leichhardt would discharge to Hawthorne Canal. The Darley Road civil and tunnel site (C4) is located within the catchment.
Whites Creek	Whites Creek is a brick and concrete-lined channel that flows through the suburbs of Leichhardt and Marrickville and discharges into Rozelle Bay. The Whites Creek catchment is heavily urbanised and comprises an area of around 262 hectares. Whites Creek at The Crescent is a 1st order stream.	The lower reach of Whites Creek is located to the south of the Rozelle interchange and associated road upgrades. Project works in this area would include the redevelopment of City West Link and The Crescent intersection, raising the level of sections of these roads, upgrade of the existing bridge structure that crosses Whites Creek at The Crescent and naturalisation of Whites Creek. The Crescent civil site (C6) is located at the confluence between Whites Creek and Rozelle Bay.
Easton Park drain	The Easton Park drain runs between Denison Street (adjacent to Easton Park) and Rozelle Bay at Rozelle and conveys runoff from a heavily urbanised catchment of around 55 hectares. Easton Park drain is a 1st order stream.	It is proposed to divert the Easton Park drain into a new channel to convey flows through Rozelle Rail Yards, with the former Easton Park drain decommissioned. An upgraded culvert would be provided to discharge flows into Rozelle Bay. An overland flow component would also be provided in the Rozelle Rail Yards to convey flooding to Rozelle Bay via box culverts below City West Link.
Johnstons Creek	The Johnstons Creek catchment is located within the suburbs of Glebe, Annandale, Petersham and Newtown. The catchment is heavily urbanised and comprises a total area of around 460 hectares (WMA Water 2014) and at this location, is a 1st order stream.	The mainline tunnel traverses beneath Johnstons Creek adjacent to Bridge Road at Stanmore, south of Parramatta Road. The Pyrmont Bridge Road tunnel site (C9) is located within the Johnstons Creek catchment.

Waterway	Description	Project components
Rozelle Bay	The Rozelle Bay catchment is highly urbanised and comprises a total area of around 857 hectares. Rozelle Bay is located between the suburbs of Glebe, Annandale, Lilyfield and Rozelle with flow inputs from Whites Creek, Johnstons Creek and Easton Park drain.	Rozelle Bay would be a receiving waterway for discharge from the operational water treatment facility at the Rozelle Rail Yards for runoff from the proposed Rozelle interchange and associated road upgrades. A new outlet would be constructed within Rozelle Bay to receive the flows from the Rozelle interchange. The Rozelle civil and tunnel site (C5), The Crescent civil site (C6) and Victoria Road civil site (C7) are located within the Rozelle Bay catchment.
Iron Cove	The Iron Cove catchment is a bay within the Parramatta River estuary. It is highly urbanised and comprises a total area of around two hectares. Iron Cove is a 2nd order stream and has been mapped as Key Fish Habitat.	A portion of the surface road upgrades (ie the widening of a section of Victoria Road) associated with the Iron Cove Link would drain into Iron Cove, using existing outlets. The Iron Cove Link civil site (C8) and proposed bioretention facility and car park improvement works within King George Park (adjacent to Manning Street at Rozelle) are located within the Iron Cove catchment.
White Bay	The White Bay catchment is highly urbanised and comprises a total area of around 163 hectares.	A portion of the proposed Victoria Road upgrade between Hornsby Street and Robert Street would drain to White Bay via the existing surface drainage network.
Alexandra Canal	The Alexandra Canal catchment (including Sheas Creek) comprises an area of around 23 square kilometres and receives runoff from Alexandria, Rosebery, Erskineville, Beaconsfield, Zetland, Waterloo, Redfern, Newtown, Eveleigh, Surry Hills and Moore Park. Near St Peters interchange, Alexandra Canal is a 2nd order stream.	The St Peters interchange is located in the catchment of Alexandra Canal. The underground connections to the St Peters interchange and ventilation facility are located in the catchment of Alexandra Canal. The Campbell Road civil and tunnel site (C10) is located within the Alexandra Canal catchment. Alexandra Canal is a 2nd order stream within the vicinity of St Peters interchange.

Rozelle Bay, Iron Cove, White Bay, Alexandra Canal and downstream portions of Dobroyd Canal (Iron Cove Creek) and Hawthorne Canal have been mapped as Key Fish Habitat, as defined in the *Fisheries Policy and Guidelines for Fish Habitat Conservation and Management* (update 2013) (Fairfull 2013). The project's receiving waters are marine environments and include the intertidal and subtidal ecosystem of Sydney Harbour and its estuarine tributaries. An assessment of the potential impacts of the project on Key Fish Habitat is provided in **Chapter 18** (Biodiversity).

Geomorphology

The waterways within the study area are hard lined (eg concrete channel, piped channel, brick channel, underground concrete channel) stormwater channels, with the exception of Alexandra Canal, which has an unlined base and hard lined banks. Sea walls have been constructed around the shoreline of Rozelle Bay and White Bay where development occurs up to the shoreline, with boat vessel moorings also located within the bays. The Iron Cove shoreline comprises a mixture of sea wall and vegetated zones with parkland and residential development occurring adjacent to the shoreline.

Current naturalisation proposals

Sydney Water is investigating the potential naturalisation of a section of Whites Creek at Annandale. The area being investigated is a 400 metre length of the creek corridor upstream of its outlet to Rozelle Bay. The concrete lined creek channel is in need of repair and the proposal would remove the deteriorated concrete banks and naturalise and rehabilitate the channel. A concept design for the works has been prepared by Sydney Water but at this stage, the design and construction timelines are not known.

Similar investigations are also underway by Sydney Water to rehabilitate about 600 metres of the concrete lined Johnstons Creek channel from the outlet at Rozelle Bay at Annandale, and about 200 metres of Iron Cove Creek east of Ramsay Street at Haberfield, both of which are in need of repair. Sydney Water is looking to develop naturalising solutions where possible. The early concept design for the naturalisation of the section of Iron Cove Creek proposes features like creek banks made of rocks and native plants and some banks turned into salt marsh areas. A similar, final concept design for the Johnstons Creek channel has been prepared. The design and construction timelines for these works are still being investigated.

Sydney Water is also preparing a proposal to implement drainage upgrades at Easton Park at Rozelle. This would involve diversion of an existing drain to a bioretention basin, designed to treat a portion of stormwater flows. The basin would remove a portion of pollutants generated by the urban catchment and may also provide the potential for re-use as irrigation for the park. The design for the project is understood to be prepared in 2017 with construction scheduled for 2018.

Surface water quality

Surface water quality in the study area is influenced by several factors including:

- Current and former polluting land uses within the catchments
- Stormwater and sewage overflows and leachate from contaminated and/or reclaimed land
- Urbanisation of the catchments and subsequent reduction in permeable area, increasing run-off and pollutant loads entering waterways
- Illegal dumping.

A review of water quality data was undertaken (including samples collected as part of the water quality monitoring program for the project as outlined in **section 15.1.7**) to determine the water quality of waterways in the study area. These are detailed in **Appendix Q** (Technical working paper: Surface water and flooding) and summarised in **Table 15-9**. Water quality monitoring results are presented in Annexure A of **Appendix Q** (Technical working paper: Surface water and flooding).

Table 15-9 Existing water quality conditions in the study area

Waterway	Samples collected/data obtained	Description of water quality
Dobroyd Canal (Iron Cove Creek)	• Samples collected at SW08 and SW09 • Water quality data from samples collected as part of the M4 East project	• Elevated concentrations of heavy metals (copper, chromium, lead, nickel and zinc) and nutrients (phosphorus, nitrogen and nitrate) were recorded in tidal and non-tidal zones • The pH was outside guideline levels and the turbidity exceeds guideline levels on some occasions • High electrical conductivity (EC) indicates brackish conditions on occasion, indicating this location may be tidally influenced • Total recoverable hydrocarbons were detected

Waterway	Samples collected/data obtained	Description of water quality
Hawthorne Canal	• Samples collected at SW05 and SW06 • Water quality data from samples collected as part of the M4 East project	• Elevated concentrations of heavy metals (chromium, copper, lead and zinc) and nutrients (phosphorus, nitrogen and nitrate) were recorded • On some occasions, the pH was outside guideline levels and the turbidity exceeds guideline levels
Whites Creek	• Samples collected at SW02 • Samples collected by The University of Sydney on behalf of UrbanGrowth NSW within a tidally influenced location (at SW02) as part of The Bays Precinct transformation project between June and September 2016	• Elevated concentrations of heavy metals (chromium, copper, lead and zinc), phosphorus, nitrogen, nitrate and oxides of nitrogen were recorded • On some occasions the pH was outside guideline levels and the turbidity exceeds guideline levels
Easton Park drain	• Samples collected at SW07	• Elevated concentrations of heavy metals (copper, lead, and zinc) and nutrients (nitrogen phosphorus and nitrate) were recorded • On some occasions, the pH was outside guideline levels and the turbidity exceeded guideline levels
Johnstons Creek	• Samples collected at SW03, SW04 and SW14 • Samples collected by The University of Sydney on behalf of UrbanGrowth NSW within a tidally influenced location (at SW01) as part of The Bays Precinct transformation project between June and September 2016	• Elevated concentrations of heavy metals (cadmium, copper, chromium, lead, nickel and zinc), nitrogen, phosphorous and nitrate were recorded • On some occasions the pH was outside guideline levels and the turbidity exceeded guideline levels • EC indicates brackish conditions and that this location may be tidally influenced • Total recoverable hydrocarbons have been detected at SW04
Rozelle Bay	• Samples collected at SW01 • Samples collected by The University of Sydney on behalf of UrbanGrowth NSW at BW1 as part of The Bays Precinct transformation project between June and September 2016	• Elevated concentrations of heavy metals (copper, chromium, lead and zinc), nitrogen, phosphorous, nitrate, oxides of nitrogen, ammonia and chlorophyll have been recorded • On some occasions the pH is outside guideline levels and the turbidity exceeds guideline levels

Waterway	Samples collected/data obtained	Description of water quality
Iron Cove	• Samples collected at SW11 and SW12	• Elevated concentrations of metals (copper, chromium, lead, mercury and zinc), nitrogen, nitrate and phosphorous have been recorded • Turbidity exceeds guideline values • The pH was outside guideline levels on occasions
White Bay	• Samples collected by The University of Sydney on behalf of UrbanGrowth NSW at BW2 as part of The Bays Precinct transformation project between June and September 2016	• Elevated concentrations of metals (copper and zinc), nitrogen, nitrate and phosphorous have been recorded • Turbidity also exceeds the guideline values
Alexandra Canal	• Samples collected at SW10 • Samples collected at SW01 as part of the New M5 project surface water sampling conducted between June 2015 and November 2015	• Elevated pH, concentrations of metals (copper, lead, chromium, nickel, manganese and zinc) and nutrients (nitrogen, nitrate and phosphorus) and turbidity have been recorded • The pH was also outside guideline levels on occasions

Sensitive receiving environments

A sensitive receiving environment is an environment that has high conservation or community value, or that supports ecosystem or human uses of water, and that is particularly sensitive to pollution or degradation of water quality.

The project has the potential to interact with the following sensitive receiving environments:

- Protected wetlands at Iron Cove
- Iron Cove (classified as a water recreation zone)
- Johnstons Creek constructed wetland at Federal Park
- Whites Creek constructed wetland at Whites Creek Valley Park
- Mapped Key Fish Habitat at Rozelle Bay, Iron Cove, White Bay, Alexandra Canal and downstream portions of Dobroyd Canal (Iron Cove Creek) and Hawthorne Canal
- Parramatta River Estuary, Cooks River and Botany Bay
- Cooks River
- Seagrasses in Botany Bay.

15.3 Assessment of potential construction impacts

15.3.1 Soils

Erosion and sedimentation

Construction of the project has the potential to result in erosion and sediment migration. Surface disturbance and vegetation removal exposes soils and may weaken surface soil structure. This could lead to erosion sedimentation and soil slippage within and around waterways and slopes in the study area, particularly during periods of high wind or rainfall. Areas of high erosion potential are at a higher risk of being subject to erosion and sedimentation. These areas are identified in **section 15.2.1**.

Uncompacted or unconsolidated materials (such as excavated and stockpiled soils) have the potential to leave construction areas during rain (through surface water run-off) causing downstream sedimentation. Sedimentation in natural waterways can result in reduced water quality as well as smothering of vegetation and clogging of channels, impacting the natural flow paths of the waterway.

During construction, soil erosion would be adequately managed in accordance with Managing Urban Stormwater: Soils and Construction Volume 1 (Landcom 2004) and Managing Urban Stormwater: Soils and Construction Volume 2 (NSW Department of Environment and Climate Change 2008a), commonly referred to as the 'Blue Book'. The number, location and size of sediment basins would be confirmed during detailed design. The Blue Book recommends that where receiving waters are sensitive, sediment basins should be sized for an 80th percentile or 85th percentile five-day rainfall depth for disturbance periods of less than or greater than six months respectively.

Erosion and sediment control would be focussed on areas of surface disturbance (ie surface road works, construction ancillary facility sites and areas of excavation and vegetation removal). Particular emphasis would be given to areas of surface disturbance near waterways, including at Rozelle Bay, where Whites Creek naturalisation and drainage works and Easton Park drain outfall works would be undertaken. These measures would minimise the potential for sedimentation at Rozelle Bay.

There is a risk that any erosion and/or runoff within the Rozelle Rail Yards could be contaminated. Further details about water management within the Rozelle Rail Yards during construction are provided in **Chapter 16** (Contamination). To help avoid and minimise these potential impacts, a soil conservation consultant would be engaged to provide input during detailed design so as to minimise the potential for erosion and sediment migration, from the Rozelle Rail Yards specifically. The soil conservation consultant would provide input to a Construction Soil and Water Management Plan (CSWMP) which would form part of the Construction Environmental Management Plan (CEMP) that would be prepared during detailed design.

Soil salinity

Construction of the project has the potential to contribute to urban salinity through soil compaction at areas of surface disturbance, such as the construction ancillary facility sites, which can restrict groundwater flow and result in a concentrate of salt in one area. As outlined in **section 15.2.1**, urban salinity is not considered a significant concern within the project footprint.

Acid sulfate soils

The risk of acid sulfate soil varies across the project footprint. There is a high probability of encountering these soils around Rozelle Bay, Manning Street at Rozelle and St Peters interchange (see **Figure 15-4**).

Further soil testing would be conducted in areas with a high risk of acid sulfate soils prior to disturbance to confirm the presence of acid sulfate material. Testing would be carried out in areas identified as containing acid sulfate soils (or potential acid sulfate soils) as identified in **section 15.2.1** including:

- Rozelle civil and tunnel site (C5)
- The Crescent civil site (C6)
- Bioretention facility at Manning Street in Rozelle
- Campbell Road civil and tunnel site (C10).

If acid sulfate soils are identified, they would be managed in accordance with the *Acid Sulfate Soil Manual* (Acid Sulfate Soil Management Advisory Committee 1998). The manual includes procedures for the investigation, handling, treatment and management of such soils.

Appropriate measures to manage acid sulfate soils are provided in **section 15.5**. Further measures to manage acid sulfate soils would be included as part of the CSWMP which would form part of the CEMP.

15.3.2 Water quality

Discharge of tunnel wastewater

During construction, tunnelling works would result in large volumes of wastewater being generated from the following sources:

- Groundwater seepage
- Rainfall runoff into tunnel portals and ventilation shafts
- Machinery washdown runoff
- Heat and dust suppression water.

Most of the wastewater generated during tunnelling would be collected from groundwater seepage. Estimated volumes of construction wastewater are included in **Chapter 23** (Resource use and waste minimisation).

There is the potential for groundwater that seeps into the tunnels and other areas of excavation during construction to contain elevated levels of salinity. Existing groundwater quality along the tunnel alignments is variable, with Ashfield Shale typically being more saline than Hawkesbury Sandstone. Groundwater closer to Sydney Harbour and Botany tends to be more saline due to increased tidal influences. In low lying areas, groundwater may also be acidic due to acid sulfate materials.

However, considering the total amount of groundwater tunnel ingress, saline groundwater would make up a small fraction of the total volume. Further discussion around the quality of discharged groundwater is included in **Chapter 19** (Groundwater).

Previous and current land use practices, including light industrial activities, may have introduced contaminants such as hydrocarbons or heavy metals, which could impact groundwater quality at some locations. The use of chemicals in the treatment and curing process of concrete, as well as the concrete dust itself, could also result in tunnel wastewater having increased alkalinity.

Groundwater monitoring carried out for the project indicates that there are elevated levels of ammonia, total nitrogen and total phosphorus compared to ANZECC (2000) guideline levels (marine, freshwater and recreational protection levels). Other heavy metals including copper, chromium, lead, nickel and zinc were also recorded at elevated levels on a limited number of occasions (refer to **Chapter 19** (Groundwater)). Tunnel wastewater, if discharged untreated or poorly treated, has the potential to impact the receiving waterways by introducing increased nutrient loading and result in algal growth with increased risk to human health. There is also potential for reduction in visual amenity and impacts on aquatic species as a result of heavy metal or other toxicants.

The total volume of wastewater generated during construction would depend on construction activities taking place, the amount of groundwater infiltrating the tunnel, and the length of the tunnel that has been excavated. Indicative daily volumes of wastewater at each site and associated indicative discharge points are summarised in **Table 15-10**.

Tunnel wastewater would be treated prior to discharge (or disposal) to minimise impacts on receiving waterways, including Dobroyd Canal (Iron Cove Creek), Hawthorne Canal, Whites Creek, Easton Park drain, Johnstons Creek, Rozelle Bay, Iron Cove, White Bay and Alexandra Canal.

Table 15-10 Estimated daily discharge rate (kL/day) and indicative discharge points for construction wastewater

Site	Estimated daily discharge rate (kL/day)	Indicative discharge points
Wattle Street civil and tunnel site (C1a)	Managed by Haberfield civil and tunnel site	Discharges to a stormwater pipe under Parramatta Road that connects to Dobroyd Canal (Iron Cove Creek)
Haberfield civil and tunnel site (C2a)	1,200	Discharging to a stormwater pipe under Parramatta Road, connected to Dobroyd Canal (Iron Cove Creek)

Site	Estimated daily discharge rate (kL/day)	Indicative discharge points
Northcote Street civil site (C3a)	Managed by Haberfield civil and tunnel site	Discharges to a stormwater pipe under Parramatta Road that connects to Dobroyd Canal (Iron Cove Creek)
Parramatta Road West civil and tunnel site (C1b)	1,200	Discharging to a stormwater pipe under Parramatta Road that connects to Dobroyd Canal (Iron Cove Creek)
Haberfield civil site (C2b)	Managed by Parramatta Road West civil and tunnel site	Discharging to a stormwater pipe under Parramatta Road that connects to Dobroyd Canal (Iron Cove Creek)
Parramatta Road East civil site (C3b)	Managed by Parramatta Road West civil and tunnel site	Discharging to a stormwater pipe under Parramatta Road that connects to Dobroyd Canal (Iron Cove Creek)
Darley Road civil and tunnel site (C4)	700	Existing drainage system draining to Hawthorne Canal
Rozelle civil and tunnel site (C5)	2,400	Existing drainage system at City West Link draining to Rozelle Bay Easton Park drain discharging to Rozelle Bay
The Crescent civil site (C6)	10	Existing drainage system at City West Link draining to Rozelle Bay
Victoria Road civil site (C7)	200	Existing drainage system at Victoria Road draining to White Bay
Iron Cove Link civil site (C8)	300	Existing drainage system at Victoria Road draining to Iron Cove
Pyrmont Bridge Road tunnel site (C9)	1,200	Discharging to a stormwater pipe under Parramatta Road, connected to Johnstons Creek
Campbell Road civil and tunnel site (C10)	1,200	Discharging to a stormwater pipe connected to Alexandra Canal

During construction, the wastewater collected in the tunnel would be tested and treated at construction water treatment facilities prior to reuse or discharge. The type, arrangement and performance of construction water treatment facilities would be further refined during detailed design, and may consist of:

- Primary settling tanks/ponds to remove sand and silt sediment fractions as well as oil and grease
- A pH balance/metals oxidation tank with primary flocculation whereby individual particles of clay are clumped together
- Secondary flocculation tanks
- Clarifiers to remove sediment and residual oil
- Filtration/settlement.

Temporary construction water treatment facilities within the construction ancillary facilities would be designed to treat dirty construction water and groundwater and would be based on the targets outlined in **section 15.1.5**, which would be refined during detailed design. The level of treatment provided would consider the characteristics of the waterbody, any operational constraints or practicalities and associated environmental impacts and be developed in accordance with ANZECC (2000) and in consideration of the relevant NSW WQOs.

Considering the highly disturbed nature of all receiving waterways and temporary nature of the construction phase, an ANZECC (2000) species protection level of 90 per cent for toxicants is considered appropriate for adoption as a discharge criterion, where practical and feasible. The discharge criteria for the treatment facilities would be finalised and included in the CSWMP.

Mobilisation of sediments and pollutants during surface works

Surface construction activities may disturb soils and other materials that have the potential to impact water quality if not effectively managed, including:

- Exposure of soils during earthworks has the potential to result in soil erosion and off-site movement of eroded sediments by wind and/or stormwater to receiving waterways
- Demolition works have the potential to disturb and/or spread sources of pollutants that could affect water quality (including asbestos and other contaminated building materials, hydrocarbons or fluids associated with demolition processes and dust)
- Disturbance of contaminated land, which could be mobilised by stormwater runoff and transported to downstream waterways, potentially increasing contaminant concentrations in the receiving environment (refer to **section 15.3.1** and **Chapter 16** (Contamination))
- Exposure of potential acid sulfate soils, which may result in generation of sulfuric acid and subsequent acidification of waterways and mobilisation of heavy metals into the environment if poorly managed
- Rinse water from plant washing and concrete slurries may contain polluting contaminants which, if discharged off-site, could impact on surface water quality
- Potential spills or leaks of fuels and/or oils from maintenance or re-fuelling of construction plant and equipment or vehicle/truck incidents could potentially be conveyed to downstream waterways via drainage infrastructure
- Disturbance of Whites Creek and Rozelle Bay during bridge construction works as part of the realignment of The Crescent and channel widening of Whites Creek to manage flooding and drainage and naturalisation works. This may lead to disturbance of contaminated sediments and erosion of exposed banks once the existing channel concrete lining has been removed (and prior to construction of the naturalised channel treatment)
- Construction of new stormwater outlets to receiving bays (Rozelle Bay and Iron Cove) would cause localised mobilisation of potentially contaminated sediments. Sediments settled on top of the hard, lined base of Whites Creek would also be disturbed.

Table 15-11 summarises the potential water quality impacts during construction of the project. These impacts are regularly encountered on major construction projects, are well understood and management measures are well developed and consistently applied to minimise impact during construction.

Residual impacts on water quality during construction

The proposed surface water management measures outlined in **section 15.5** aim to minimise short term impacts on the receiving waterways during construction. With the implementation of the management measures, and in the context of the overall catchment, any potential short term impacts are unlikely to have a material impact on ambient water quality within the receiving waterways.

Therefore, the project is likely to have a negligible influence on whether NSW WQOs are protected (if currently met) or achieved (if currently not met) during construction.

Table 15-11 Construction surface water quality impact summary

Location	Construction activities / incidents	Potentially affected waterways	Potential impacts
Civil and tunnel sites (excluding Rozelle civil and tunnel site) including their adjacent footprints, including: • Wattle Street civil and tunnel site at Haberfield (C1a) • Haberfield civil and tunnel site at Haberfield (C2a) • Northcote Street civil site at Haberfield (C3a) • Parramatta Road West civil and tunnel site at Ashfield (C1b) • Haberfield civil site at Haberfield (C2b) • Parramatta Road East civil site at Haberfield (C3b) • Darley Road civil and tunnel site at Leichhardt (C4) • The Crescent civil site at Annandale (C6) • Victoria Road civil site at Rozelle (C7) • Iron Cove Link civil site at Rozelle (C8) • Pyrmont Bridge Road tunnel site at Annandale (C9) • Campbell Road civil and tunnel site at St Peters (C10).	• Vegetation clearance and topsoil stripping • Demolition works • Establishment of construction ancillary facilities, access and utility supply • Excavations • Concrete works • Stockpiling of spoil, construction materials and demolition materials • Relocation of utilities • Access and egress of vehicles to construction ancillary facilities and public roads • Accidental spills/material drops during transportation of building waste from demolition sites with pollutants mobilised into waterways • Spills of chemicals/fuel stored on site • Operation of construction water treatment facility • Activities associated with construction for permanent works	• Dobroyd Canal (Iron Cove Creek) • Hawthorne Canal • Iron Cove • White Bay • Johnstons Creek • Alexandra Canal	• Erosion and mobilisation of exposed soils, open cuts and stockpiles by stormwater runoff and wind leading to sedimentation of waterways • Exposure of acid sulfate soils or contaminated soils which, if mobilised via stormwater runoff, could acidify or pollute waterways • Dust, litter and pollutants associated with building materials and demolition waste being mobilised by wind and stormwater runoff into waterways • Leakage/spills of hydrocarbons or other chemicals from machinery with pollutants conveyed by stormwater runoff into waterways • Increased alkalinity due to transport of chemicals used in treatment and curing of concrete and concrete dust to waterways by stormwater or wind • Vehicles transferring soil to adjacent roads and stormwater runoff conveying soil and pollutants into waterways

Location	Construction activities / incidents	Potentially affected waterways	Potential impacts
Construction works at Rozelle including the Rozelle civil and tunnel site (C5) and wider Rozelle surface works	• Vegetation clearance and topsoil stripping • Demolition works • Establishment of construction ancillary facilities, access and utility supply • Excavations • Concrete works • Stockpiling of spoil, construction materials and demolition materials • Relocation of utilities • Access and egress of vehicles to construction ancillary facilities and public roads • Accidental spills/material drops during transportation of building waste from demolition sites with pollutants mobilised into waterways • Spills of chemicals/fuel stored on site • Operation of machinery • Operation of construction water treatment facility (C5 only) • Activities associated with construction for permanent works	• Rozelle Bay • Easton Park drain • White Bay • Whites Creek	• Erosion and mobilisation of exposed soils and open cuts by stormwater runoff and wind leading to sedimentation of waterways • Scour of exposed channel bank material during Whites Creek naturalisation works and subsequent soil mobilisation and sedimentation • Exposure of acid sulfate soils or contaminated soils which, if mobilised via stormwater runoff, could acidify or pollute waterways • Dust, litter and other building materials being mobilised by wind and stormwater runoff into waterways • Leakage/spills of hydrocarbons or other chemicals from machinery with pollutants conveyed by stormwater runoff into waterways • Increased alkalinity due to transport of chemicals used in treatment and curing of concrete and concrete dust to waterways by stormwater or wind • Vehicles transferring soil to adjacent roads and stormwater runoff conveying soil and pollutants into waterways

Location	Construction activities / incidents	Potentially affected waterways	Potential impacts
	• Bridgeworks associated with new road and pedestrian bridges across and adjacent to Whites Creek • Whites Creek naturalisation works • Realignment of The Crescent • Upgraded culvert under City West Link		
Potential new permanent drainage outlets to Rozelle Bay, Iron Cove and Whites Creek	• Construction of the drainage outlets • Discharges from the outlets during construction	• Rozelle Bay • Iron Cove • Whites Creek	• Mobilisation of sediments and contaminants within the sediments at outlet locations • Scouring of sediments at outlet locations
Drainage infrastructure adjustments and upgrades	• Earthworks during drainage upgrades • Earthworks and construction of the Easton Park drain diversion	• Iron Cove • Whites Creek • Easton Park drain • Rozelle Bay	• Mobilisation of exposed soils by stormwater runoff leading to sedimentation of waterways • Exposure of acid sulfate soils or contaminated soils which, if mobilised via stormwater runoff, could acidify or pollute waterways • Increased alkalinity due to curing of concrete
Construction of new stormwater quality treatment facilities	• Vegetation removal • Earthworks to facilitate construction of the devices • Access and egress of vehicles to construction ancillary	• Iron Cove • Rozelle Bay	• Erosion and mobilisation of exposed soils and open cuts by stormwater runoff and wind leading to sedimentation of waterways • Exposure of acid sulfate soils or contaminated soils which if mobilised

Location	Construction activities / incidents	Potentially affected waterways	Potential impacts
	facilities and public roads • Activities associated with construction for permanent works • Operation of machinery		via stormwater runoff could acidify or pollute waterways • Leakage / spills of hydrocarbons or other chemicals from machinery with pollutants conveyed by stormwater runoff into waterways • Vehicles transferring soil to adjacent roads and stormwater runoff conveying soil and pollutants into waterways

15.4 Assessment of potential operational impacts

15.4.1 Soils

Erosion and sedimentation

During operation of the project, there is potential for recently disturbed soils to be susceptible to erosion, particularly during initial periods of landscaping and re-establishment of vegetation. This may occur in areas where soft landscaping is proposed for the project, including open space areas at the Rozelle interchange, adjacent to disturbed areas, along embankments and in the reinstatement of temporary ancillary facilities where topsoil is settling and vegetation is establishing. Landscaping at the Rozelle interchange also presents the greatest risk of sediment loads entering waterways through the stormwater system, due to the extent of landscaping proposed and the proximity to waterways.

Soil stabilisation work may be required following construction to prevent further erosion, topsoil loss or soil migration. This work is likely to be required following severe storms. Measures to manage erosion will be included in the Operational Environmental Management Plan (OEMP).

15.4.2 Water quality

During operation, there is potential for surface water quality to be impacted by the following processes and activities:

- Increased stormwater runoff from an overall increase in impervious area
- Spills or leaks of fuels and/or oils from vehicle accidents and/or operational facility and equipment
- Erosion of recently disturbed areas resulting in sedimentation of waterways
- Scour and mobilisation of contaminated sediments at proposed new drainage outlet locations and increased flow to existing locations (eg Rozelle Bay and Alexandra Canal).

These processes and activities, and their potential impacts on surface water quality in the study area are described in more detail in the following sections.

Operational water quality

The project would increase impervious areas (such as road pavement) that would be exposed to direct rainfall and increase runoff volume and associated pollutant mobilisation. Runoff from road pavement would typically contain pollutants such as sediments, nutrients, oils and greases, petrochemicals and heavy metals, which could potentially impact on water quality when discharged into receiving waterways.

MUSIC modelling was carried out to assess the performance of the proposed water quality treatment measures against pollutant reduction targets (see **section 15.1.7**). A summary of the MUSIC modelling results are provided in **Table 15-12**. The modelling results for the main locations where water would be discharged (Rozelle Bay, Iron Cove, White Bay and Whites Creek) and for the project as a whole indicate that:

- The project would generally reduce the mean annual stormwater pollutant loads being discharged to the Sydney Harbour and the Parramatta River estuary, when compared to the existing conditions
- The project would generally reduce the mean annual stormwater pollutant loads being discharged to the five receiving waterways, when compared to the existing conditions (except for total phosphorus loading to Dobroyd Canal (Iron Cove Creek), which would be slightly higher than the existing loading)
- The stormwater mean annual pollutant load reduction targets (see **section 15.1.5**) would not be achieved for the project or for the individual catchments, based on the treatment measures that could practically or readily be implemented.

The pollutant load reduction targets were not achievable given the lack of available space within the highly constrained project footprint. Oversizing other treatment measures to offset the reduced treatment for the project is not practical within the available project footprint, given that improvements in treatment performance are reduced as treatment facility footprint increases. An increased treatment size at Rozelle would reduce the area available for operational road infrastructure and open space.

In these highly constrained areas, good practice treatment techniques would be deployed where feasible and practical, as outlined in **section 15.5**. By reducing the mean annual stormwater pollutant load compared to existing conditions, the project would provide a beneficial effect in terms of reducing stormwater pollutant loads to the Sydney Harbour and Parramatta River catchment.

Table 15-12 MUSIC modelling results for operational water quality (kilograms per year)

Location	M4 M5 Link operation source load	M4 M5 Link operation residual load (following treatment)	Per cent reduction	Existing residual load	Impact compared to existing conditions
Project wide					
Total suspended solids	48,600	8,450	83%	33,900	-25,450
Total Phosphorus	81	39	52%	58	-19
Total Nitrogen	353	209	41%	271	-62
Gross Pollutants	3,520	242	93%	2,530	-2,288
Rozelle Bay					
Total suspended solids	36,500	5,300	86%	24,500	-19,200
Total Phosphorus	61	28	55%	42	-15
Total Nitrogen	271	156	43%	202	-46
Gross Pollutants	2,710	108	96%	1,860	-1,752
Iron Cove					
Total suspended solids	7,470	2,170	71%	6,680	-4,510
Total Phosphorus	13	6	56%	11	-6
Total Nitrogen	51	31	39%	49	-18
Gross Pollutants	501	103	80%	488	-385
White Bay					
Total suspended solids	1,130	240	79%	1,080	-840
Total Phosphorus	2	1	27%	2	-0.4
Total Nitrogen	8	5	30%	7	-2
Gross Pollutants	76	8	90%	72	-65
Whites Creek					
Total suspended solids	1,850	395	79%	1,650	-1,255
Total Phosphorus	3	2	27%	3	-1
Total Nitrogen	13	9	30%	12	-3

Location	M4 M5 Link operation source load	M4 M5 Link operation residual load (following treatment)	Per cent reduction	Existing residual load	Impact compared to existing conditions
Gross Pollutants	124	13	90%	115	-103
Dobroyd Canal (Iron Cove Creek)					
Total suspended solids	1,600	343	79%	640	-301
Total Phosphorus	3	2	27%	1	1
Total Nitrogen	11	8	30%	8	-0.4
Gross Pollutants	108	10.9	90%	92	-81

Notes:

Green shading indicates target is achieved

Orange shading indicates target not achieved

Blue shading indicates reduced load compared to existing conditions

Yellow shading indicates increased load compared to existing conditions

Stormwater runoff from the project would be controlled by a stormwater quality treatment system, designed in accordance with the project stormwater quality objectives based on pollutant load reduction consistent with the Sydney Harbour and Botany Bay water quality improvement plans rather than a specific rainfall event (see **section 15.1.5**). These would be developed during detailed design and included in the CSWMP. This would achieve the environmental outcome required from a treatment device and is standard practice for construction projects of this nature.

Where practical and appropriate, operational treatment systems would incorporate a high flow bypass for a minimum of a three-month annual recurrence interval. This would enable treatment of the majority of most runoff events, while protecting the treatment devices from scour or damage associated with larger rainfall events.

Refer to **Appendix Q** (Technical working paper: Surface water and flooding) for full details of the stormwater drainage infrastructure and proposed stormwater quality treatment systems.

Tunnel drainage and treatment

Tunnel drainage

The tunnels would include drainage infrastructure to capture groundwater and stormwater ingress, spills, maintenance wastewater, fire suppressant deluge and other potential water sources. The two tunnel drainage streams are expected to produce flows containing a variety of pollutants that require slightly different treatment before discharge to manage adverse impacts on the receiving environment. The pre-treatment water quality of each wastewater stream is expected to vary considerably, and consequently it is likely that the two streams would need to be collected and treated separately.

Tunnel wastewater from the mainline tunnels would be pumped to a water treatment facility at the Darley Road motorway operations complex (MOC1) at Leichhardt. Options for discharge of treated water from the Darley Road water treatment plant include:

- Direct discharge to Hawthorne Canal, which would require a pipe to be installed along Canal Road and the construction of a new outlet in the wall of the Hawthorne Canal
- Direct discharge to the existing stormwater pipework in an adjoining road (ie Canal Road), which would require a pipe to be installed to connect to existing piped drainage
- Direct discharge into the sewer system located on the site, which would require a Trade Waste Agreement with Sydney Water.

Further detail regarding these discharge options is included in **Appendix F** (Utilities Management Strategy). The preferred option for treated water discharge from the Darley Road water treatment plant would be confirmed during detailed design.

Tunnel wastewater from the Rozelle interchange tunnels and Iron Cove Link would be pumped to an operational water treatment facility at the Rozelle East motorway operations complex (MOC3), with flows being treated at the constructed wetland at Rozelle civil and tunnel site (C5) and then discharged into Rozelle Bay.

At the St Peters interchange, a small portion (around 1.6 kilometres) of tunnel would also drain to the New M5 operational water treatment facility at Arncliffe, draining to the Cooks River. Other sources of water captured by the tunnel drainage system (ie washdown or a spill) would be collected in one of the tunnel sumps, assessed to determine the source, tested, and either pumped to and discharged at the surface or removed directly from the sump by tanker for treatment, and disposal elsewhere.

The combined mainline tunnel (23 litres per second) and Rozelle interchange tunnel (22 litres per second) would generate up to around 1,418 megalitres per year of groundwater.

Tunnel wastewater treatment

Elevated metals and nutrients were recorded during groundwater sampling and groundwater was identified as brackish (refer to **Chapter 19** (Groundwater)). Metal, nutrient and ammonia loading to Hawthorne Canal and Rozelle Bay is likely to increase as a result of the continuous treated groundwater discharges. To prevent adverse impacts on downstream water quality within Rozelle Bay and Hawthorne Canal, treatment facilities would be designed so that tunnel wastewater would be of suitable quality for discharge to the receiving environment.

The operational water treatment facilities would be designed such that effluent would be of suitable quality for discharge to the receiving environment and developed in accordance with the ANZECC (2000) and relevant NSW WQOs. The ANZECC (2000) 'marine' default trigger values for 95 per cent level of species protection are considered appropriate for establishing discharge criteria for parameters which require treatment, where practical and feasible (refer to **Appendix Q** (Technical working paper: Surface water and flooding)).

The project water treatment facilities would treat iron and manganese (as no 'marine' trigger value is available for iron and manganese; alternative discharge criteria are provided in **Table 15-13**). The proposed constructed wetland at Rozelle would provide 'polishing' treatment to treated groundwater flows from the Rozelle interchange and Iron Cove Link tunnels, which would likely remove a proportion of the nutrient and metal load. As no constructed wetland is proposed at Darley Road (due to space constraints), opportunities to incorporate other forms of nutrient treatment within the facility at Darley Road would be investigated during detailed design if subsequent groundwater monitoring indicates it may be required.

A qualitative assessment (refer to **Appendix Q** (Technical working paper: Surface water and flooding)) of the risk posed by treated groundwater discharges to ambient water quality within Rozelle Bay and Hawthorne Canal determined the following:

- Considering the groundwater quality and proposed treatment, impacts on ambient water quality within Rozelle Bay are likely to be negligible
- Considering the groundwater quality and proposed treatment, impacts on ambient water quality within Hawthorne Canal are likely to be negligible and localised to near the outlet.

Impacts associated with discharge quality from the Arncliffe operational water treatment facility were assessed as part of the New M5 EIS. No adverse impacts are likely to occur as a result of the minor additional flow (1.6 litres per second) draining to the Arncliffe operational water treatment facility.

Indicative operational discharge locations are provided in **Figure 15-5**.

Scour and channel geomorphology

There is potential for sediment to be scoured and mobilised where stormwater or wastewater is discharged to receiving waterways and bays including Hawthorne Canal, Dobroyd Canal (Iron Cove Creek), Rozelle Bay, Iron Cove and Whites Creek. This could increase turbidity and lead to mobilisation of contaminants that are bound to sediments.

The Whites Creek widening and improvement works would follow Sydney Water's naturalisation works and extend between Rozelle Bay and the realigned The Crescent. The design of the naturalisation works would be finalised during detailed design, but are likely to incorporate features such as sandstone blocks and vegetated benches to provide ecological benefits to the channel. The proposed channel bed and bank treatments would be hard lined.

As a result, impacts on channel form and geomorphology are unlikely to occur once the works are complete. Any vegetated zones (eg benches) would be susceptible to erosion and would be protected during the vegetation establishment period. Management measures to minimise the potential for scour are outlined in **section 15.5** and would be incorporated into the CSWMP.

Spills and leakages

Vehicle or plant and equipment leakages or a vehicle crash may cause spills of oils, lubricants, hydraulic fluids and chemicals during the operation of the project. Spills and leakages within the project footprint have the potential to pollute downstream waterways, as a result of being conveyed to waterways via the stormwater network. The severity of the potential impact would depend on the magnitude and/or location of the spill in relation to sensitive receivers, emergency response procedures and/or management measures implemented on site and the nature of the receiving environment.

Further discussion on accidental spills is included in **Chapter 25** (Hazard and risk). Spill control measures, as outlined in **section 15.5**, would be implemented to reduce and manage the potential for environmental impacts to occur.

Residual impacts on water quality during operation

As discussed in **section 15.2.2**, receiving waterways in the study area do not achieve all the Sydney Harbour and Parramatta River catchment WQOs, with records of elevated levels of some heavy metals, nutrients, turbidity and pH. MUSIC modelling carried out indicates that the project would reduce the stormwater pollutant loading to the receiving waterways when compared to the existing conditions. Therefore, residual impacts on receiving waterways are anticipated to be negligible and/or beneficial. The project is not expected to worsen the existing conditions of receiving waterways.

Tunnel water would be treated, and spill controls and water quality monitoring would be implemented to manage operational impacts on ambient water quality within the receiving waterways. With consideration to groundwater quality, proposed treatment and receiving water quality, residual impacts associated with treated tunnel water discharges to ambient water quality are likely to be negligible.

As no constructed wetland is proposed at Darley Road, opportunities to incorporate other forms of nutrient treatment (eg ion exchange or reverse osmosis) within the water treatment plant at Darley Road will be investigated during detailed design with consideration to the ongoing groundwater quality monitoring and other factors such as available space, increased power requirements and increased waste production.

In the context of the entire catchment draining to Sydney Harbour, the project is likely to have a negligible influence on achieving the Sydney Harbour and Parramatta River WQOs.

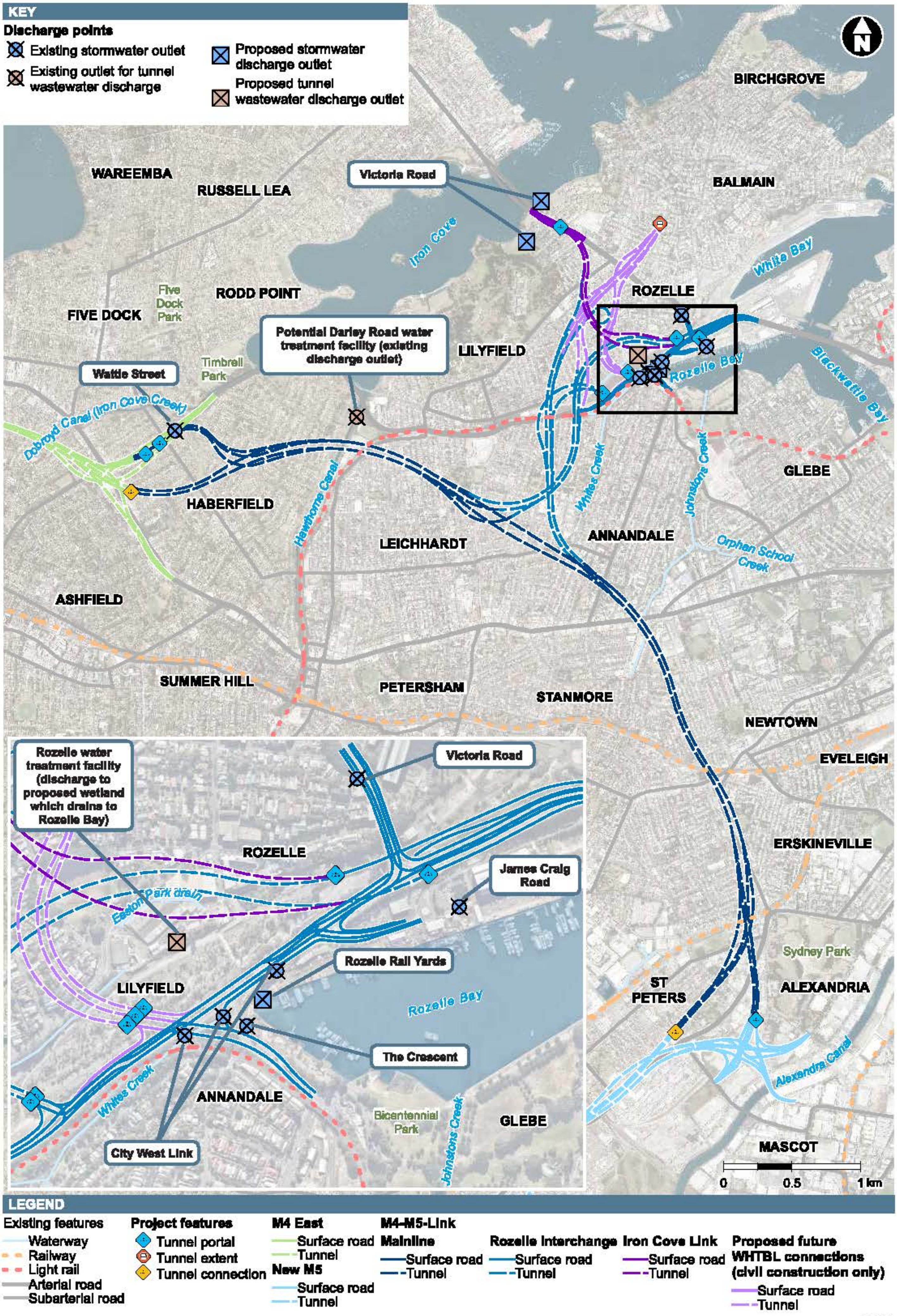


Figure 15-5 Indicative operational discharge points

15.5 Environmental management measures

Management measures would be implemented to avoid, minimise or mitigate impacts on soil and water quality within the study area. These management measures are outlined in **Table 15-13**.

Table 15-13 Environmental management measures – soil and water quality

Impact	No.	Environmental management measure	Timing
Construction			
Impacts on surface water quality	SW01	A CSWMP will be prepared for the project. The plan will include the measures that will be implemented to manage and monitor potential surface water quality impacts during construction. The CSWMP will be developed in accordance with the principles and requirements in Managing Urban Stormwater – Soils and Construction, Volume 1 (Landcom 2004) and Volume 2D (DECCW 2008), commonly referred to as the 'Blue Book'.	Construction
	SW02	A program to monitor potential surface water quality impacts due to the project will be developed and included in the CSWMP. The program will include the water quality monitoring parameters and the monitoring locations identified in Annexure E of **Appendix Q** (Technical working paper: Surface water and flooding) to the EIS where appropriate. The monitoring program will commence prior to any ground disturbance to establish appropriate baseline conditions and continue for the duration of construction, as well as for a minimum of three years following the completion of construction or until the affected waterways are certified by a suitably qualified and experienced independent expert as being rehabilitated to an acceptable condition (or as otherwise required by any project conditions of approval). Further details to be included in the program are outlined in **Appendix Q** (Technical working paper: Surface water and flooding).	Construction
Sedimentation of waterways	SW03	Erosion and Sediment Control Plans (ESCPs) will be prepared for all work sites in accordance with the Blue Book. ESCPs will be implemented in advance of site disturbance and will be updated as required as the work progresses and the sites change.	Construction
	SW04	A soil conservation specialist will be engaged for the duration of construction to provide advice regarding erosion and sediment control.	Construction
	SW05	The extent of ground disturbance and exposed soil will be minimised to the greatest extent practicable to minimise the potential for erosion.	Construction
	SW06	Disturbed ground and exposed soils will be temporarily stabilised prior to extended periods of site inactivity to minimise the potential for erosion.	Construction
	SW07	Disturbed ground and exposed soils will be permanently stabilised and proposed landscaped areas will be suitably profiled and vegetated as soon as possible following disturbance to minimise the potential erosion.	Construction

Impact	No.	Environmental management measure	Timing
Impacts on the form and aquatic habitat of Whites Creek	SW08	The proposed bridge crossing over and widening of Whites Creek, including all associated temporary and permanent infrastructure, will be designed and constructed in a manner consistent with: • *NSW Guidelines for Controlled Activities Watercourse Crossings* (DPI 2012) • *Why do Fish Need to Cross the Road? Fish Passage* Requirements *for Waterway Crossings* (Fairfull and Witheridge 2003) • *Policy and Guidelines for Fish Friendly Waterway Crossings* (NSW Fisheries February 2004) • *Policy and Guidelines for Fish Habitat Conservation and* Management (DPI Fisheries, 2013). Appropriate fish passage will be provided for crossings of fish habitat streams.	Construction
	SW09	Consultation will be undertaken with Sydney Water regarding the timing of the works at Whites Creek and compatibility of the proposed design and Sydney Water's naturalisation works.	Construction
Impacts on water quality from the discharge of treated wastewater	SW10	Temporary construction water treatment plants will be designed and managed so that treated water would be of suitable quality for discharge to the receiving environment. The level of treatment provided will consider the characteristics of the waterbody, any operational constraints or practicalities and associated environmental impacts and be developed in accordance with ANZECC (2000) and with consideration to the relevant NSW WQOs and *Protection of the Environment Operations Act 1997* (NSW). An ANZECC (2000) species protection level of 90 per cent is considered appropriate for adoption as discharge criteria for toxicants where practical and feasible. The discharge criteria for the treatment facilities will be included in the CSWMP.	Construction
Impacts on water quality from disturbance of acid sulfate soils	SW11	Procedures, prepared in accordance with the requirements of the *Acid Sulfate Soil Manual* (Acid Sulfate Soil Management Advisory Committee 1998), will be included in the CSWMP and implemented in the event that acid sulfate soils, rocks or monosulfidic black oozes are encountered during construction of the project.	Construction
Operation			
Impacts on surface water quality	OSW12	Stormwater from the project will be treated prior to discharge. Where space is available, bioretention systems or constructed wetlands will be installed. Where space is not available, other smaller devices, such as proprietary stormwater treatment devices, will be installed. The final design of treatments will be supported by MUSIC modelling and water sensitive urban design principles.	Construction and operation

Impact	No.	Environmental management measure	Timing
	OSW13	Maintenance requirements for all stormwater treatment systems and devices installed as part of the project will be identified and included in relevant operational maintenance schedules/systems.	Construction and operation
	OSW14	Spill containment will be provided on the motorway. Spill management and emergency response procedures will be documented in the OEMP or Emergency Response Plan.	Construction and operation
	OSW15	The constructed wetland at the Rozelle interchange will be appropriately designed to cater for the continuous flow of treated groundwater from the water treatment plant and onsite stormwater flows.	Construction and operation
	OSW16	The operational water treatment facilities will be designed such that effluent will be of suitable quality for discharge to the receiving environment. Discharge criteria will be developed in accordance with the ANZECC (2000) and relevant NSW WQOs, including the following discharge criteria: • 0.3 milligrams per litre for iron • 1.8 milligrams per litre for manganese. The discharge criteria for the treatment facilities will be included in the OEMP.	Construction and operation
Sedimentation or scouring effects at discharge locations	OSW17	New discharge outlets will be designed with appropriate energy dissipation and scour protection measures as required to minimise the potential for sediment disturbance and resuspension in the receiving waters. Outlet design and energy dissipation/scour protection measures will be informed by drainage modelling.	Construction
	OSW18	Existing drainage outlets that will be subject to increased inflow from the project will be assessed. If necessary, energy dissipation or scour protection will be added to prevent sediment disturbance and resuspension in receiving waters.	Construction