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/m^3)	1 hour (mg/m^3)	8 hours (mg/m^3)	1 hour ($\mu g/m^3$)	1 day ($\mu g/m^3$)	1 year ($\mu g/m^3$)	24 hours ($\mu g/m^3$)	1 year ($\mu g/m^3$)	24 hours ($\mu g/m^3$)	1 year ($\mu g/m^3$)
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 $\mu g/m^3$ value is initially a target, but became a limit in 2015. There is also an indicative 'Stage 2' limit of 20 $\mu g/m^3$ 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**.

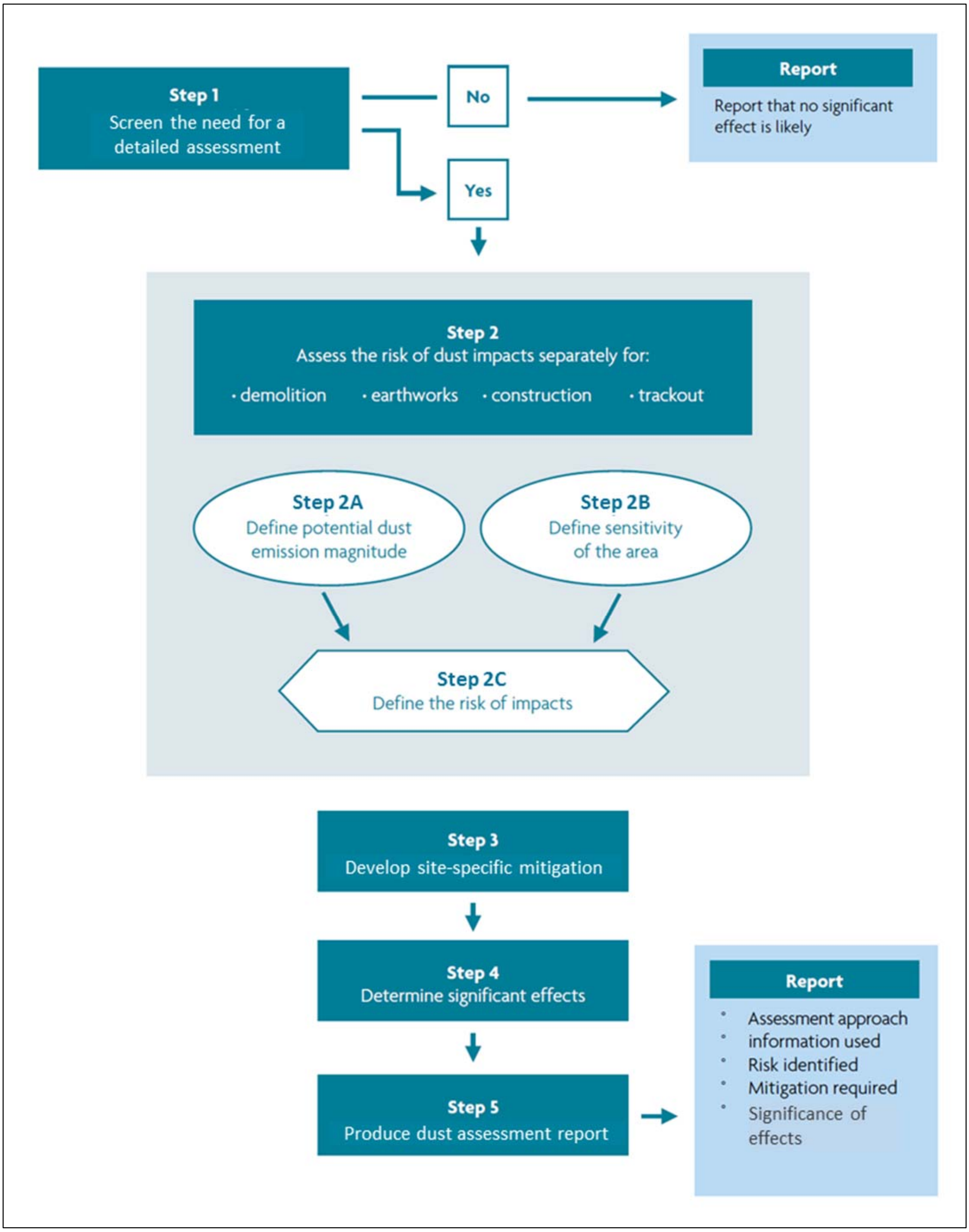

Figure 9-1 Steps in an assessment of construction dust (IAQM 2014)

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**).

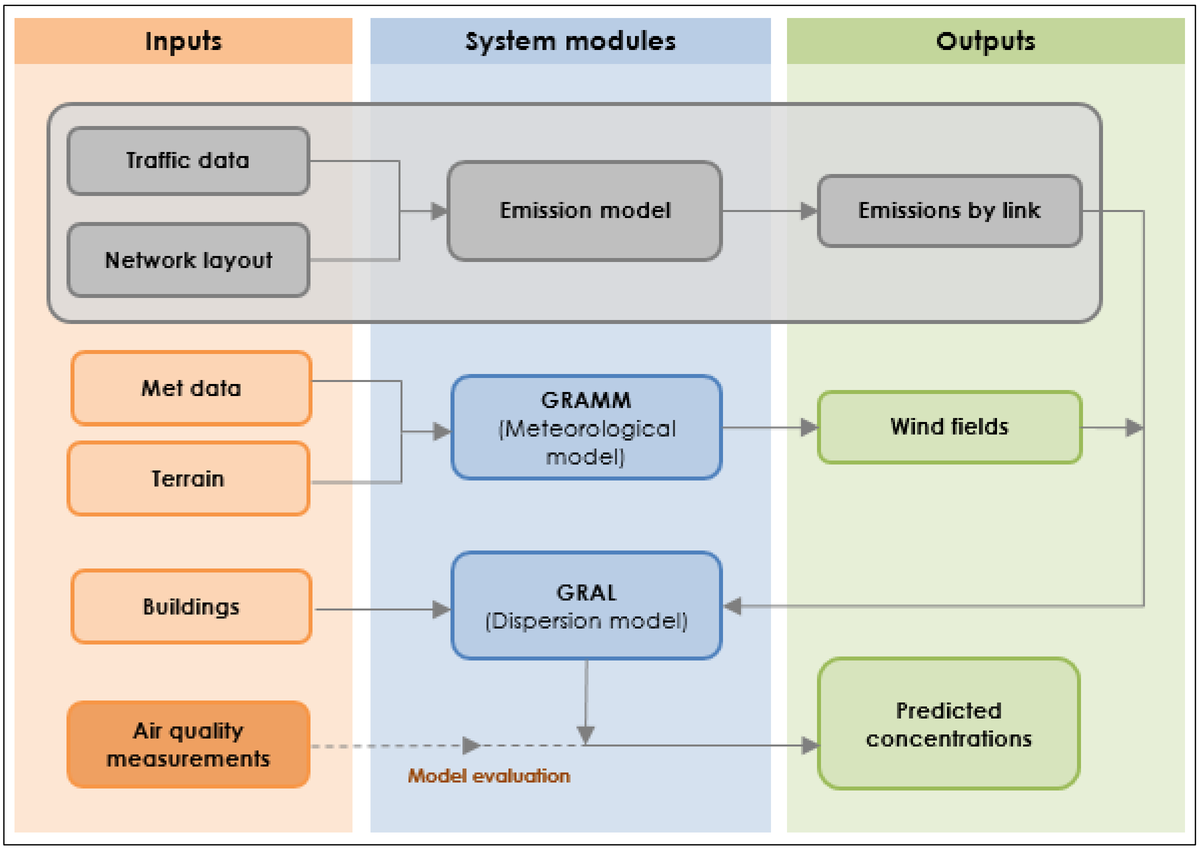

Figure 9-2 Overview of the GRAMM/GRAL modelling system

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.

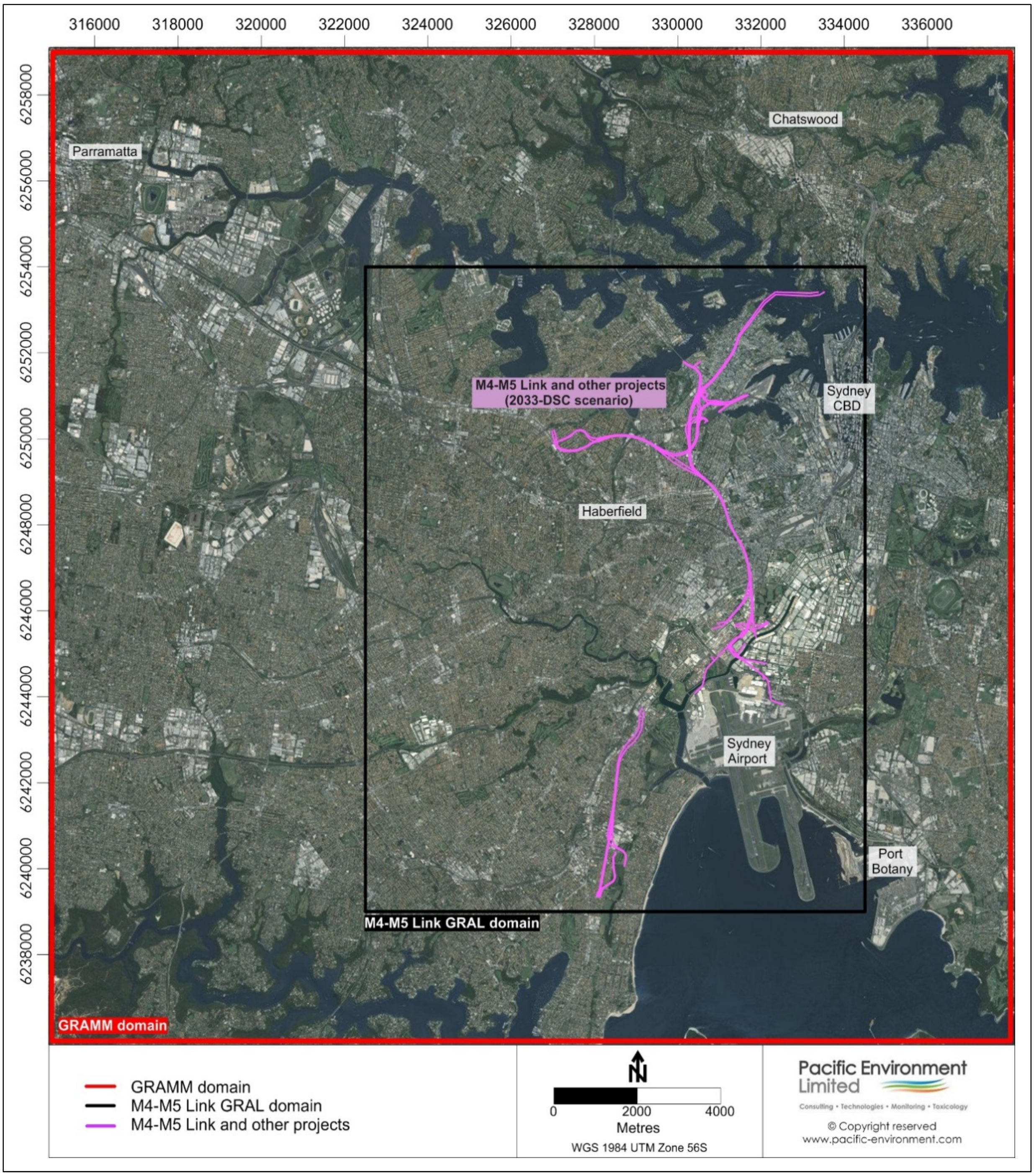

Figure 9-3 Modelling domains for GRAMM and GRAL (grid system MGA94)

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.

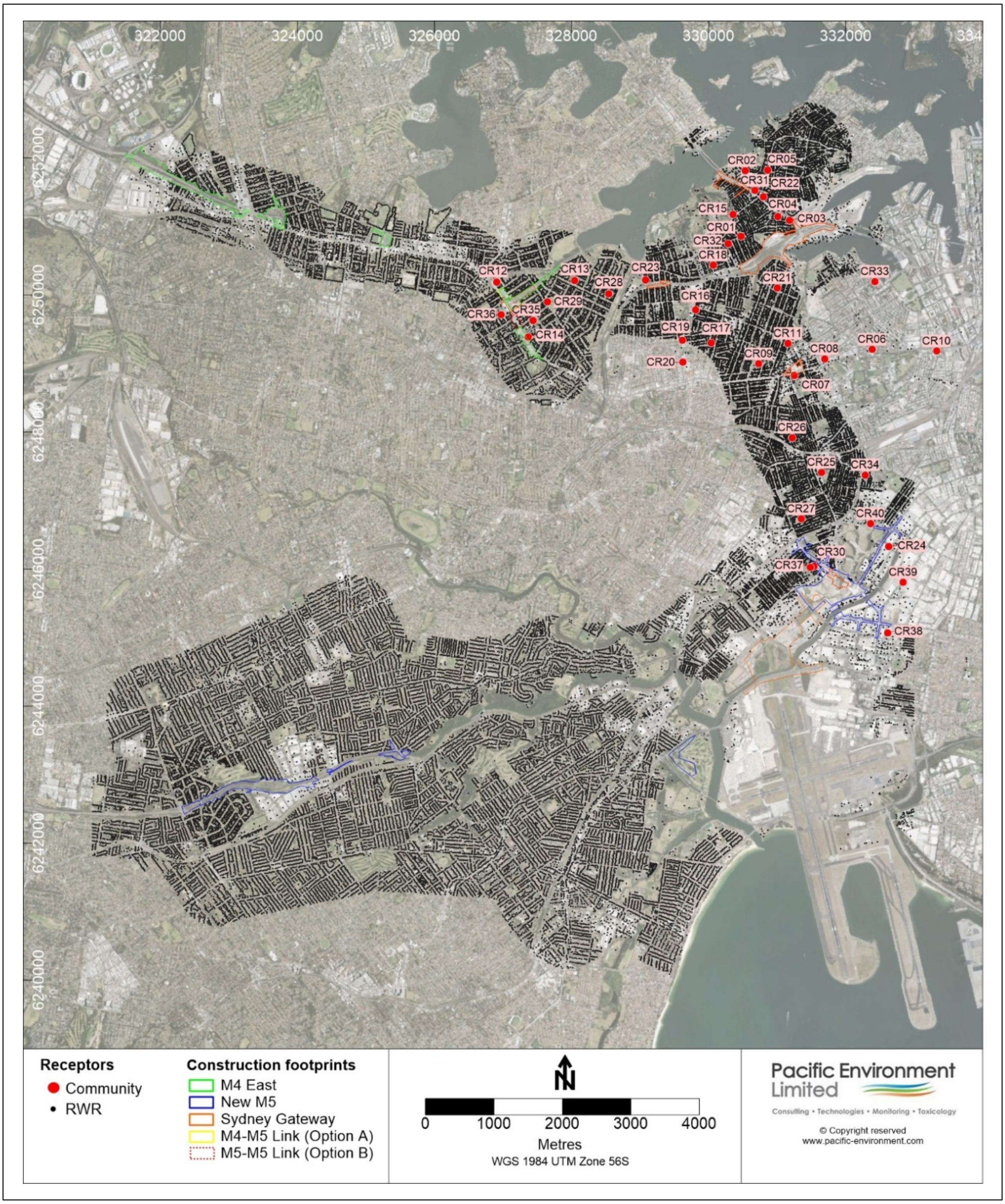

Figure 9-4 Modelled discrete receptor locations

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**.

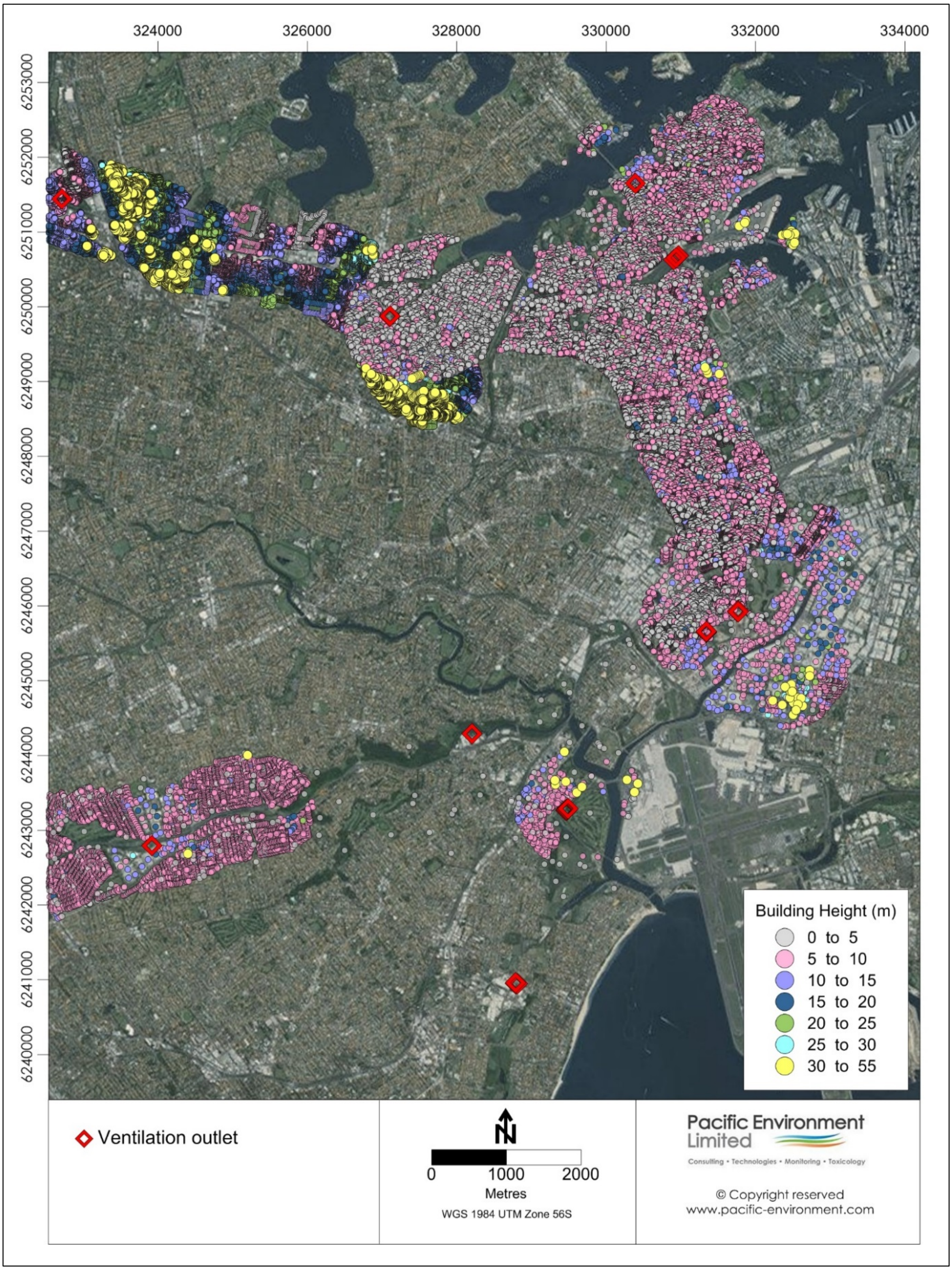

Figure 9-5 Sample of building heights in the GRAL domain (grid system MGA94)

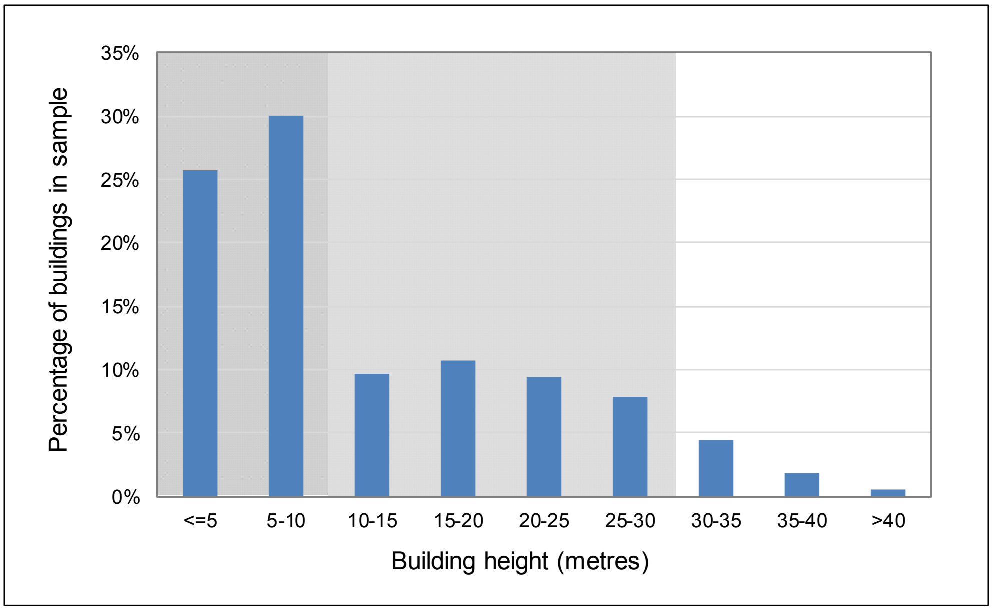

Figure 9-6 Frequency distribution of building heights

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.

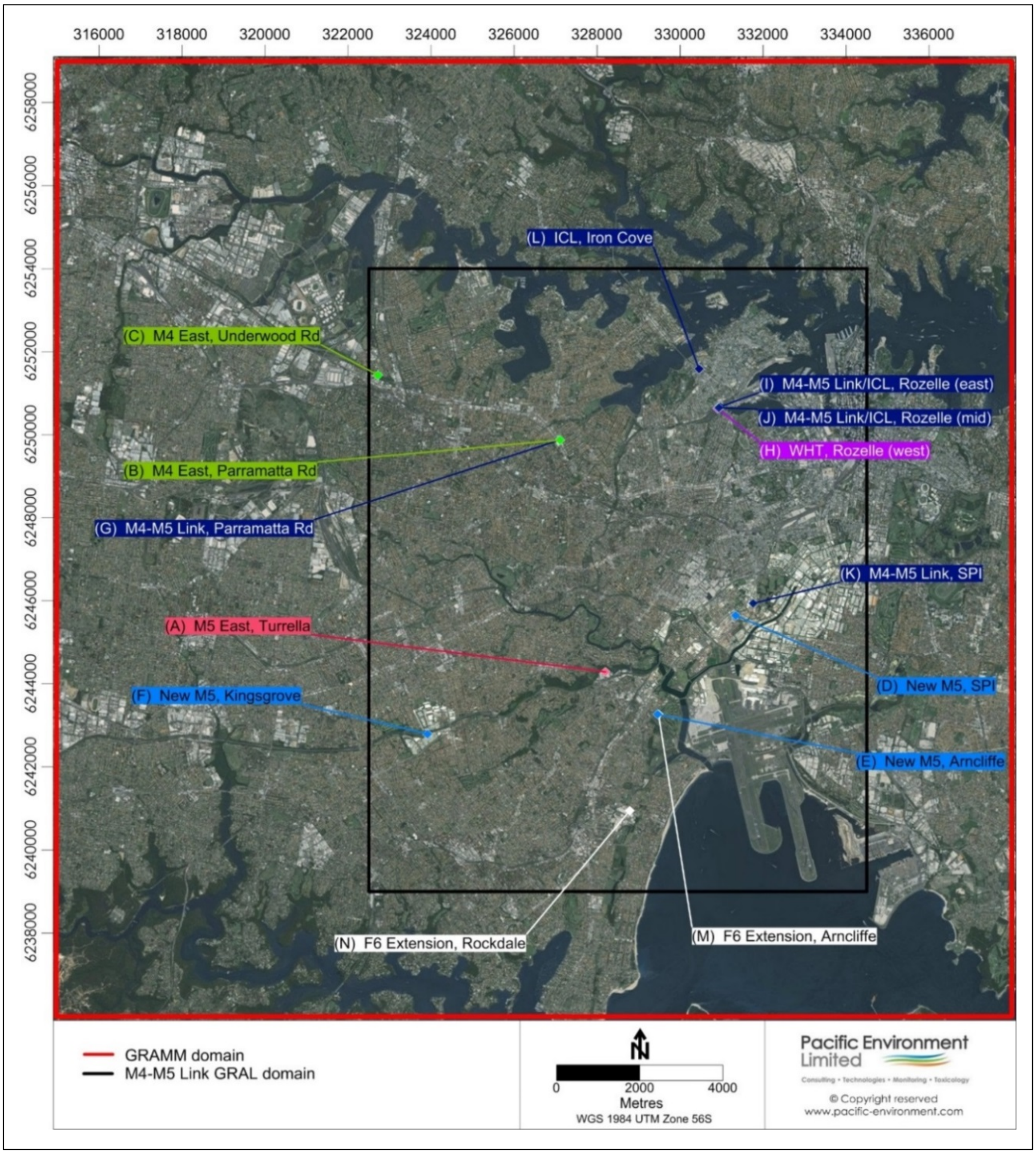

Figure 9-7 Locations of all tunnel ventilation outlets included in the assessment (grid system MGA94)

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[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.

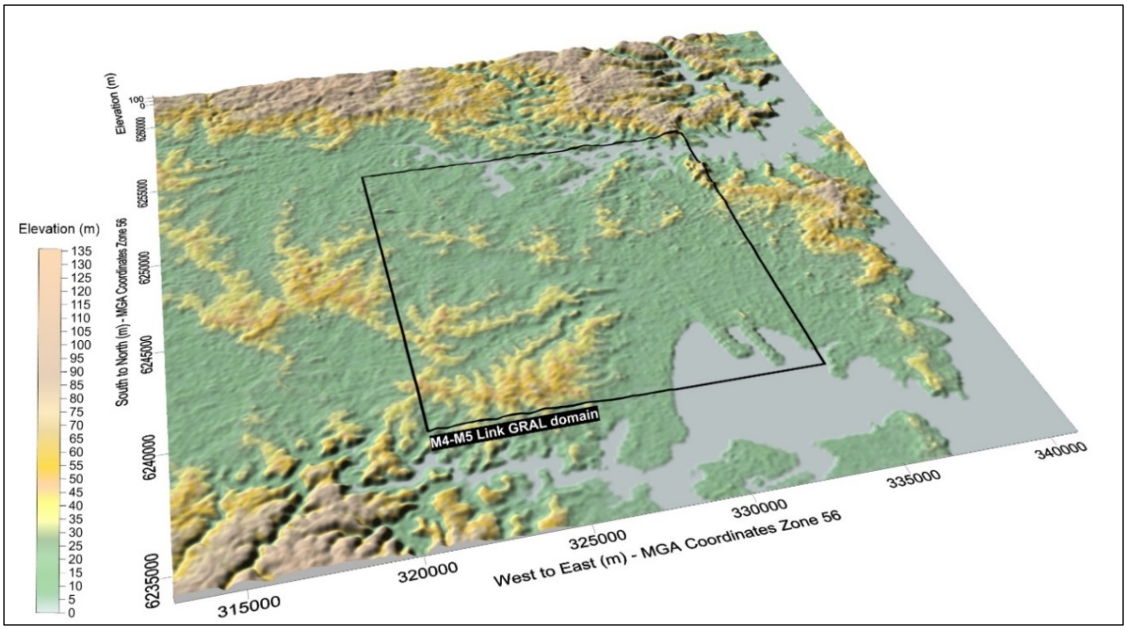

Figure 9-8 Terrain in the GRAMM domain (grid system MGA94)

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).

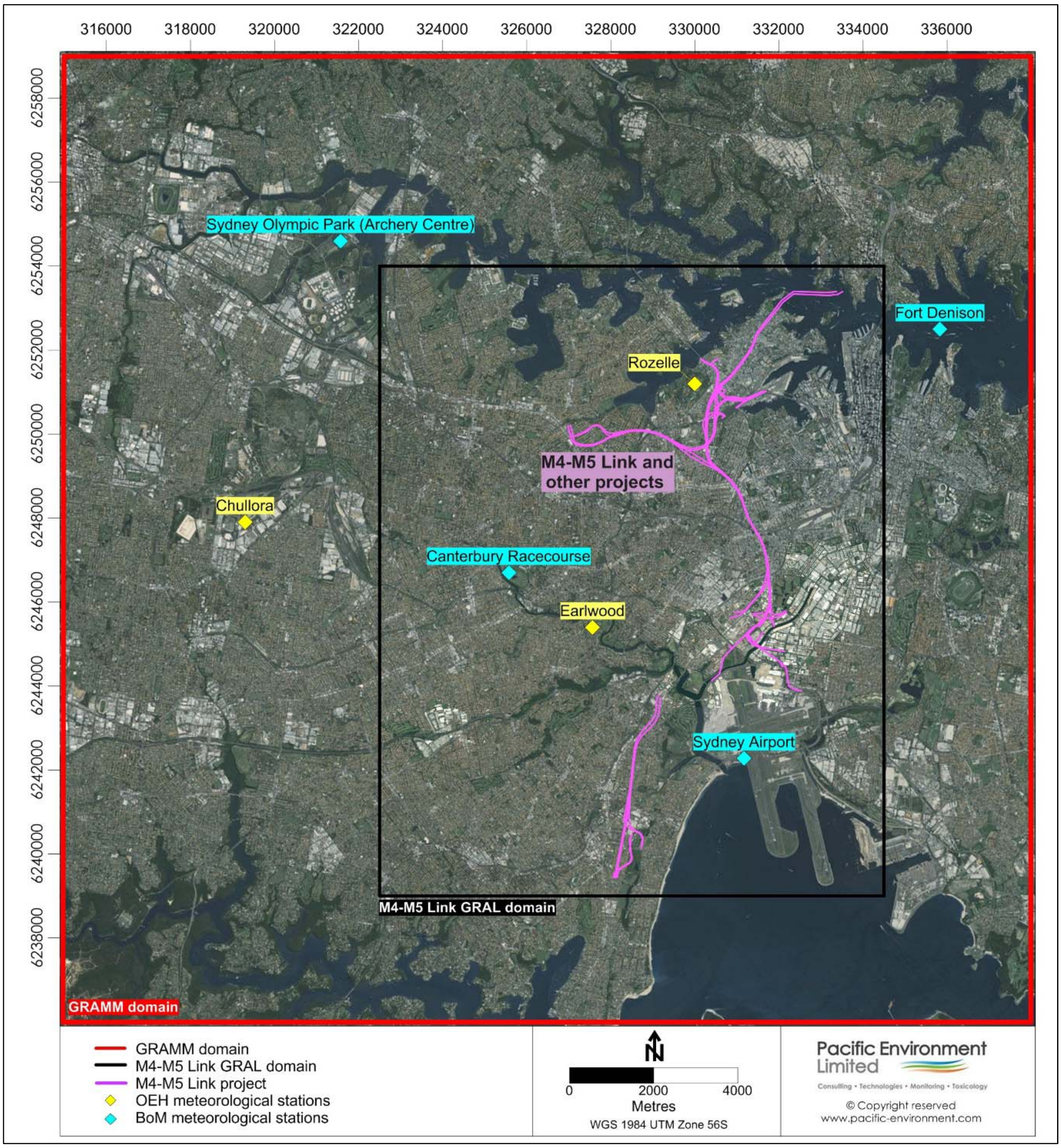

Figure 9-9 Meteorological stations in the model domains (grid system MGA94)

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.

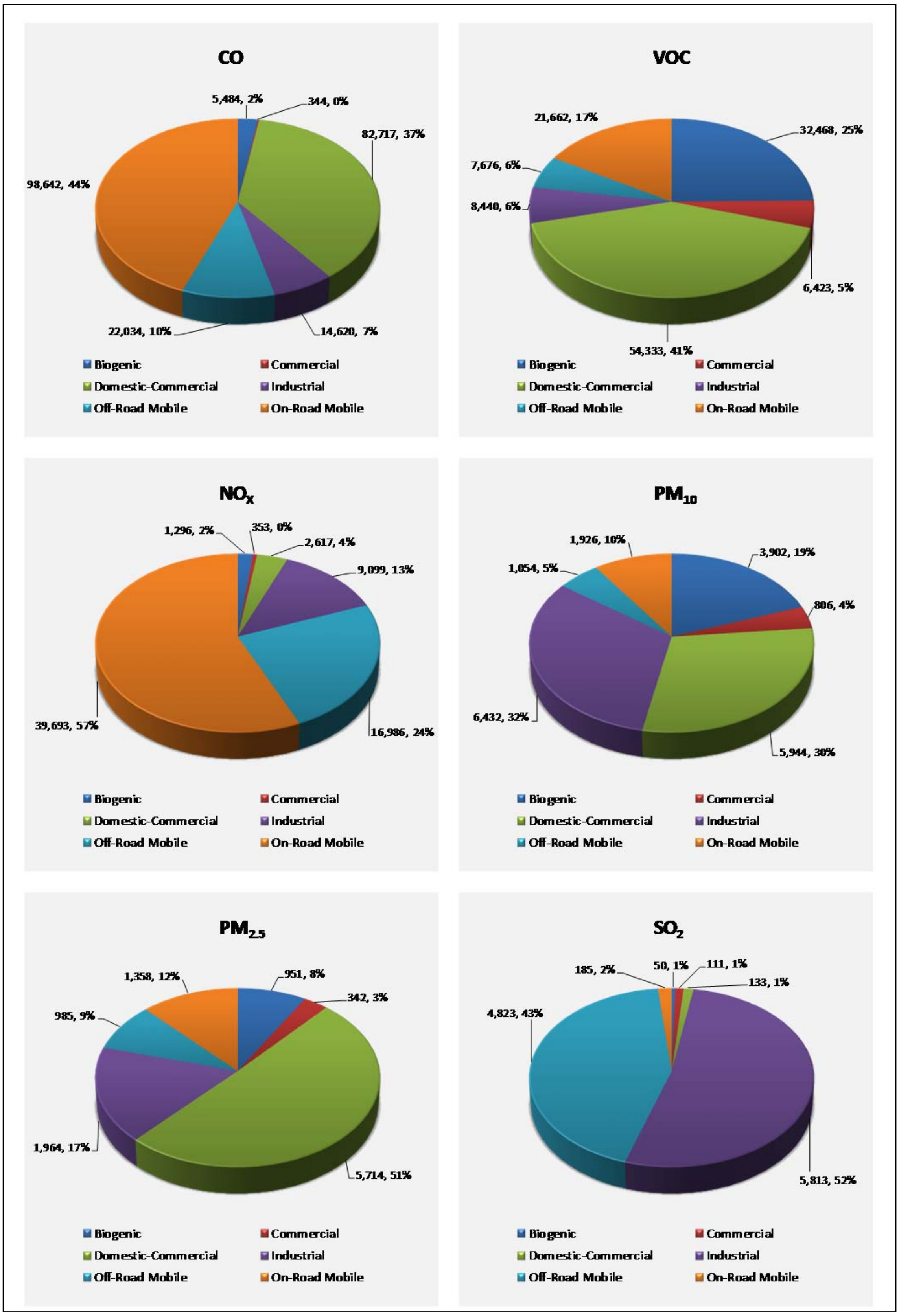

Figure 9-10 Sectoral emissions in Sydney 2011 (tonnes per year and percentage of total)

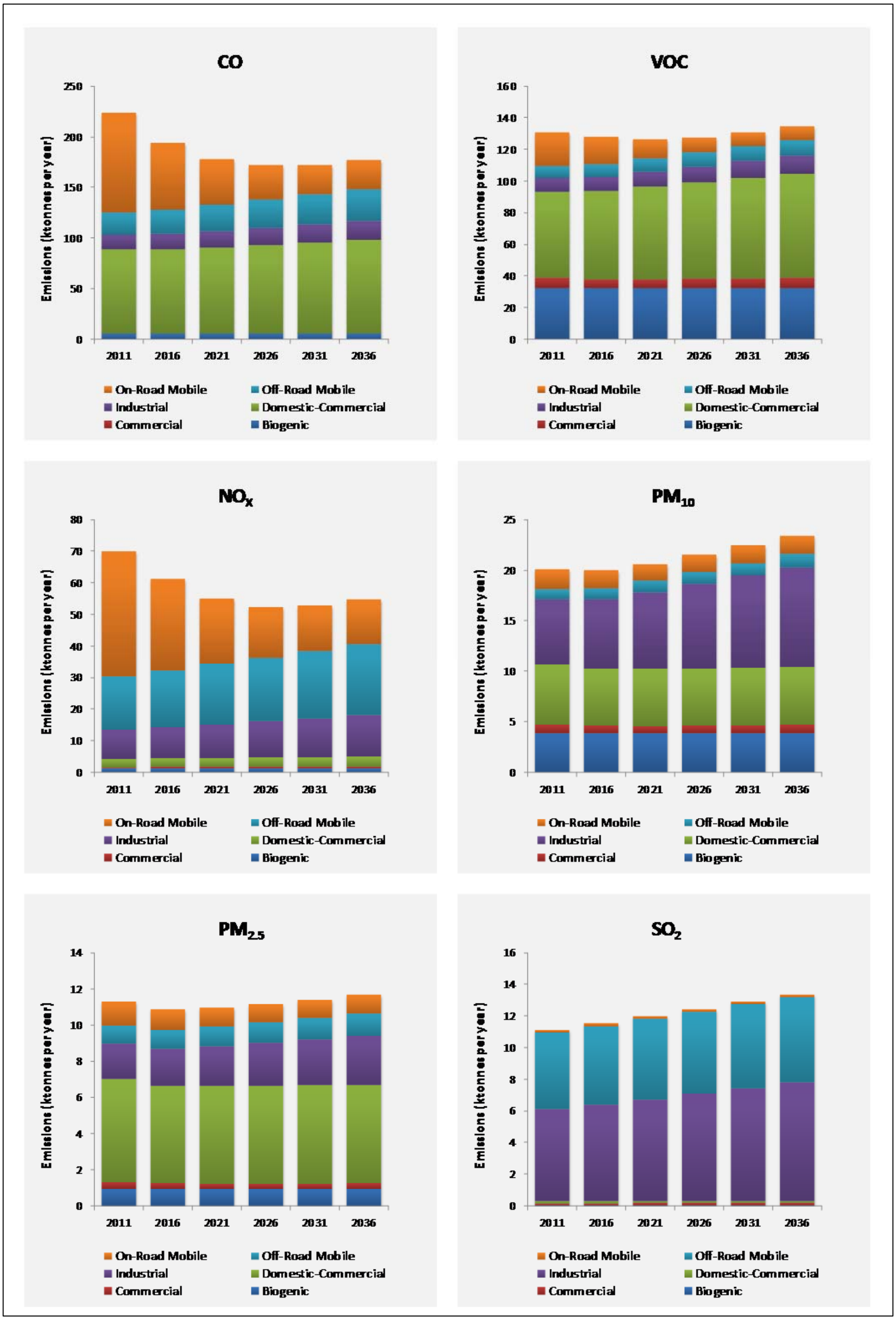

Figure 9-11 Future projections of sectoral emissions – Sydney 2011–2036

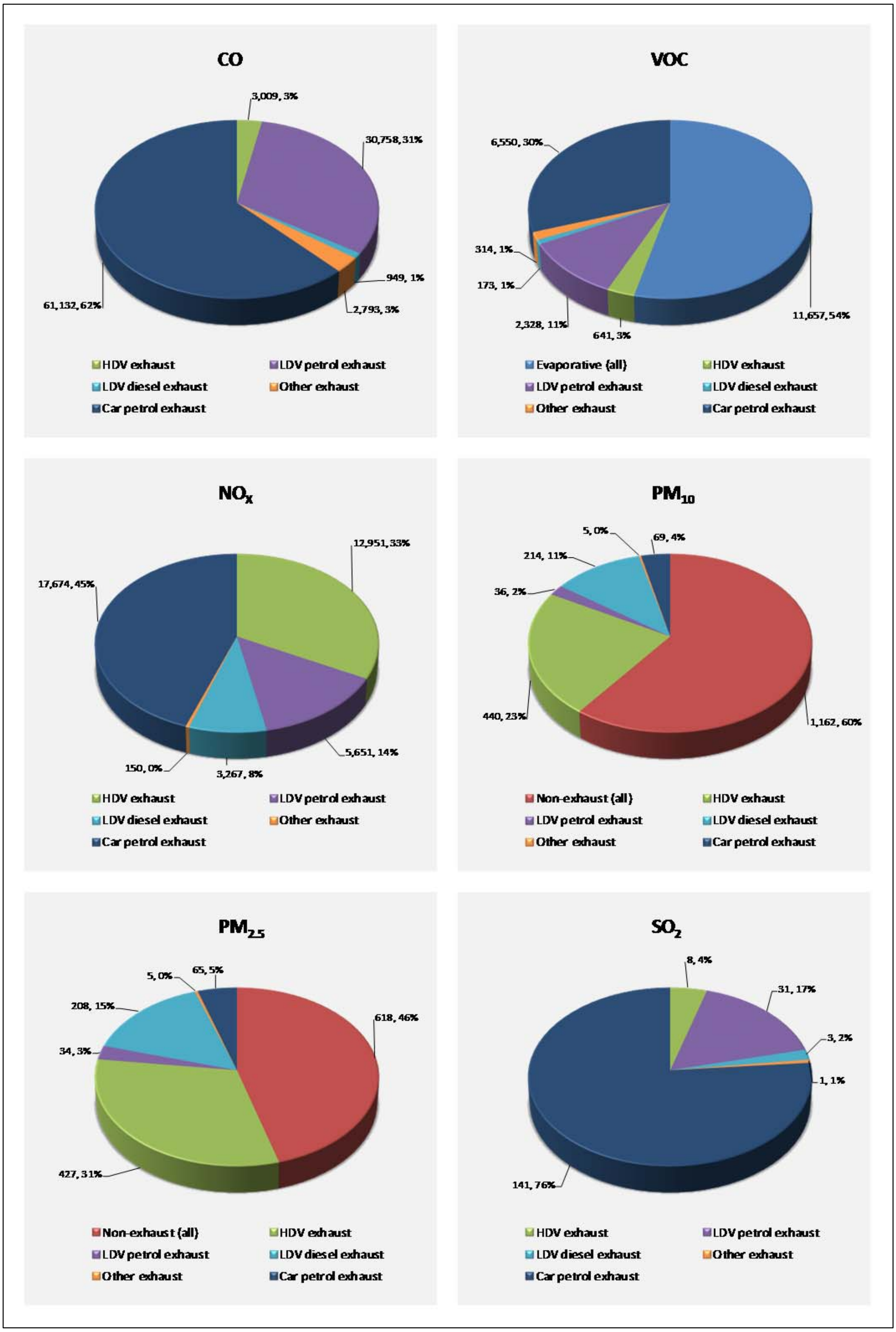

Figure 9-12 Breakdown of road transport emissions – Sydney, 2011 (tonnes per year and percentage of total)

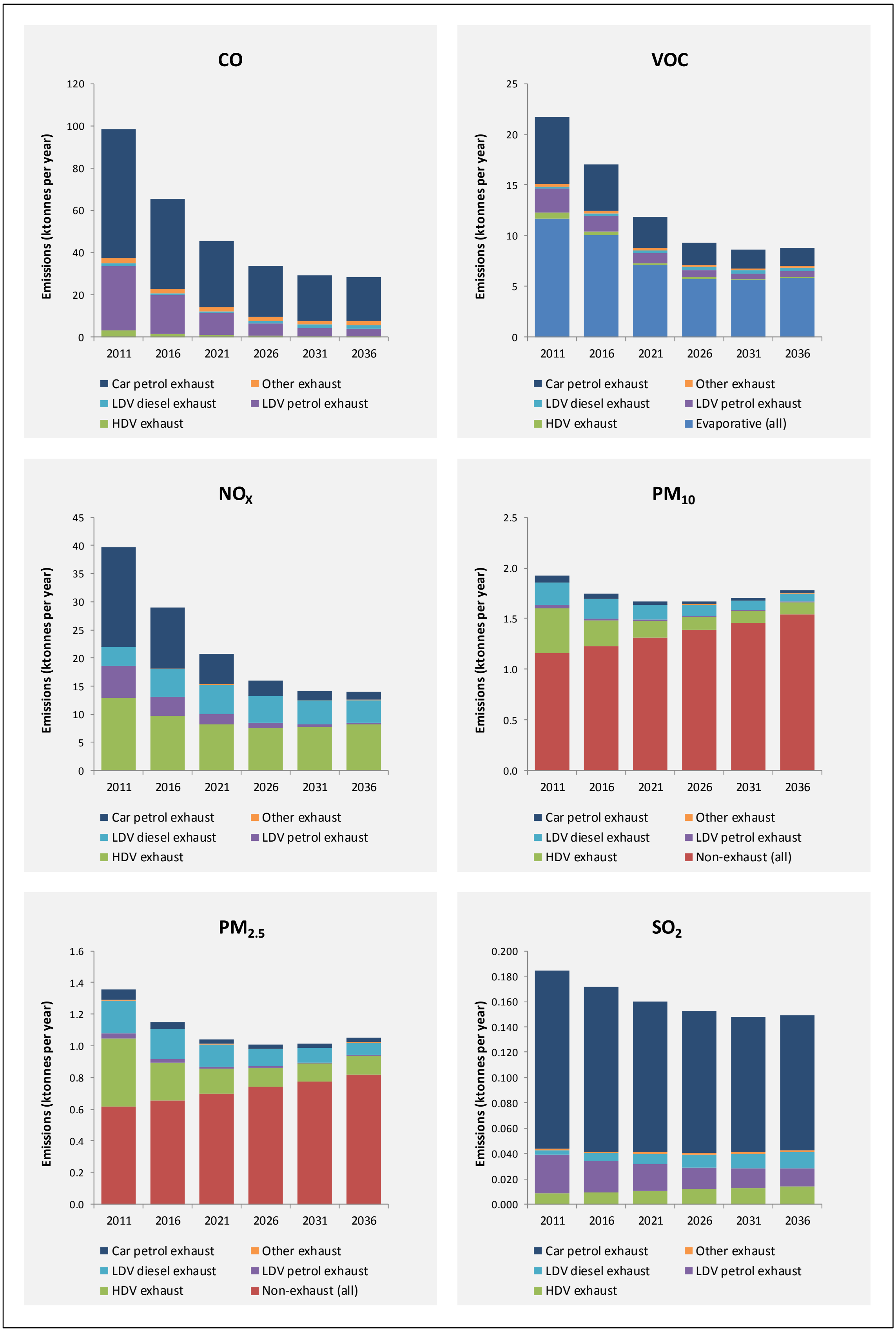

Figure 9-13 Future projections of road transport emissions – Sydney 2011–2036

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 $\mu g/m^3$, and above the long-term goal of seven $\mu g/m^3$
- 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 $\mu g/m^3$, and were generally above the long-term goal of 20 $\mu g/m^3$.

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	$\mu g/m^3$	Spatially varying	-	-
	1 hour	Synthetic profile	$\mu g/m^3$	65.9	769.6	301.4
PM_{10}	Annual	Map	$\mu g/m^3$	Spatially varying	-	-
	24 hours	Synthetic profile	$\mu g/m^3$	20.0	46.2	35.8
$PM_{2.5}$	Annual	Single value	$\mu g/m^3$	8.0	-	-
	24 hours	Synthetic profile	$\mu g/m^3$	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

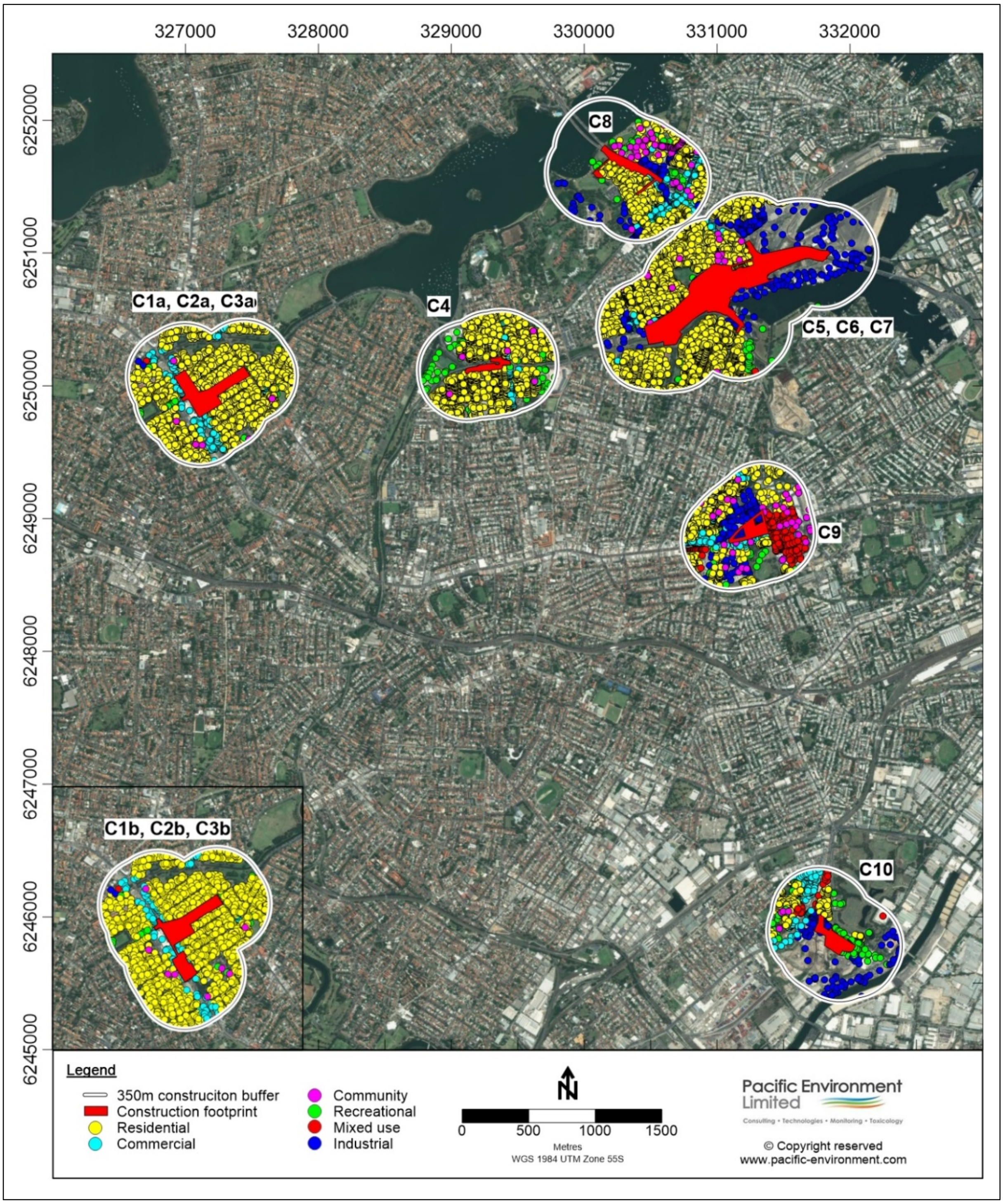

Figure 9-14 Screening assessment – receptors near the project footprint

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 PM_{10} conc.	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 4 (C5, C6,	Demolition	High	<18	960	679	1,691	4,231	6,041	Medium
	Earthworks	High	<18	960	679	1,691	4,231	6,041	Medium
	Construction	High	<18	960	679	1,691	4,231	6,041	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.

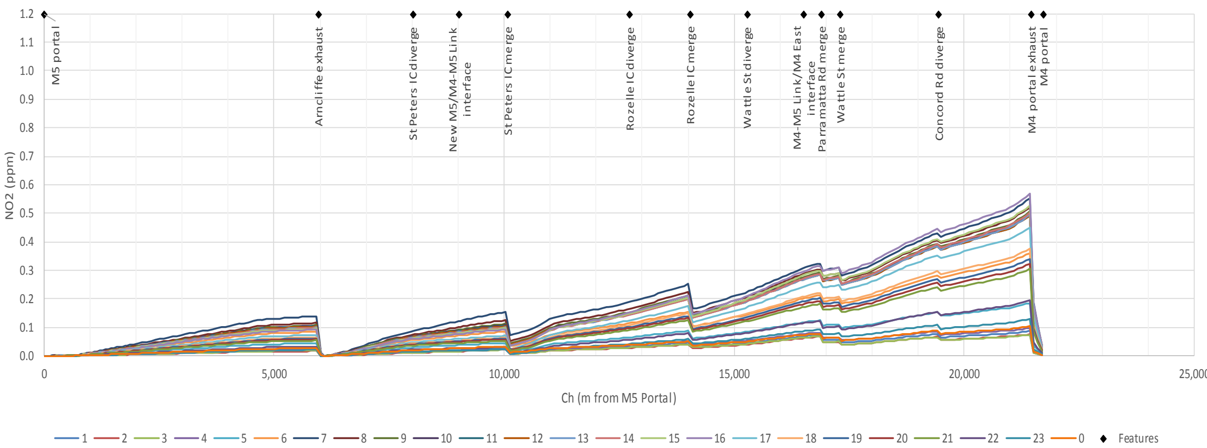

Figure 9-15 In-tunnel hourly NO_2 levels along the route from New M5 portal to M4 East portal through the project 2023-DS

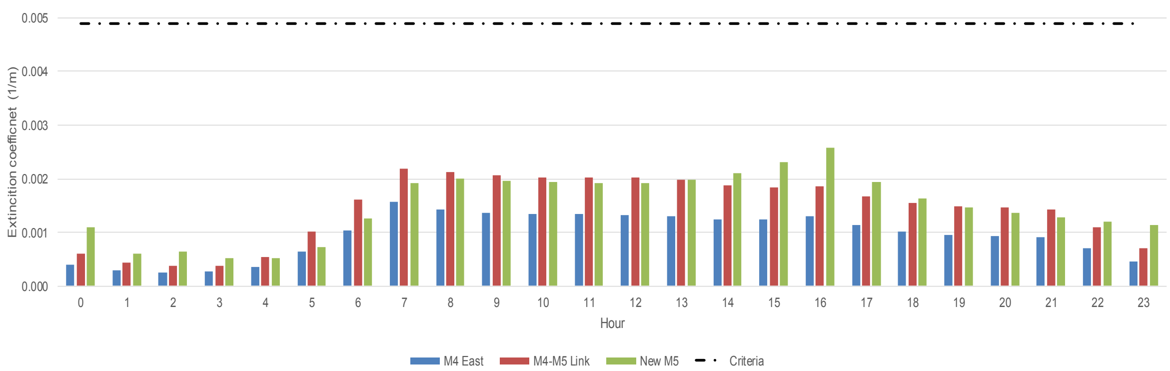

Figure 9-16 Maximum in-tunnel visibility coefficients each hour for each WestConnex tunnel (M4 Motorway to M5 Motorway direction) 2023-DS

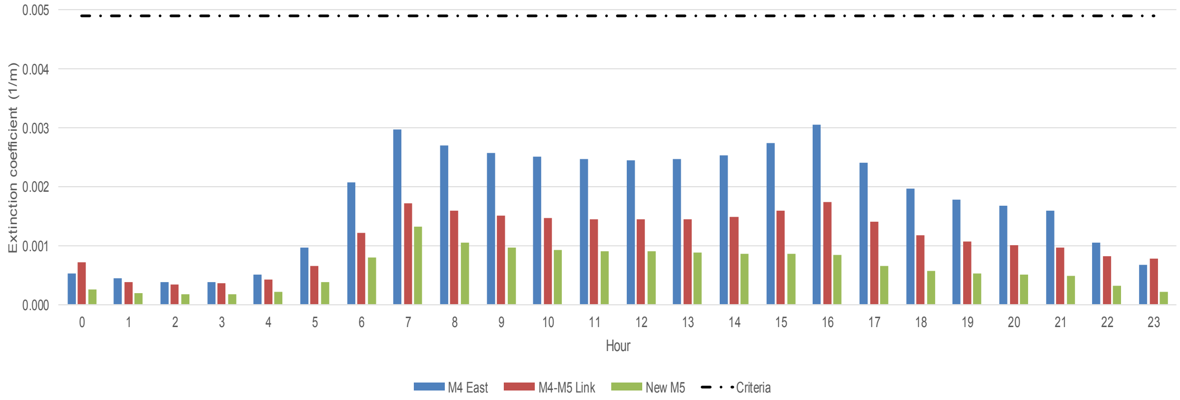

Figure 9-17 Maximum in-tunnel visibility coefficients each hour for each WestConnex tunnel (M5 Motorway to M4 Motorway direction) 2023-DS

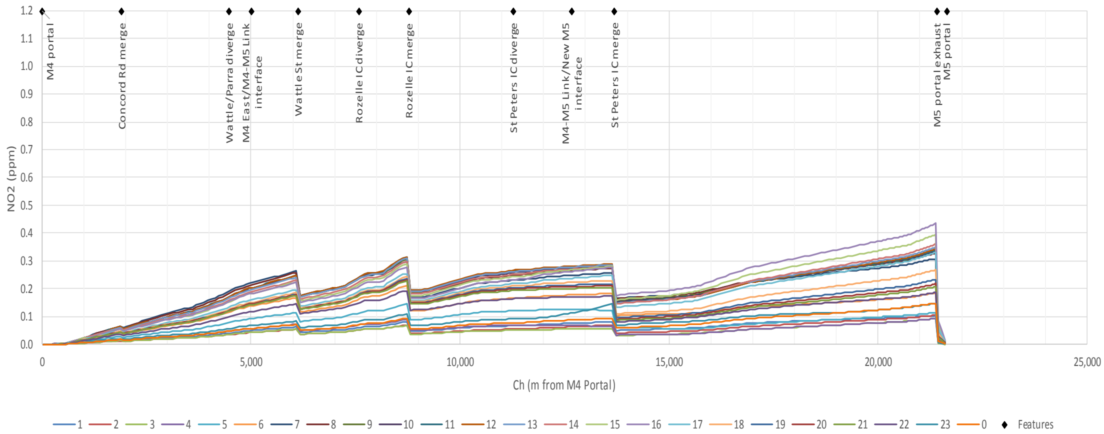

Figure 9-18 In-tunnel NO_2 levels along the route from M4 portal to M5 portal through the project 2033-DS

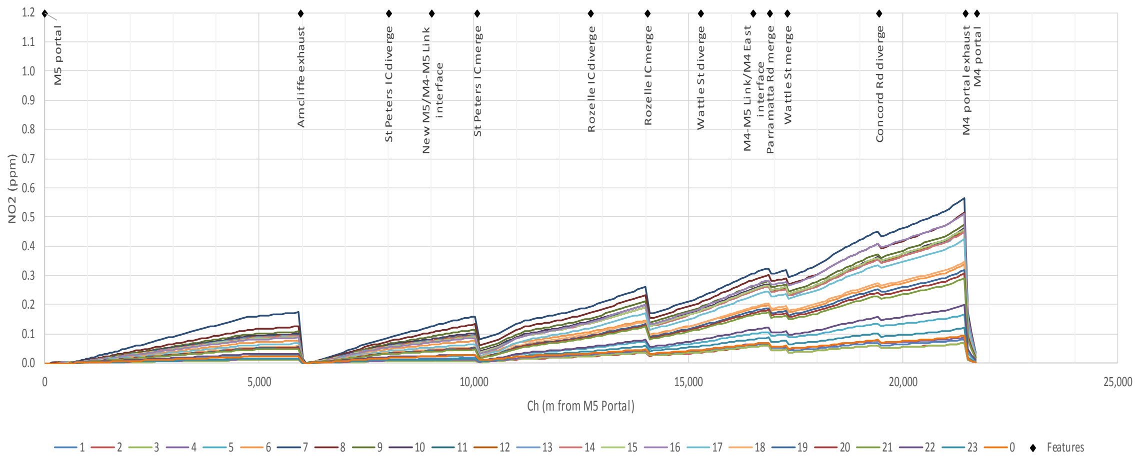

Figure 9-19 In-tunnel NO_2 levels along the route from M5 portal to M4 portal through the project 2033-DS

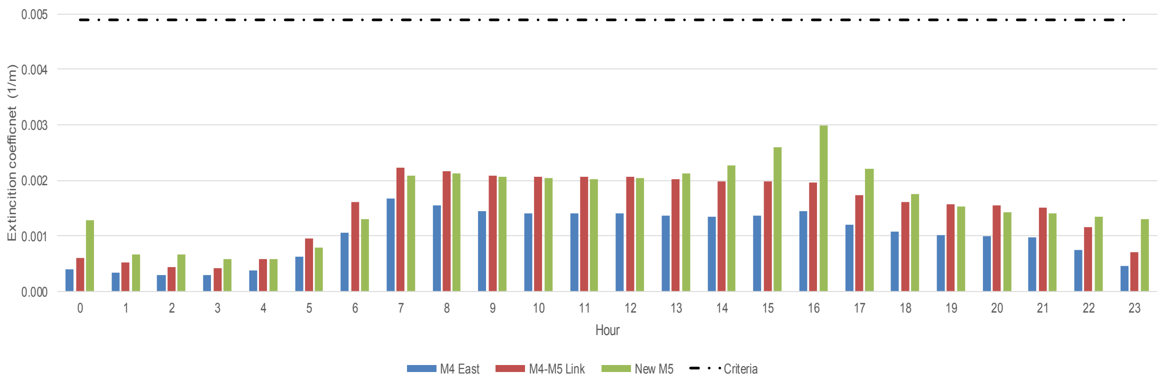

Figure 9-20 Maximum In-tunnel visibility coefficients for each hour for each WestConnex tunnel (M4 Motorway to M5 Motorway direction) 2033-DS

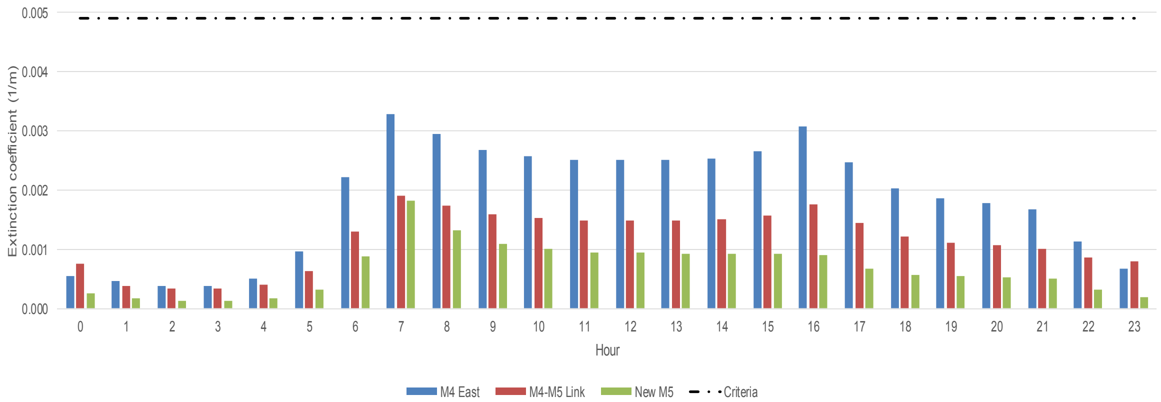

Figure 9-21 Maximum In-tunnel visibility coefficients for M5 Motorway to M4 Motorway direction 2033-DS

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.

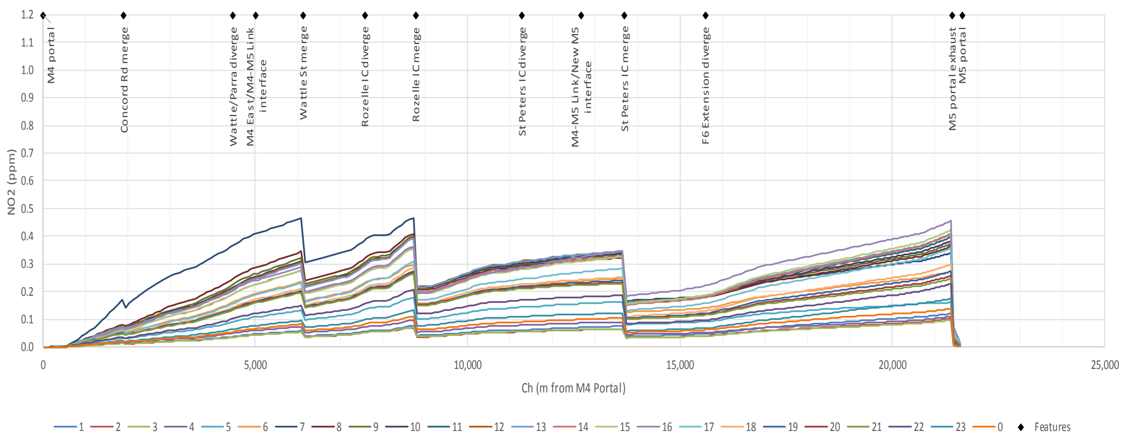

Figure 9-22 In-tunnel NO_2 levels along the route from M4 portal to M5 portal 2033-DSC

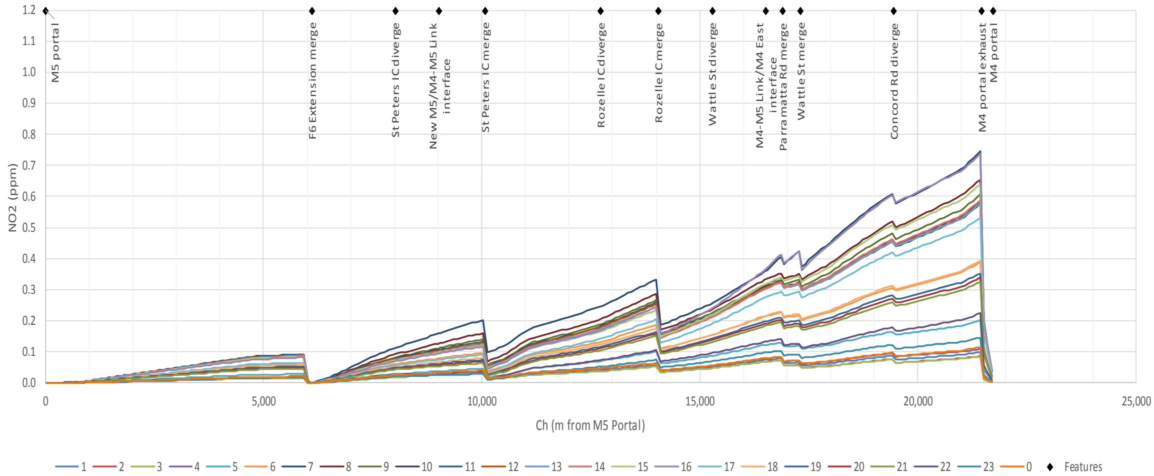

Figure 9-23 In-tunnel NO_2 levels along the route from M5 portal to M4 portal 2033-DSC

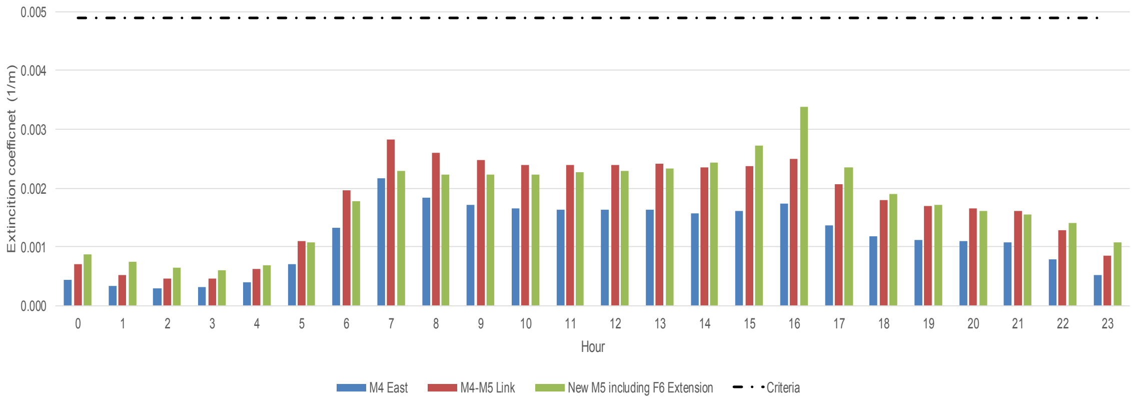

Figure 9-24 Maximum In-tunnel visibility coefficients for M4 Motorway to M5 Motorway direction 2033-DSC

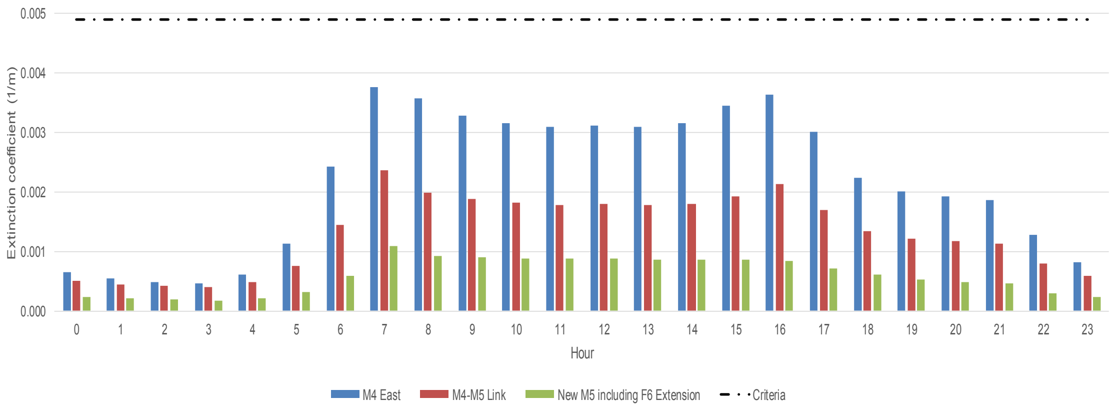

Figure 9-25 Maximum In-tunnel visibility for M5 Motorway to M4 Motorway direction 2033-DSC

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).

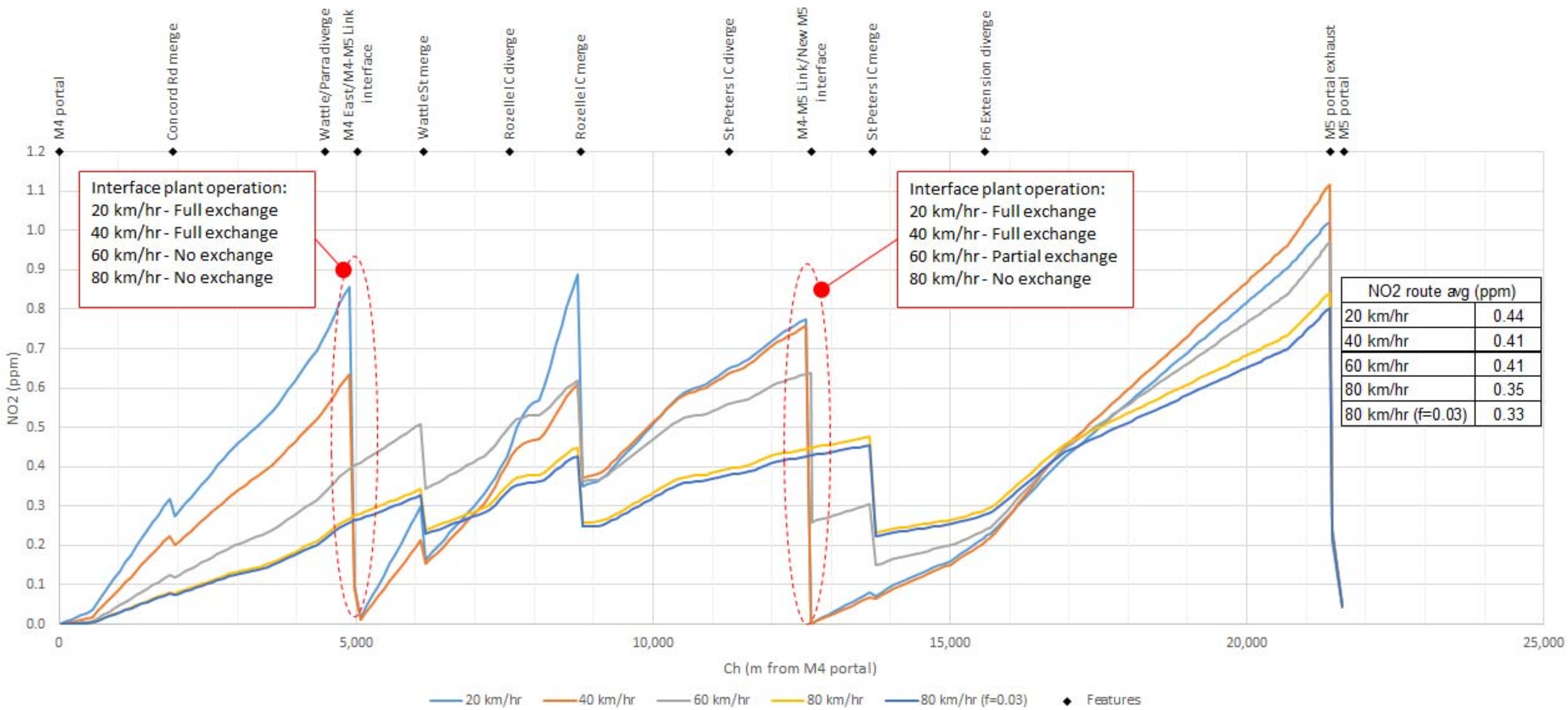

Figure 9-26 In-tunnel NO_2 levels along the route from M4 portal to M5 portal (cumulative, worst case operations)

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).

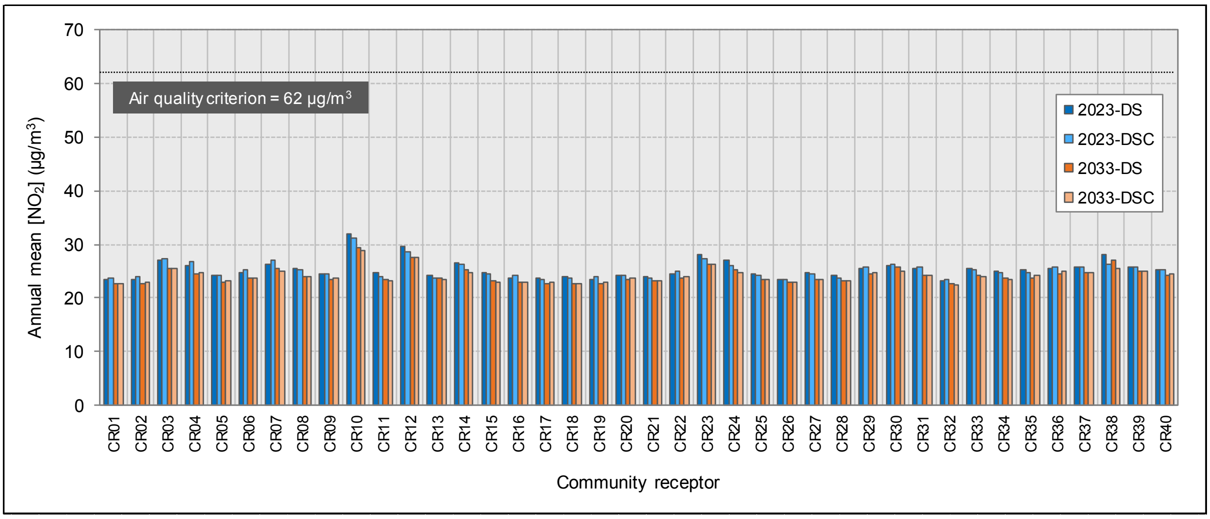

Figure 9-27 Annual mean NO_2 concentration at community receptors (with 2023 and 2033 project (DS) and cumulative (DSC) scenarios)

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).

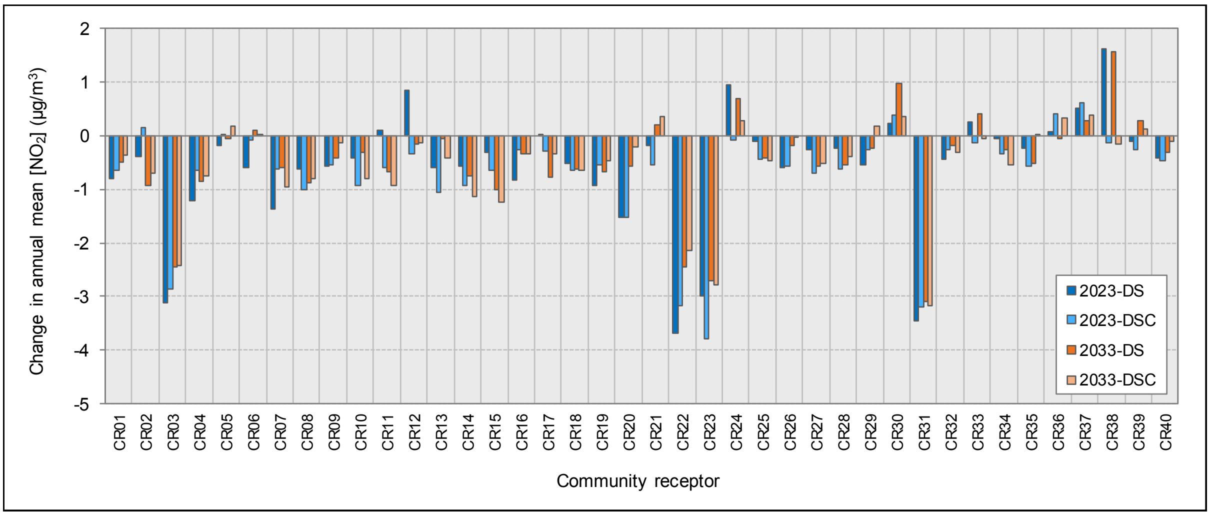

Figure 9-28 Change in annual mean NO_2 concentration at community receptors (with 2023 and 2033 project (DS) and cumulative (DSC) scenarios, relative to Do Minimum scenarios)

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**.

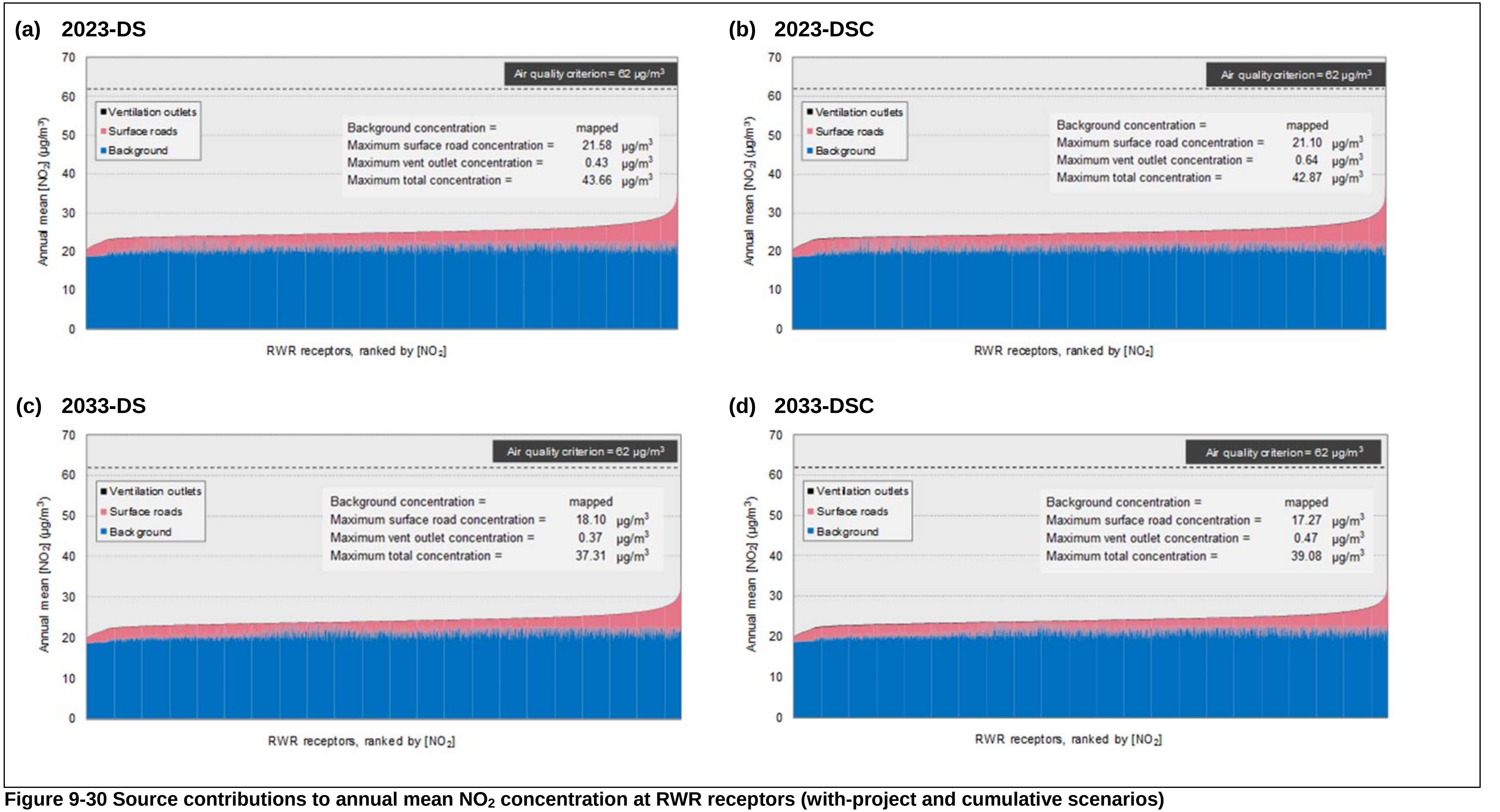

Figure 9-30 Source contributions to annual mean NO_2 concentration at RWR receptors (with-project and cumulative scenarios)

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.

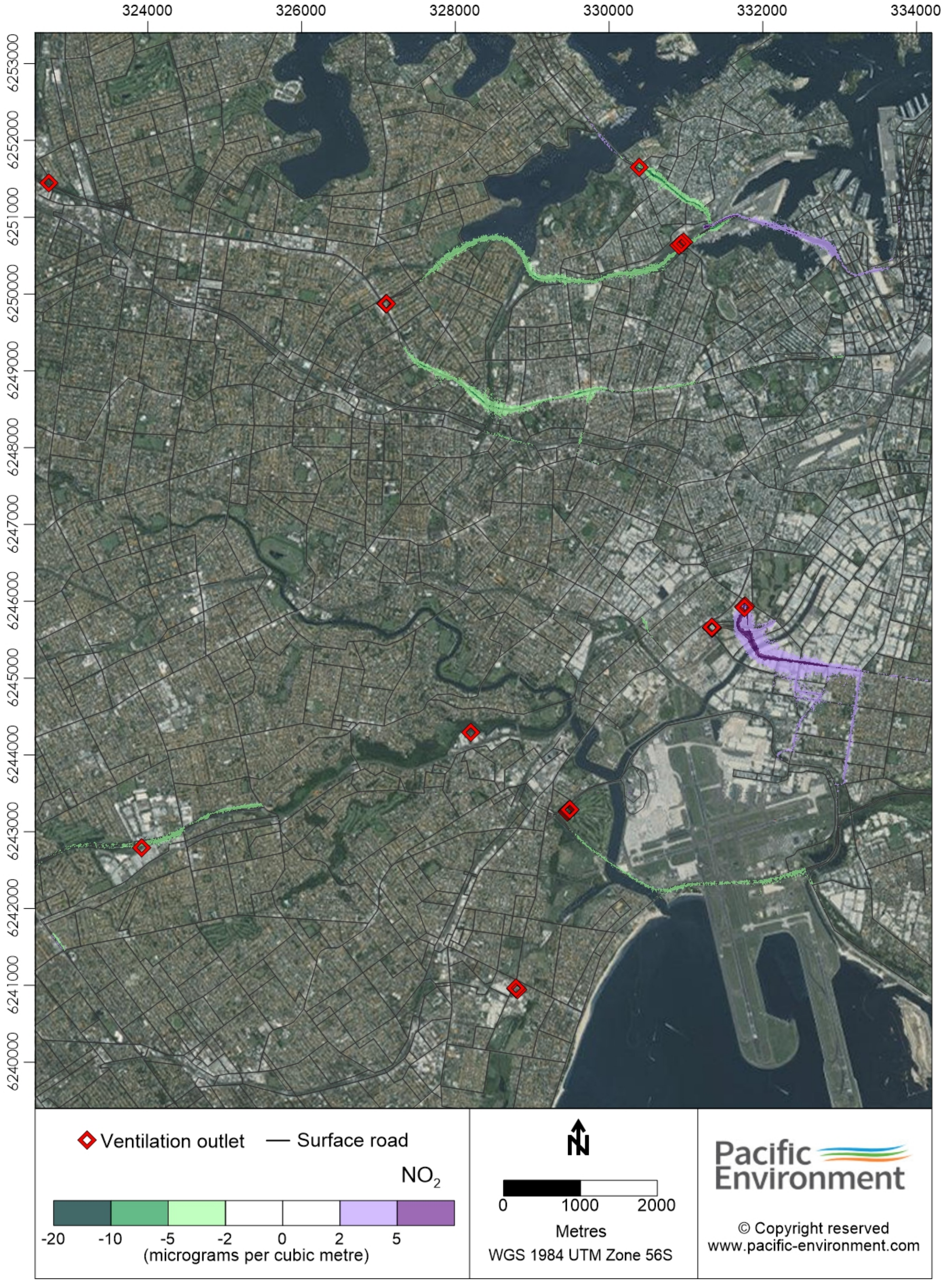

Figure 9-31 Contour plot of change in annual mean NO_2 concentration with the project (2023-DS)

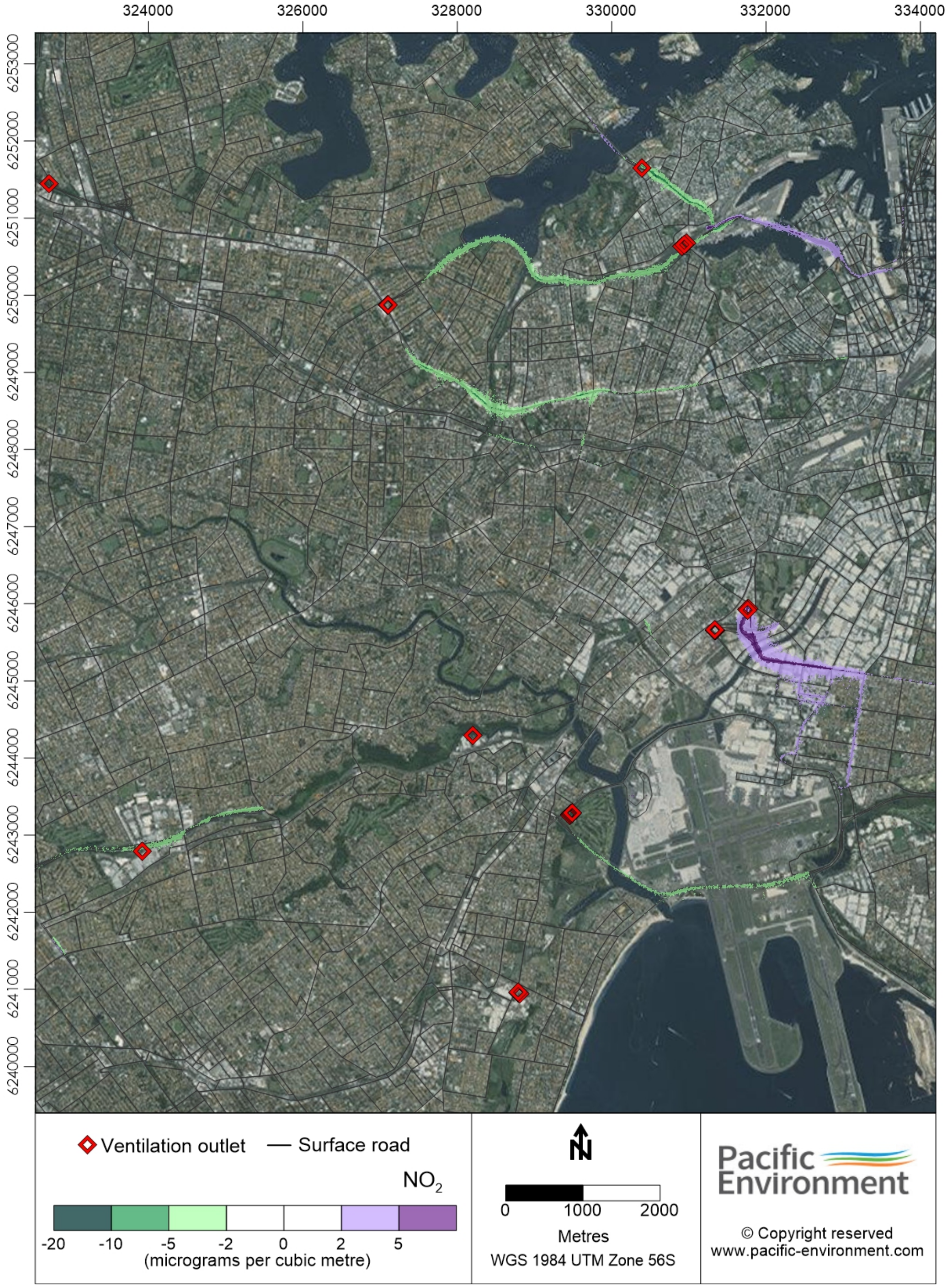

Figure 9-32 Contour plot of change in annual mean NO_2 concentration with the project (2033-DS)

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.

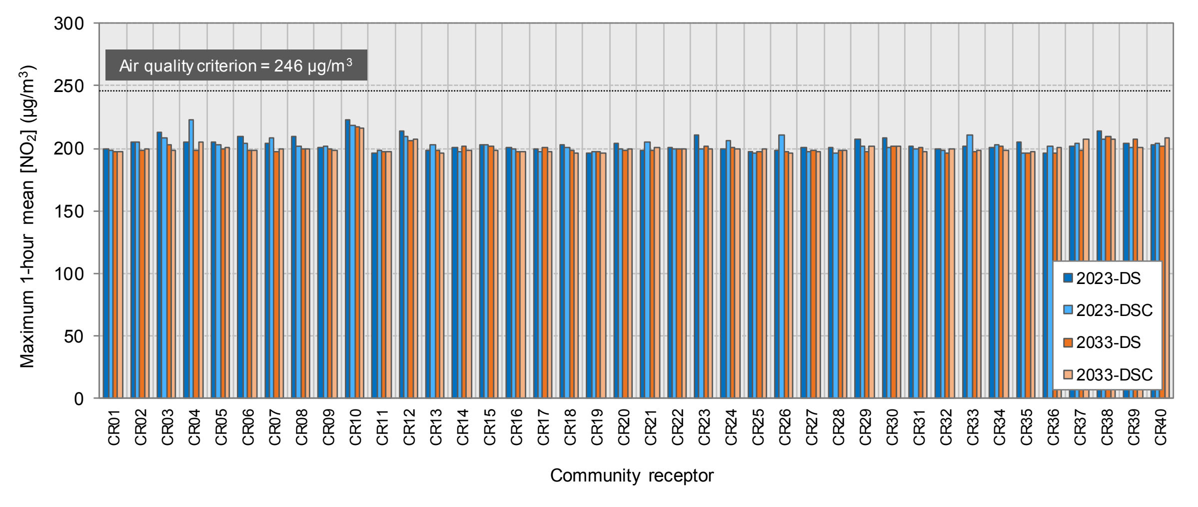

Figure 9-33 Maximum one hour mean NO_2 concentration at community receptors (with-project and cumulative scenarios)

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.

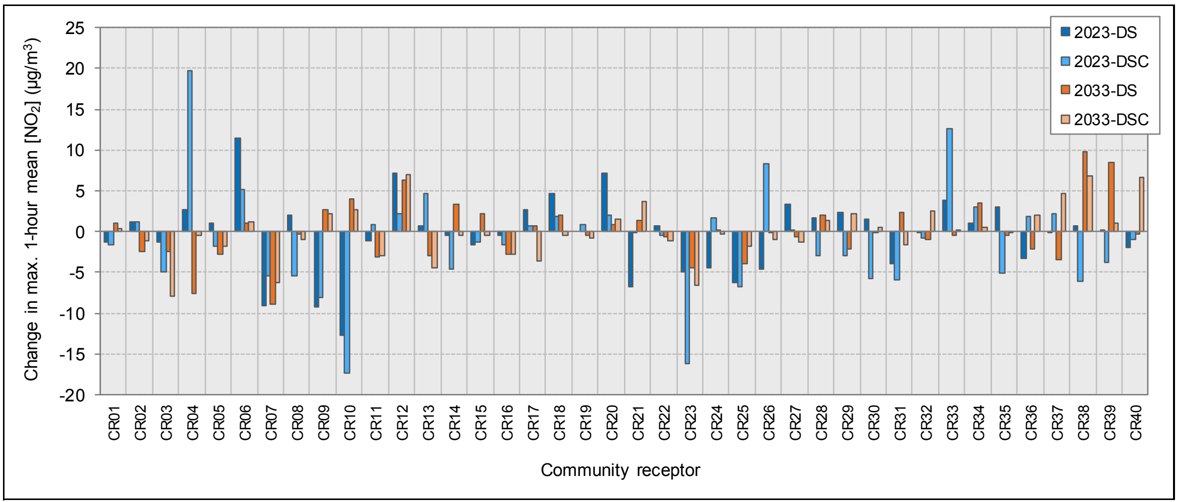

Figure 9-34 Change in maximum one hour mean NO_2 concentration at community receptors (with-project and cumulative scenarios, relative to corresponding Do Minimum scenarios)

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).

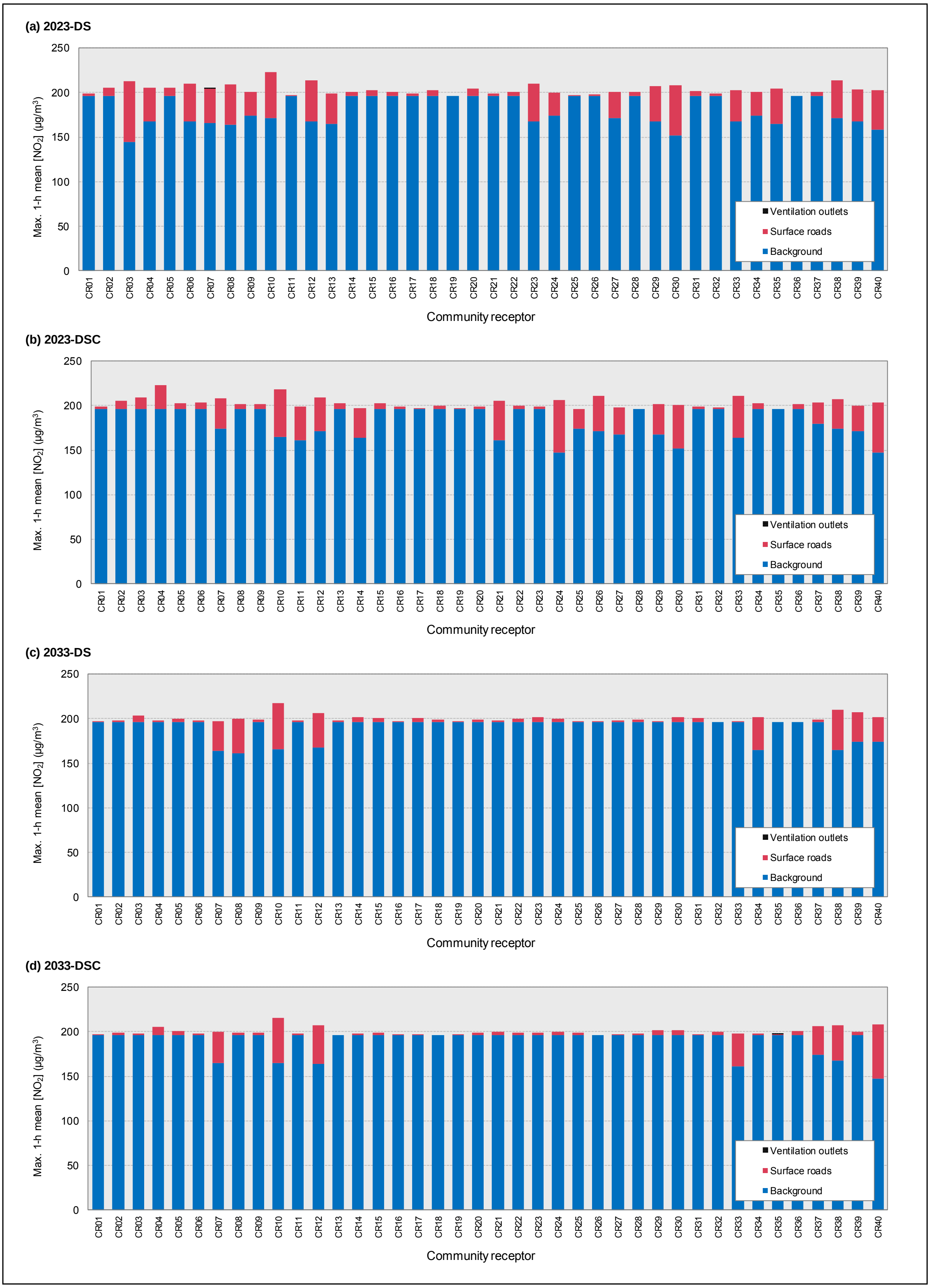

Figure 9-35 Source contributions to maximum one hour mean NO_2 concentration at community receptors (2023 and 2033 with-project (DS) and cumulative (DSC) scenarios)

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**.

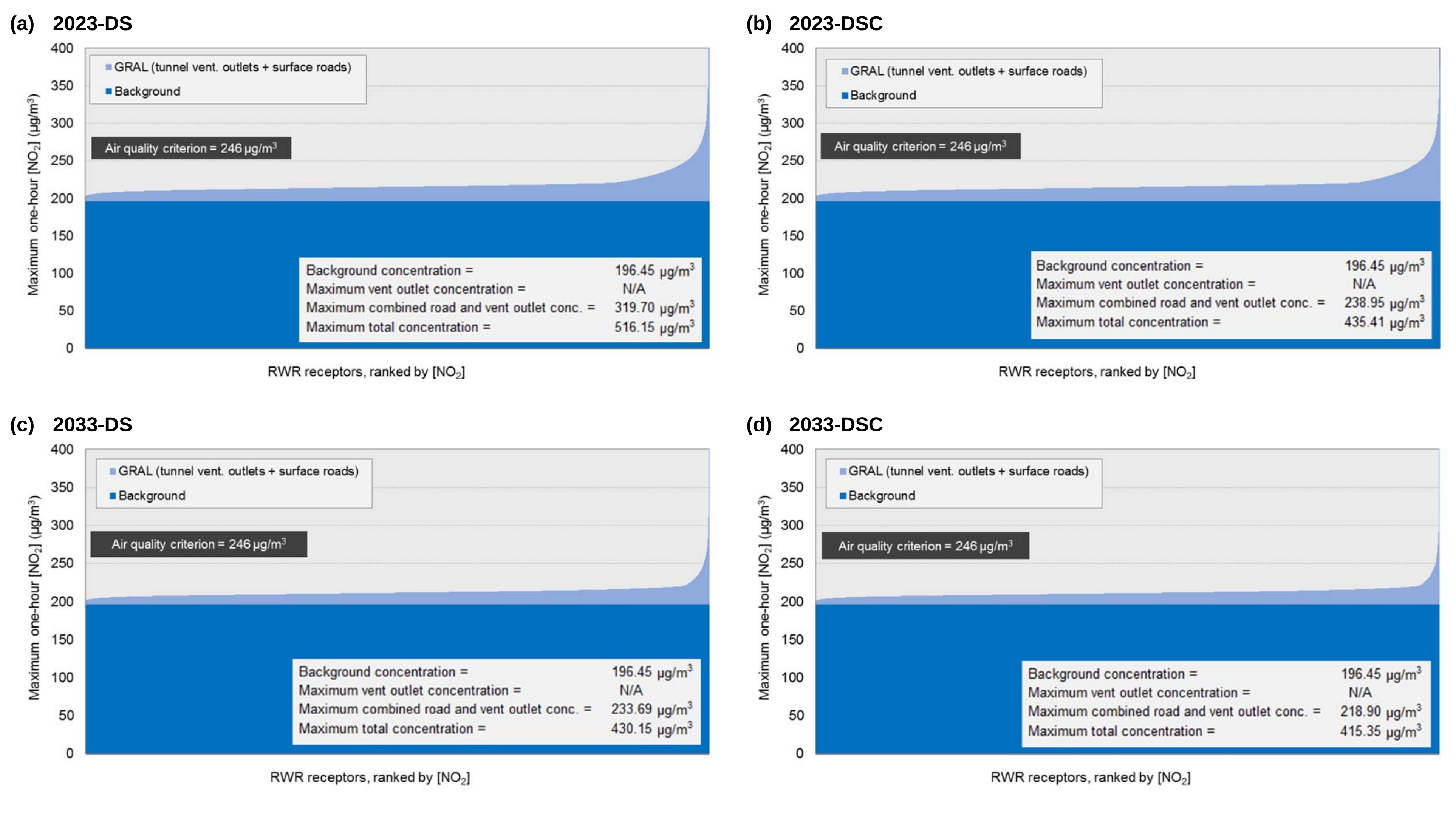

Figure 9-36 Source contributions to maximum one-hour mean NO_2 concentration at RWR receptors (with-project and cumulative scenarios)

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).

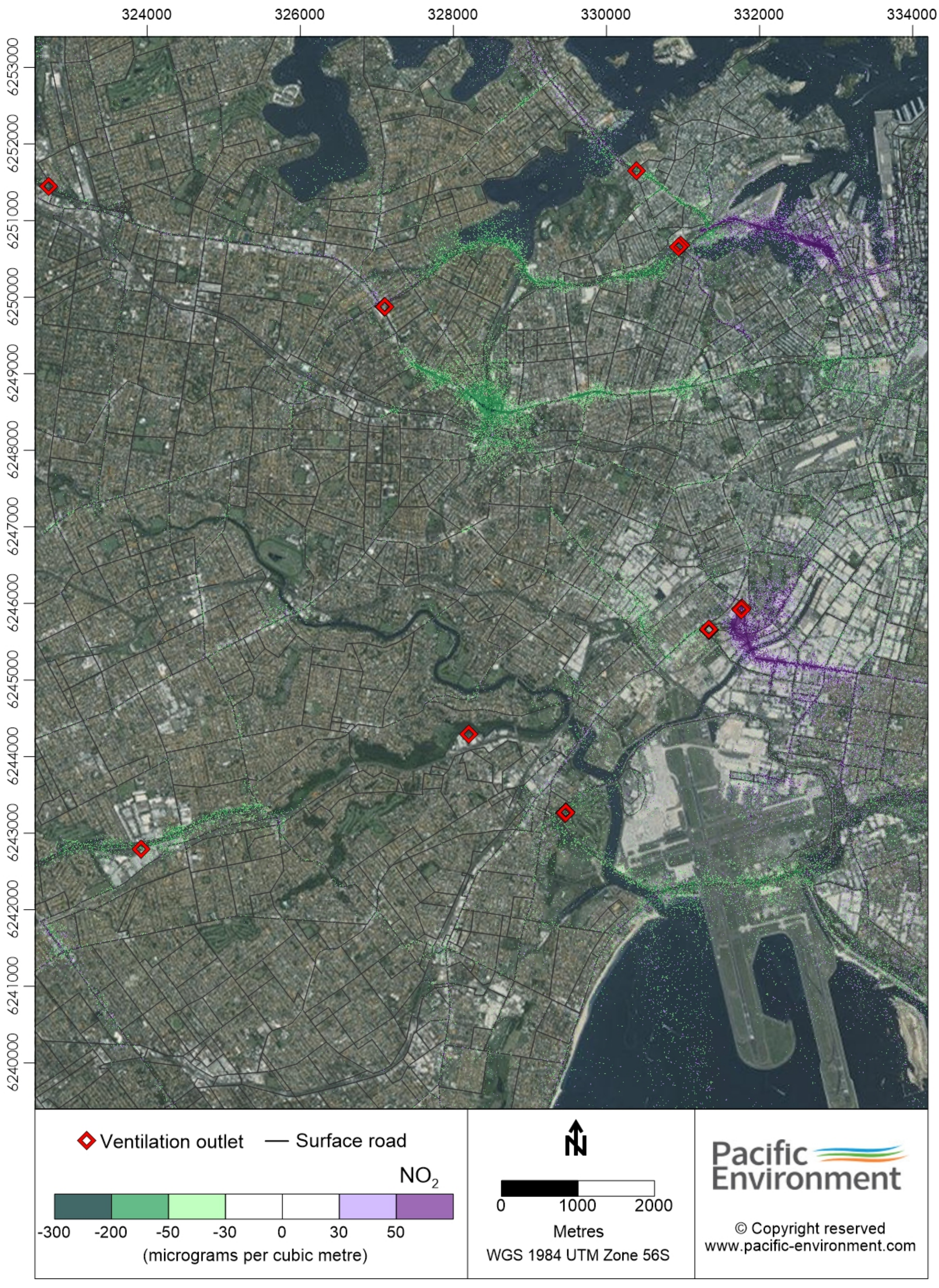

Figure 9-37 Contour plot of change in maximum one hour NO_2 concentration with the project (2023-DS)

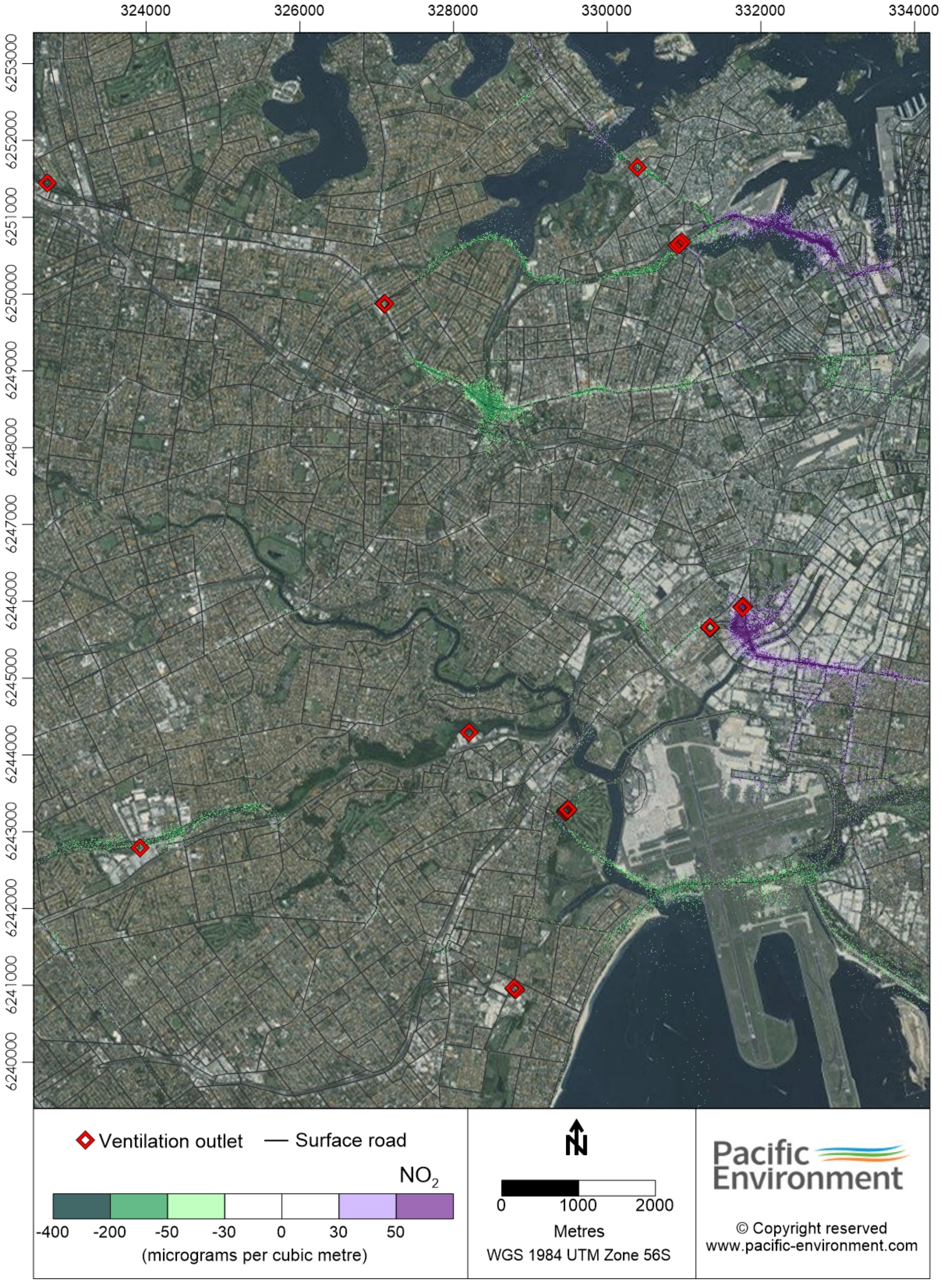

Figure 9-38 Contour plot of change in maximum one hour NO_2 concentration with the project in (2033-DS)

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).

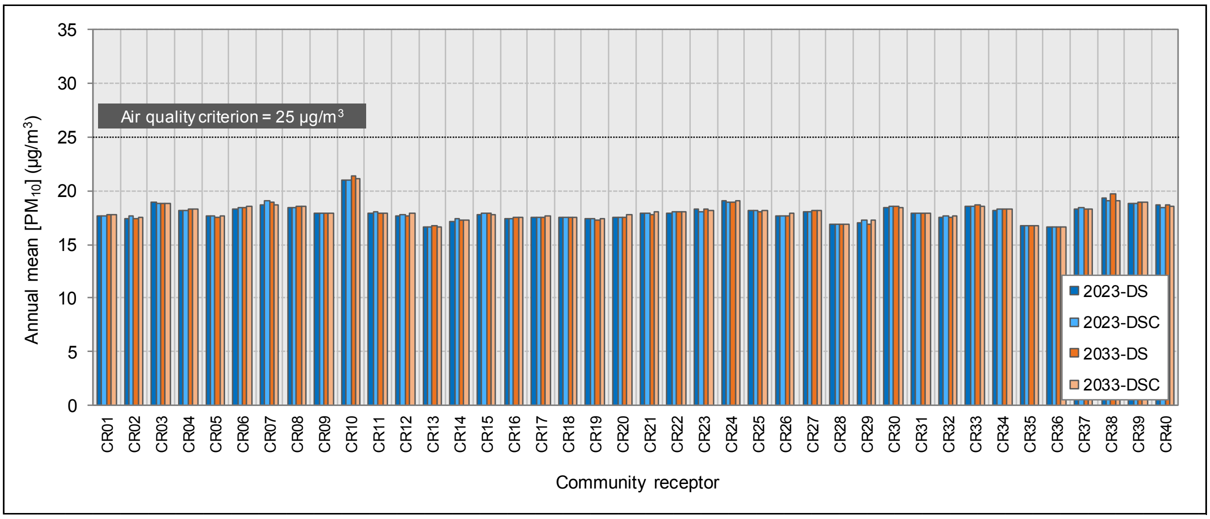

Figure 9-39 Annual mean PM_{10} concentration at community receptors (with-project (DS) and cumulative (DSC) scenarios)

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.

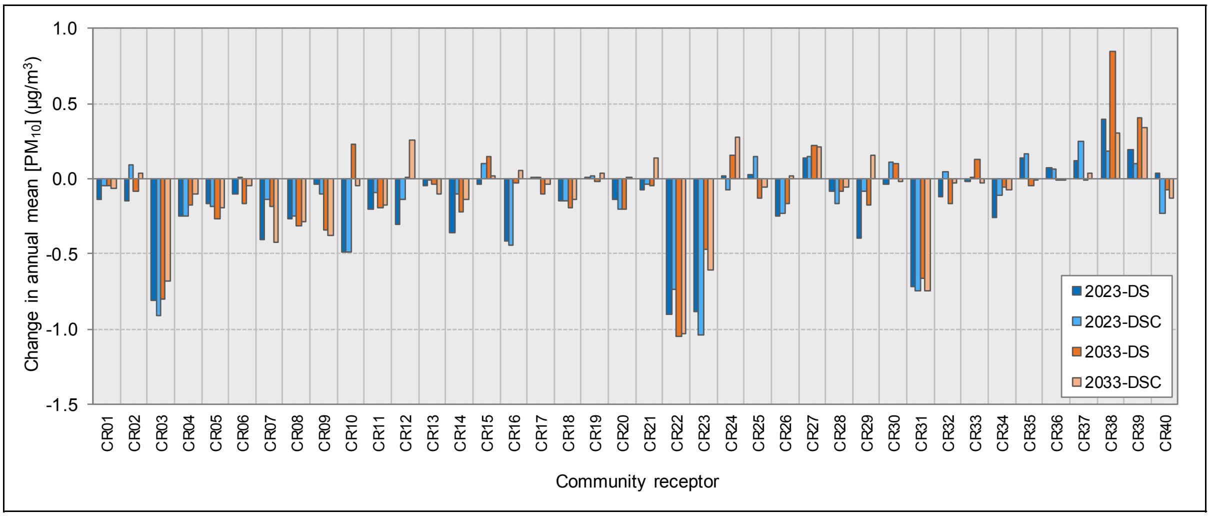

Figure 9-40 Change in annual-mean PM_{10}-concentration at community receptors DS and DSC scenarios, relative to corresponding DM scenarios)

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.

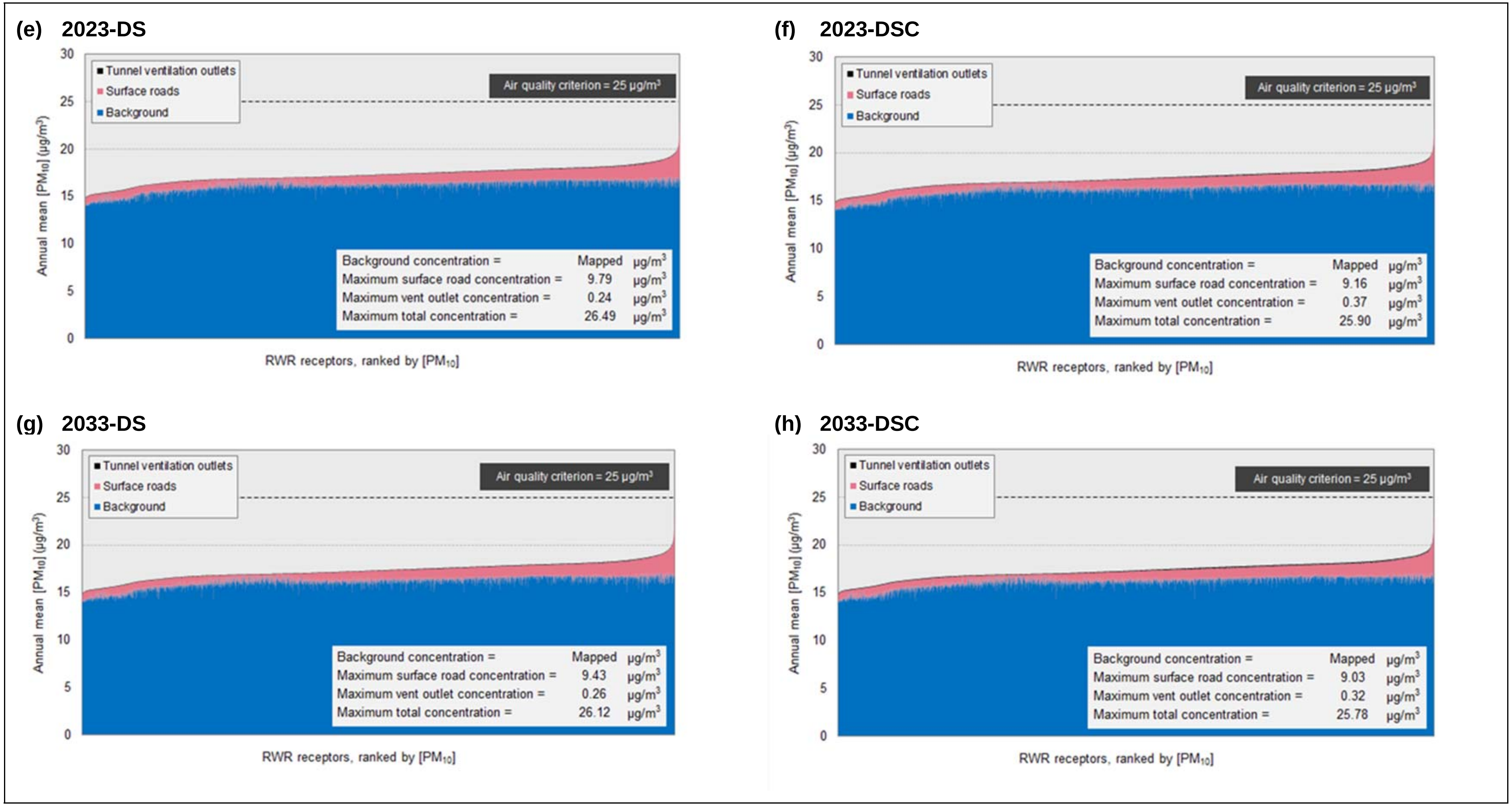

Figure 9-42 Source contributions to annual mean PM_{10} concentration at RWR receptors (with-project and cumulative scenarios)

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.

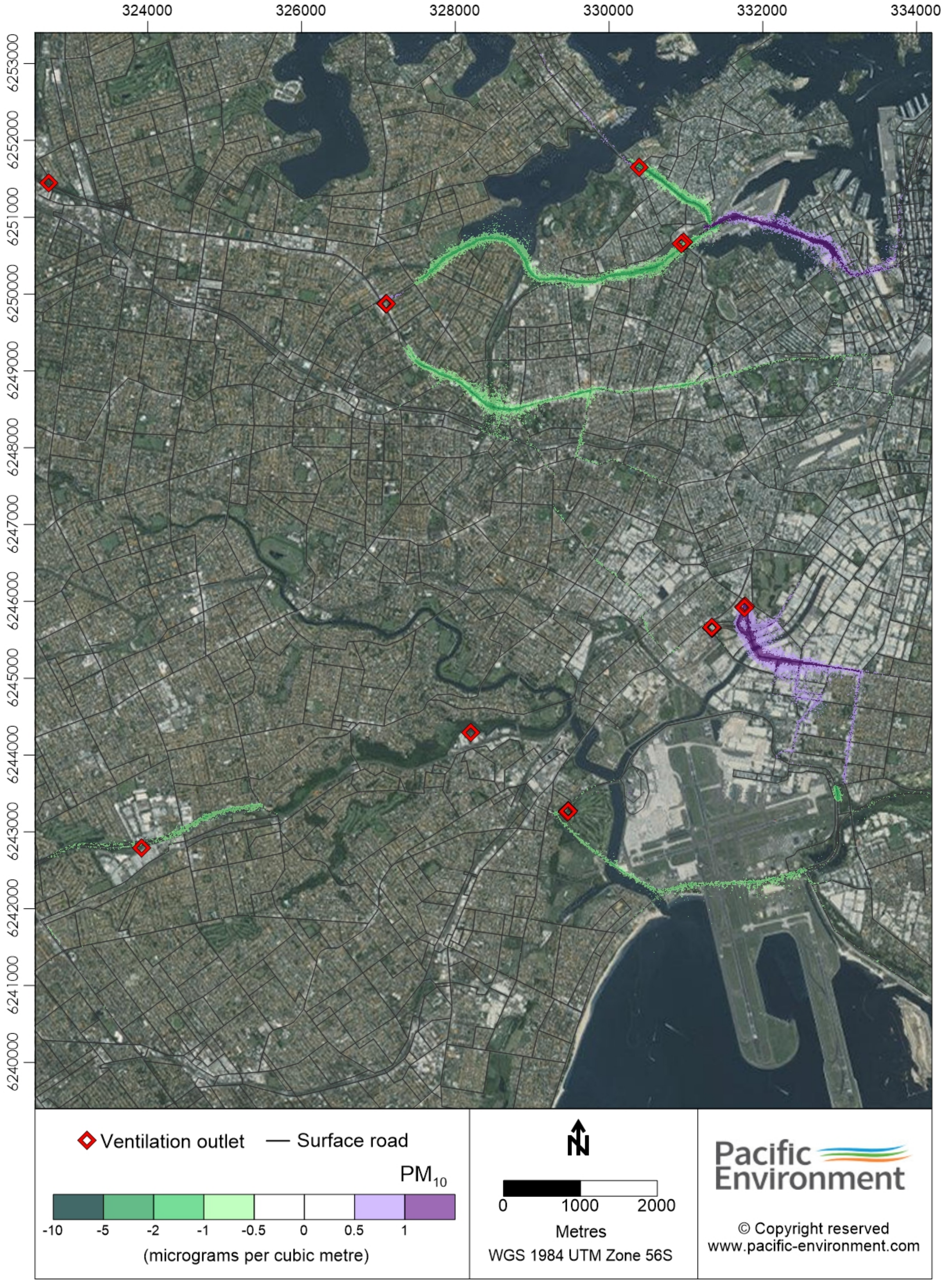

Figure 9-43 Contour plot of change in annual mean PM_{10} concentration with the project (2023-DS)

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.

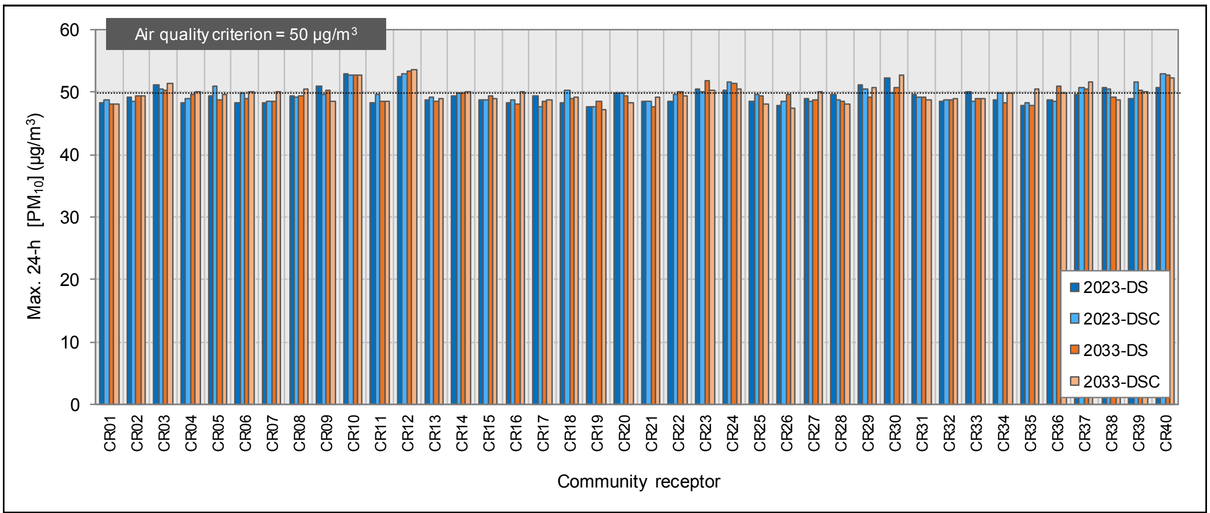

Figure 9-45 Maximum 24 hour mean PM_{10} concentration at community receptors (with-project (DS) and cumulative (DSC) scenarios)

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.

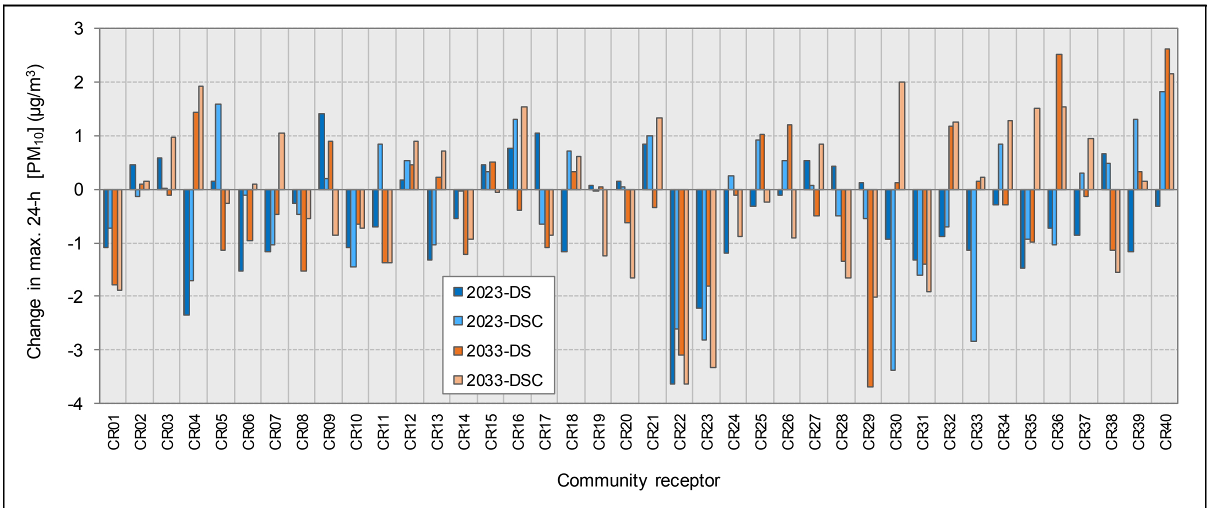

Figure 9-46 Change in maximum 24 hour mean PM_{10} concentration at community receptors (with-project (DS) and cumulative (DSC) scenarios, relative to corresponding Do Minimum scenarios)

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.

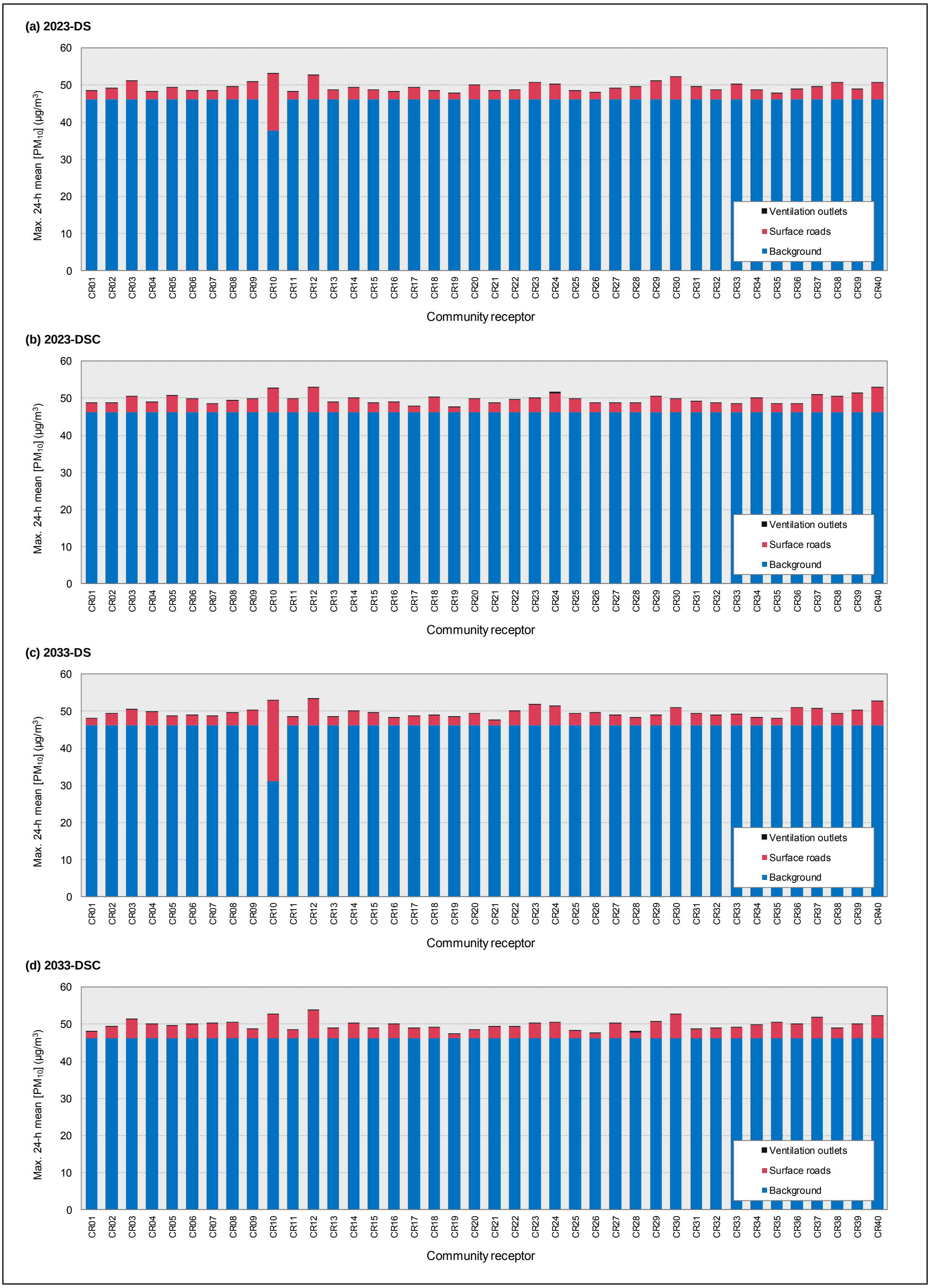

Figure 9-47 Source contributions to maximum 24 hour mean PM_{10} concentration at community receptors in the DS and DSC scenarios

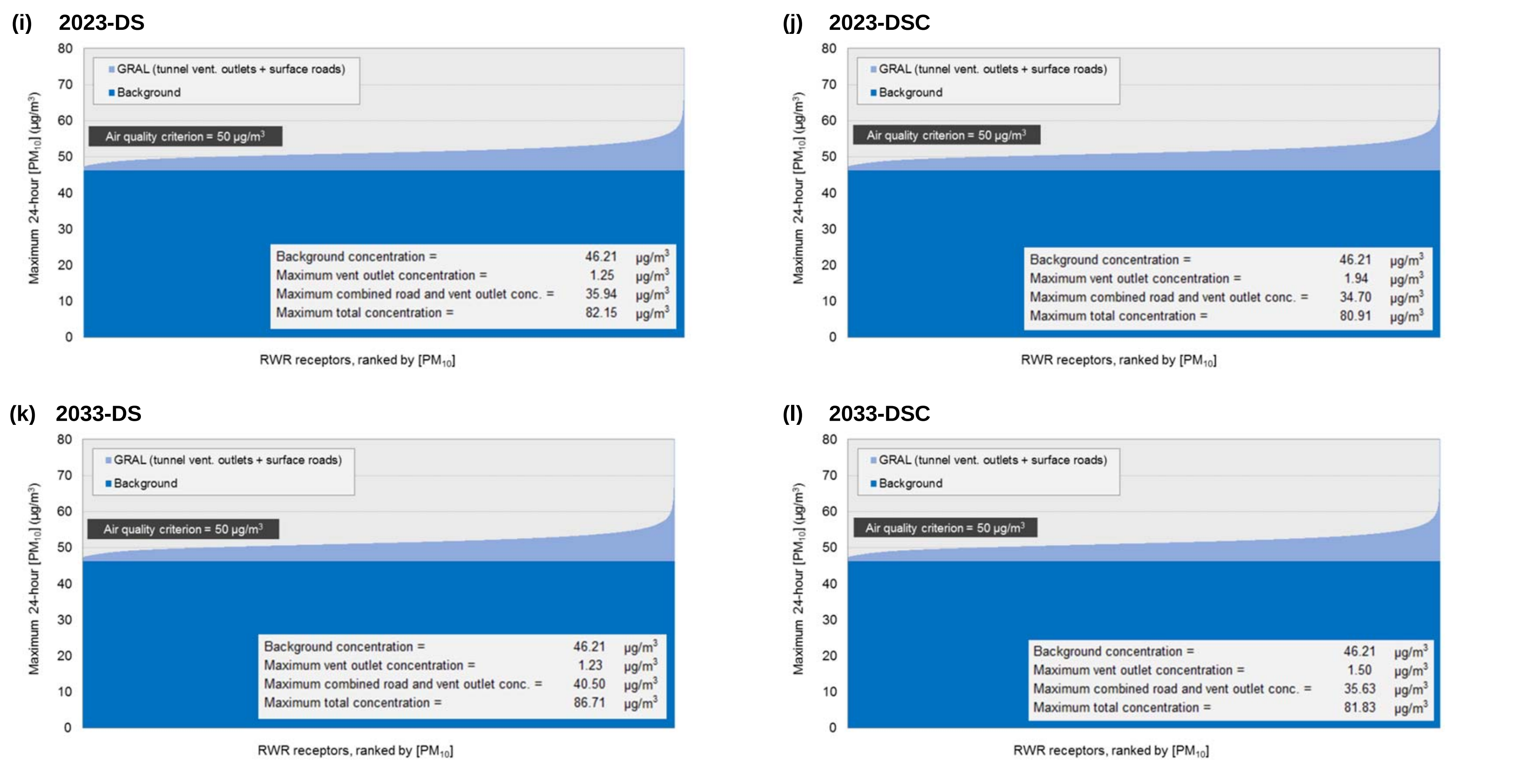

Figure 9-48 Source contributions to maximum 24-hour mean PM_{10} concentration at RWR receptors (with-project and cumulative scenarios)