WestConnex

Australian Government
BUILDING OUR FUTURE

NSW GOVERNMENT

M4-M5 Link

Environmental Impact Statement

August 2017

Appendix I

Volume 2C (Part A)

Since finalisation of the Environmental Impact Statement, the project has been declared by Ministerial Order to be State significant infrastructure and critical State significant infrastructure under sections 115U (4) and 115V of the *Environmental Planning and Assessment Act 1979*. The Ministerial Order also amended Schedule 5 of *State Environmental Planning Policy (State and Regional Development) 2011*. The project remains subject to assessment under Part 5.1 of the *Environmental Planning and Assessment Act 1979* and requires the approval of the Minister for Planning.

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Volume 2C (Part A)

Appendix

WestConnex

Appendix I

Technical working paper: Air quality - Main report

WestConnex

Roads and Maritime Services

WestConnex – M4-M5 Link

Technical working paper: Air quality

August 2017

Prepared for

Roads and Maritime Services

Prepared by

Pacific Environment

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Glossary of terms and abbreviations

Term	Meaning
A	
AAQ NEPM	National Environment Protection (Ambient Air Quality) Measure
ABS	Australian Bureau of Statistics
Abutment	A support structure at the end of a bridge
ACTAQ	Advisory Committee on Tunnel Air Quality
Acute exposure	Contact with a substance that occurs once or for only a short time (up to 14 days)
Airshed	A part of the atmosphere that shares a common flow of air and is exposed to similar influences
ANSTO	Australian Nuclear Science and Technology Organisation
AQM	Air quality management
AWS	Automatic weather station
B	
Background concentration (air quality)	Describes all contributing sources of a pollutant concentration other than road traffic. It includes, for example, contributions from natural sources, industry and domestic activity
BAM	Beta attenuation monitor
BTEX	Benzene, toluene, ethylbenzene and xylenes
C	
Campbell Road civil and tunnel site	A construction ancillary facility for the M4-M5 Link project at St Peters
Campbell Road motorway operations complex	An area where operational ancillary facilities are established. Located within the St Peters interchange, south of Campbell Road at St Peters, on land occupied during construction by the Campbell Road civil and tunnel site
Campbell Road ventilation facility	Ventilation supply and exhaust facilities, axial fans, ventilation outlets and ventilation tunnels. Located at St Peters, within the St Peters interchange site
CALINE	California Line Source Dispersion Model, a steady-state Gaussian dispersion model designed to determine concentrations downwind of highways in relatively uncomplicated terrain
CALMET	A meteorological model that is a component of CALPUFF modelling system
CBD	Central business district
COAG	Council of Australian Governments
CO	Carbon monoxide
CO_2	Carbon dioxide
Concept design	Initial functional layout of a road/road system or other infrastructure. Used to facilitate understanding of a project, establish feasibility and provide basis for estimating and to determine further investigations needed for detailed design
Construction	Includes all physical work required to construct the project
Construction ancillary facilities	Temporary facilities during construction that include, but are not limited to construction sites (civil and tunnel), sediment basins, temporary water treatment plants, pre-cast yards and material stockpiles, laydown areas, parking, maintenance workshops and offices
Construction fatigue	Impact on receivers in the vicinity of concurrent and consecutive construction activities
CSA	Cross-sectional area
CSIRO	Commonwealth Scientific and Industrial Research Organisation

D	
Darley Road civil and tunnel site	A construction ancillary facility for the M4-M5 Link project located at Leichhardt
Darley Road motorway operations complex	An area where operational ancillary facilities are established. Located at Leichhardt, south of City West Link and the Inner West Light Rail line on land occupied during construction by the Darley Road civil and tunnel site
DEC	NSW Department of Environment and Conservation (now OEH and EPA)
DECCW	NSW Department of Environment, Climate Change and Water (formerly DECC, now OEH)
DEFRA	(UK) Department for Environment, Food and Rural Affairs
DERM	(Queensland) Department of Environment and Resource Management
DP&E	NSW Department of Planning and Environment
DPF	Diesel particulate filter
DSEWPC	(Commonwealth) Department of Sustainability, Environment, Water, Population and Communities
E	
EC	Elemental carbon
EIA	Environmental impact assessment
EIS	Environmental impact statement
Emission factor (EF)	A quantity which expresses the mass of a pollutant emitted per unit of activity. For road transport, the unit of activity is usually either distance (i.e. g/km) or fuel consumed (i.e. g/litre).
Emission rate	A quantity which expresses the mass of a pollutant emitted per unit of time (eg g/second)
EP&A Act	*Environmental Planning and Assessment Act 1979* (NSW)
EP&A Regulation	*Environmental Planning and Assessment Regulation 2000* (NSW)
EPHC	Environment Protection Heritage Council
ESP	Electrostatic precipitator
EU	European Union
G	
GHG	Greenhouse gas
GLC	Ground-level concentration
GMR	(NSW) Greater Metropolitan Region
GRAL	Graz Lagrangian (dispersion model) An air quality modelling package
GRAMM	Graz Mesoscale Model
GVM	Gross vehicle mass
H	
Haberfield civil and tunnel site/Haberfield civil site	Construction ancillary facilities for the M4-M5 Link project located at Haberfield
HCV	Heavy commercial vehicle (interchangeable with HGV – see below)
HDV	Heavy-duty vehicle, which includes heavy goods vehicles, buses and coaches
HGV	Heavy goods vehicle (truck)
HVAS	High volume air sampler
I	
IAQM	(UK) Institute of Air Quality Management
Inner West subsurface interchange	A subsurface interchange at Leichhardt and Annandale that would link the mainline tunnels with the Rozelle interchange and the Iron Cove Link

Iron Cove Link	Around one kilometre of twin tunnels that would connect Victoria Road near the eastern abutment of Iron Cove Bridge and Anzac Bridge
Iron Cove Link civil site	A construction ancillary facility for the M4-M5 Link project located at Rozelle
Iron Cove Link motorway operations complex	An area where operational ancillary facilities are established. Located south of the realigned Victoria Road carriageway between Callan Street and Springside Street at Rozelle, on land occupied during construction by the Iron Cove Link civil site
Iron Cove Link ventilation facility	Ventilation supply and exhaust facilities, axial fans, ventilation outlets and ventilation tunnels. Located at Rozelle
L	
LCT	Lane cove tunnel
LCV	Light commercial vehicle
LDV	Light-duty vehicle, which includes cars and light commercial vehicles
M	
M4 East Motorway/project	A component of the WestConnex program of works. Extension of the M4 Motorway in tunnels between Homebush and Haberfield via Concord. Includes provision for a future connection to the M4-M5 Link at the Wattle Street interchange
M4 East mainline stub tunnels	Eastbound and westbound extensions of the M4 East mainline tunnel being built as part of the M4 East project (to connect with the M4-M5 Link)
M4 East mainline connection	The underground connection between the M4-M5 Link mainline tunnels and the M4 East mainline stub tunnels
M4 Motorway	The M4 Motorway is a 40 kilometre motorway that extends from Concord in Sydney's inner west to Lapstone at the foothills of the Blue Mountains
M4 Widening	A component of the WestConnex program of works. Widening of the existing M4 Motorway from Parramatta to Homebush
M4-M5 Link	The project which is the subject of this EIS. A component of the WestConnex program of works
M5 East Motorway	Part of the M5 Motorway corridor. Located between Beverly Hills and Sydney Airport (General Holmes Drive)
M5 Motorway corridor	The M5 East Motorway and the M5 South West Motorway
M5 South West Motorway	Part of the M5 Motorway corridor. Located between Prestons and Beverly Hills
Mainline tunnels	The M4-M5 Link mainline tunnels connecting with the M4 East Motorway at Haberfield and the New M5 Motorway at St Peters
N	
NEPC	National Environment Protection Council
NEPM	National Environment Protection Measure
New M5 Motorway/project	A component of the WestConnex program of works. Located from Kingsgrove to St Peters (under construction)
New M5 mainline stub tunnels	Northbound and southbound extensions of the New M5 mainline tunnel being built as part of the New M5 project (to connect with the M4-M5 Link)
New M5 mainline connection	The underground connection between the M4-M5 Link mainline tunnels and the New M5 mainline stub tunnels
NH_3	Ammonia
NHMRC	National Health and Medical Research Council
NIWA	National Institute of Water and Atmospheric Research (New Zealand)
NMVOC	Non-methane volatile organic compound
NO	Nitric oxide
NO_2	Nitrogen dioxide
NO_X	Oxides of nitrogen

Northcote Street civil site	A construction ancillary facility for the M4-M5 Link project located at Haberfield
NPI	National Pollutant Inventory
NSW	New South Wales
NSW EPA	NSW Environment Protection Authority
NSW Health	NSW Department of Health
O	
O_3	Ozone
OC	Organic carbon
OEH	NSW Office of Environment and Heritage (Formerly DECCW)
P	
PAH(s)	Polycyclic aromatic hydrocarbon(s)
Parramatta Road East civil site	A construction ancillary facility for the M4-M5 Link project at Haberfield
Parramatta Road ventilation facility	A ventilation facility located on the south eastern corner of the Parramatta Road/Wattle Street intersection (referred to as the Eastern ventilation facility in the M4 East EIS). The facility is being built as part of the M4 East project. As part of the M4-M5 Link project, fit out works would be carried out on a section of this facility
Parramatta Road West civil and tunnel site	A construction ancillary facility for the M4-M5 Link project at Ashfield
PIARC	Permanent International Association of Road Congresses
PM	(airborne) particulate matter
PM_{10}	airborne particulate matter with an aerodynamic diameter of less than 10 µm
$PM_{2.5}$	airborne particulate matter with an aerodynamic diameter of less than 2.5 µm
ppb	Parts per billion
ppm	Parts per million
Project	A new multi-lane road link between the M4 East Motorway at Haberfield and the New M5 Motorway at St Peters. The project would also include an interchange at Lilyfield and Rozelle (the Rozelle interchange) and a tunnel connection between Anzac Bridge and Victoria Road, east of Iron Cove Bridge (Iron Cove Link). In addition, construction of tunnels, ramps and associated infrastructure to provide connections to the proposed future Western Harbour Tunnel and Beaches Link project would be carried out at the Rozelle interchange
Project footprint	The land required to construct and operate the project. This includes permanent operational infrastructure (including the tunnels), and land required temporarily for construction
PV	Passenger vehicle
Pyrmont Bridge Road tunnel site	A construction ancillary facility for the M4-M5 Link project at Annandale
Q	
R	
RH	Relative humidity
Roads and Maritime	NSW Roads and Maritime Services ('RMS' is used in some Figures and Tables)
Rozelle civil and tunnel site	A construction ancillary facility for the M4-M5 Link project located at Lilyfield and Rozelle
Rozelle East motorway operations complex	An area where operational ancillary facilities are established. Located at the western end of the Rozelle Rail Yards on land occupied during construction by the Rozelle civil and tunnel site

Rozelle interchange	A new interchange at Lilyfield and Rozelle that would connect the M4-M5 Link mainline tunnels with City West Link, Anzac Bridge, the Iron Cove Link and the proposed future Western Harbour Tunnel and Beaches Link
Rozelle Rail Yards	The Rozelle Rail Yards is bound by City West Link to the south, Lilyfield Road to the north, Balmain Road to the west, and White Bay to the east. Note that the project only occupies part of the Rozelle Rail Yards site
Rozelle ventilation facility	Ventilation supply and exhaust facilities, axial fans, ventilation outlets and ventilation tunnels. Located at the Rozelle Rail Yards, the ventilation supply facility is located at the Rozelle West motorway operations complex and a ventilation exhaust facility at the Rozelle East motorway operations complex
Rozelle West motorway operations complex	An area where operational ancillary facilities are established. Located at the central/eastern end of the Rozelle Rail Yards, on land occupied during construction by the Rozelle civil and tunnel site
RWR	Residential, workplace and recreational This term refers to all discrete receptor locations along the project corridor, and mainly covers residential and commercial land uses
S	
SCR	Selective catalytic reduction
SEARs	Secretary's Environmental Assessment Requirements Requirements and specifications for an environmental assessment prepared by the Secretary of the NSW Department of the Planning and Environment under section 115Y of the *Environmental Planning and Assessment Act 1979* (NSW)
SER	Strategic Environmental Review
SMC	Sydney Motorway Corporation
SMPO	Sydney Motorways Project Office
SO_2	Sulfur dioxide
SO_X	Sulfur oxides
St Peters interchange	A component of the New M5 project, located at the former Alexandria Landfill site at St Peters. Approved and under construction as part of the New M5 project. Additional construction works proposed as part of the M4-M5 Link project
T	
TAPM	The Air Pollution Model
TEOM	Tapered Element Oscillating Microbalance
The Crescent civil site	A construction ancillary facility for the M4-M5 Link project located at Annandale
THC	Total hydrocarbons
TRAQ	Tool for Roadside Air Quality
TSP	Total suspended particulate (matter)
U	
UFP	Ultrafine particles
UK	United Kingdom
UN	United Nations
US	United States
USEPA	United States Environmental Protection Agency

V	
Ventilation facility	Facility for the mechanical removal of air from the mainline tunnels, or mechanical introduction of air into the tunnels. May comprise one or more ventilation outlets
Victoria Road civil site	A construction ancillary facility for the M4-M5 Link project located at Rozelle
VKT	Vehicle kilometres travelled
VOCs	Volatile organic compounds
W	
Wattle Street civil and tunnel site	A construction ancillary facility for the M4-M5 Link project located at Haberfield
Wattle Street interchange	An interchange to connect Wattle Street (City West Link) with the M4 East and the M4-M5 Link tunnels. Approved and under construction as part of the M4 East project. Additional construction works proposed as part of the M4-M5 Link project
WDA	WestConnex Delivery Authority (now the Sydney Motorway Corporation)
Western Harbour Tunnel and Beaches Link	The Western Harbour Tunnel component would connect to the M4-M5 Link at the Rozelle interchange, cross underneath Sydney Harbour between the Birchgrove and Waverton areas, and connect with the Warringah Freeway at North Sydney. The Beaches Link component would comprise a tunnel that would connect to the Warringah Freeway, cross underneath Middle Harbour and connect with the Burnt Bridge Creek Deviation at Balgowlah and Wakehurst Parkway at Seaforth. It would also involve the duplication of the Wakehurst Parkway between Seaforth and Frenchs Forest
WestConnex program of works	A program of works that includes the M4 Widening, King Georges Road Interchange Upgrade, M4 East, New M5 and M4-M5 Link projects
WHO	World Health Organization
WRTM	WestConnex Road Traffic Model

Executive summary

E.1 The project

NSW Roads and Maritime Services (Roads and Maritime) is seeking approval to construct and operate the WestConnex M4-M5 Link (the project), which would comprise a new multi-lane road link between the M4 East Motorway at Haberfield and the New M5 Motorway at St Peters. The project would also include an interchange at Lilyfield and Rozelle (the Rozelle interchange) and a tunnel connection between Anzac Bridge and Victoria Road, east of Iron Cove Bridge (Iron Cove Link). In addition, construction of tunnels, ramps and associated infrastructure to provide connections to the proposed future Western Harbour Tunnel and Beaches Link project would be carried out at the Rozelle interchange.

Approval is being sought under Part 5.1 of the *Environmental Planning and Assessment Act 1979* (NSW) (EP&A Act) for the project. A request has been made for the NSW Minister for Planning to specifically declare the project to be State significant infrastructure and also critical State significant infrastructure. An environmental impact statement (EIS) is therefore required.

The main components of the project of relevance to air quality would include the following:

- Twin mainline motorway tunnels between the M4 East at Haberfield and the New M5 at St Peters. Each tunnel would be around 7.5 kilometres long and would generally accommodate up to four lanes of traffic in each direction
- An underground interchange at Leichhardt and Annandale (the Inner West subsurface interchange) that would link the mainline tunnels with the Rozelle interchange and the Iron Cove Link
- A new interchange at Lilyfield and Rozelle (the Rozelle interchange) that would connect the M4-M5 mainline tunnels with
  - City West Link
  - Anzac Bridge
  - The Iron Cove Link
  - The proposed future Western Harbour Tunnel and Beaches Link
- Twin tunnels that would connect Victoria Road near the eastern abutment of Iron Cove Bridge and Anzac Bridge (the Iron Cove Link)
- Tunnel ventilation systems, including ventilation supply and exhaust facilities, axial fans, ventilation outlets and ventilation tunnels
- Fitout of part of the Parramatta Road ventilation facility being built as part of M4 East project for use by the M4-M5 Link project
- Three new ventilation facilities, including:
  - The Rozelle ventilation facility at the Rozelle Rail Yards, which would include a ventilation supply facility at the Rozelle West motorway operations complex (MOC2) and a ventilation exhaust facility at the Rozelle East motorway operations complex (MOC3)
  - The Iron Cove Link ventilation facility at Rozelle
  - The Campbell Road ventilation facility at St Peters, within the St Peters interchange site.

The project would be generally located within the City of Sydney and Inner West local government areas. The project is located about two to seven kilometres south, southwest and west of the Sydney central business district and would cross the suburbs of Ashfield, Haberfield, Leichhardt, Lilyfield, Rozelle, Annandale, Stanmore, Camperdown, Newtown and St Peters.

E.2 The purpose of this report

The purpose of this report is to address the requirements of the air quality section of the revised Secretary's Environmental Assessment Requirements (SEARs) for the M4-M5 Link project (SSI 7485), issued on 3 May 2017, and to thus support the EIS. The report presents an assessment of the construction and operational activities for the project that have the potential to affect in-tunnel, local ambient and regional ambient air quality.

The report:

- Describes the project
- Identifies key air quality issues for the project
- Summarises the regulation of emissions, air pollution and exposure
- Provides an overview of the air quality assessment methodology
- Describes the existing environment in the general area of Sydney affected by the project, with specific reference to terrain, meteorology, emissions and ambient (outdoor) air quality
- Describes the assessment of the impact of construction of the project on air quality
- Describes the assessment of the impact of the operation of the project on air quality
- Deals with the cumulative air quality impacts of the project with other projects
- Provides a review of proposed air quality mitigation measures, and recommendations on measures to manage any impacts of the project.

Specific emphasis has been placed on the assessment and management of the following:

- In-tunnel air quality. The report demonstrates that the proposed ventilation system and management approaches would comply with some of the most stringent standards in the world for operational, in-tunnel air quality
- Portal emissions. No portal emissions are proposed for the M4-M5 Link project, and the report demonstrates that the design of the ventilation system would achieve this
- Ambient air quality. The potential for ambient air quality impacts during project construction is assessed in the report, which includes a comprehensive range of management measures to be implemented during construction of the project'. The potential for ambient air quality impacts during project operation was assessed in detail using an air pollution dispersion model, and the report demonstrates that the proposed ventilation system would be effective at maintaining ambient air quality overall.

The following impacts of the project were outside the scope of work and have not been addressed in this report:

- Air quality inside buildings and vehicles. This is because air quality criteria applies to outdoor locations and ambient air quality monitoring is conducted at such locations
- Health risks associated with air quality (refer to **Chapter 11** (Human health risk) and **Appendix K** (Technical working paper: Human health risk assessment) of the EIS)
- Greenhouse gas emissions (assessed in **Chapter 22** (Greenhouse gas) of the EIS).

E.3 Construction impacts

There is currently no specific policy or guideline for assessing the impacts of air quality during construction of road and tunnel projects in NSW. The potential impacts of the construction phase of the project were assessed using guidance published by the UK Institute of Air Quality Management[1]. The UK guidance was adapted for use in NSW, taking into account factors such as the assessment criteria for ambient particulate matter (PM_{10}) concentrations.

The risks associated with construction dust emissions were assessed for four types of activity: demolition, earthworks, construction, and track-out (the transport of dust and dirt by heavy-duty vehicles from the work sites onto the public road network, where it may be deposited and then re-suspended by other vehicles). The assessment methodology considered three separate dust impacts: annoyance due to dust soiling, the risk of health effects due to an increase in human exposure, and harm to ecological receptors. Above-ground construction activities would take place at a number of separate locations.

For dust soiling impacts, the sensitivity for all areas and all activities was determined to be 'high'. For human health impacts, the sensitivity for all areas and all activities was determined to be 'medium'. For ecological impacts, the sensitivity of activities and areas was either 'medium' or 'low'.

Several locations and activities were determined to have a high risk of impacts. Consequently, a wide range of management measures has been recommended to mitigate the effects of construction works on local air quality at the nearest receptors. Most of the recommended measures are routinely employed as 'good practice' on construction sites.

E.4 Operational impacts – in-tunnel air quality

E.4.1 Scenarios

The scenarios evaluated for in-tunnel air quality reflected the potential modes of operation of the tunnel ventilation system, as well as a worst case trip scenario for in-tunnel exposure to nitrogen dioxide (NO_2). NO_2 was used for the worst case trip scenarios because it has become the critical vehicle exhaust pollutant for ventilation control. These scenarios were:

- Expected traffic (24 hour) scenarios:

  These scenarios represented the 24 hour operation of the tunnel ventilation system under day-to-day conditions of expected traffic demand in 2023 and 2033

- Regulatory demand (24 hour) traffic scenarios:

  In these scenarios, in-tunnel air quality was calculated with traffic scaled up to the maximum capacity of the tunnel to demonstrate that the in-tunnel air quality criteria would still be met

- Worst case traffic scenarios:

  These simulations addressed the most onerous traffic conditions for the ventilation system to manage air quality, based on traffic conditions between 20 and 80 kilometres per hour that included:

  - Congestion (down to 20 kilometres per hour, on average)
  - Breakdown or minor incident
  - Free-flowing traffic at maximum capacity

[1] IAQM (2014).*Guidance on the assessment of dust from demolition and construction*. Institute of Air Quality Management, London

- Travel route scenarios:

  All possible travel routes through the M4-M5 Link and the adjoining WestConnex tunnels (being the M4 East and New M5 tunnels) were identified for each direction of travel, and route-average NO_2 concentrations were assessed against the corresponding in-tunnel criterion.

E.4.2 Methodology and conclusions

In-tunnel air quality for the project was modelled using the IDA Tunnel software and Australia-specific emission factors from the Permanent International Association of Road Congresses (PIARC). Traffic volume projections were taken from the WestConnex Road Traffic Model (WRTM) version 2.3 (as in **Appendix H** (Technical working paper: Traffic and transport) of the EIS), and other sources were used to provide a representative traffic mix for the tunnel.

Consideration was given to peak in-tunnel concentrations of carbon monoxide (CO) and NO_2, as well as the peak extinction coefficient (for visibility). The information presented in the report has confirmed that the tunnel ventilation system would be designed to maintain in-tunnel air quality well within operational limits for all scenarios.

E.5 Operational impacts – ambient air quality (expected traffic)

E.5.1 Scenarios

Two types of scenario were considered for ambient air quality, as described below:

- Expected traffic scenarios:

  The expected traffic scenarios included in the operational ambient air quality assessment were:

  - 2015 Base Year. This represented the road network with no new projects (including WestConnex projects) or upgrades, 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 quality monitoring data
  - 2023 Do Minimum. In this scenario it was assumed that the following WestConnex projects would be constructed and open to traffic:
    - M4 Widening
    - M4 East
    - New M5
    - King Georges Road Interchange Upgrade

    The M4-M5 Link and other projects (Western Harbour Tunnel (WHT), Sydney Gateway, Beaches Link (BL) and F6 Extension) would not be completed
  - 2023 Do Something. As for 2023 Do Minimum, but with the M4-M5 Link also completed and open to traffic
  - 2023 Do Something Cumulative. As for 2023 Do Minimum, but with the M4-M5 Link and some other projects (Sydney Gateway and WHT (but not BL or the F6 Extension)) also completed
  - 2033 Do Minimum. As for 2023 Do Minimum, but for 10 years after project opening
  - 2033 Do Something. As for 2033 Do Minimum, including the M4-M5 Link completed, but for 10 years after project opening
  - 2033 Do Something Cumulative. As for 2033 Do Minimum, with the M4-M5 Link, Sydney Gateway, WHT, BL and F6 Extension also completed
- Regulatory worst case scenarios:

These scenarios assessed emissions from the ventilation outlets only, with pollutant concentrations fixed at the regulatory limits. The scenarios represented the theoretical maximum changes in air quality for all potential traffic operations in the tunnel, including unconstrained and worst case traffic conditions from an emissions perspective, as well as vehicle breakdown situations. The assumptions underpinning these scenarios were very conservative, and resulted in contributions from project ventilation outlets that were much higher than those that could occur under any foreseeable operational conditions in the tunnel.

E.5.2 Methodology and conclusions

For each scenario, a spatial emissions inventory was developed for road traffic sources in the dispersion modelling domain. The following components were treated separately:

- Emissions from existing and proposed tunnel ventilation outlets
- Emissions from the traffic on the surface road network, including any new roads associated with the project (or projects in the cumulative scenario).

Emission modelling – tunnel ventilation outlets

The assessment was conducted assuming no emissions from any tunnel portals. That is, all emissions from the traffic in tunnels were assumed to be released to the atmosphere via ventilation outlets.

In total, 14 separate tunnel ventilation outlets (labelled A to N) were included in the assessment:

- Existing facility:
  - Outlet A M5 East Motorway tunnel outlet at Turrella
- Facilities currently under construction for M4 East and New M5:
  - Outlet B M4 East facility at Parramatta Road, Haberfield
  - Outlet C M4 East facility at Underwood Road, Homebush
  - Outlet D New M5 facility at St Peters interchange
  - Outlet E New M5 facility at Arncliffe
  - Outlet F New M5 facility at Kingsgrove
- Ventilation facilities for the M4-M5 Link (subject of this EIS):
  - Ventilation facility at Haberfield:
    - Outlet G M4-M5 Link facility at Parramatta Road, Haberfield (under construction as part of the M4 East project with fitout occurring as part of the M4-M5 Link project)
  - Ventilation facility at Rozelle:
    - Outlet H WHT facility at Rozelle (the M4-M5 Link project is constructing this outlet, although the fitout would be subject to separate assessment and approval under that project's EIS)
    - Outlets I and J M4-M5 Link/Iron Cove Link (ICL) facility at Rozelle
  - Ventilation facility at St Peters:
    - Outlet K M4-M5 Link facility at St Peters interchange
  - Ventilation facility at Iron Cove:
    - Outlet L Iron Cove Link facility at Rozelle near Iron Cove

- Proposed ventilation facilities for the possible future F6 Extension:
  - Outlet M F6 Extension facility at Arncliffe
  - Outlet N F6 Extension facility at Rockdale.

The ventilation outlets that would be specific to the M4-M5 Link are G, I, J, K and L. The remaining outlets (A, B, C, D, E, F, H, M and N) were included to assess potential cumulative impacts only. Further details of the project ventilation facilities, including the locations and surrounding environments, are provided in **Chapter 5** (Project description) of the EIS.

Emission modelling – surface roads

The road network (including tunnels) had between 5,502 and 5,733 individual road links, depending on the scenario. Data on traffic volume, composition and speed were taken from WRTM.

Comparing the Do Something scenarios with the Do Minimum scenarios, emissions of CO, oxides of nitrogen (NO_X), PM_{10} and $PM_{2.5}$ increased by 1.6 to 2.9 per cent in 2023, and by 2.9 to 3.2 per cent in 2033, depending on the pollutant. For the Do Something Cumulative scenarios, emissions of these pollutants increased by 3.2 to 5.1 per cent in 2023 and by 7.2 to 8.2 per cent in 2033, depending on the pollutant. The changes in total hydrocarbon (THC) emissions were relatively small (less than or equal to 1.6 per cent). The changes in the total emissions resulting from the project can be viewed as a proxy for its regional air quality impacts.

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.

Dispersion modelling

The dispersion modelling was conducted using the GRAMM/GRAL system (version 14.11). The system consists of two main modules: a prognostic wind field model (Graz Mesoscale Model - GRAMM) and a dispersion model (GRAL itself). The GRAMM domain covered most of the WestConnex project, being 23 x 23 kilometres in size (refer to **section 5.5.3**). Meteorological data from the BoM Canterbury Racecourse automatic weather station (AWS) site for 2015 were selected for use in GRAMM to determine three-dimensional wind fields across the modelling domain.

Two types of discrete receptor location were defined for use in the dispersion modelling:

- ‘Community receptors’. These were taken to be representative of particularly sensitive locations such as schools, child care centres and hospitals within a zone around 500-600 metres either side of the project corridor, and generally near significantly affected roadways. This zone was sufficiently large to capture the largest impacts of the project. For these receptors, a detailed ‘contemporaneous’ approach was used to calculate the total concentration of each pollutant. In total, 40 community receptors were included in the assessment
- ‘Residential, workplace and recreational (RWR) receptors’. These were all discrete receptor locations along the project corridor, and mainly covered residential and commercial land uses. For these receptors, a simpler statistical approach was used to combine a concentration statistic for the modelled roads and outlets with an appropriate background statistic. In total, 86,375 RWR receptors were included in the assessment.

The main reason for the distinction was to permit a more detailed analysis of short-term impacts on community receptors.

The following general conclusions have been drawn from the dispersion modelling:

- The predicted total concentrations of all criteria pollutants at receptors were usually dominated by the existing background contribution
- For some pollutants and metrics (such as annual mean NO_2) there was also a significant contribution from the modelled surface road traffic in all scenarios

- Under expected traffic conditions, the contribution of tunnel ventilation outlets to pollutant concentrations was negligible for all receptors
- Predicted changes in pollutant concentration were driven by changes in traffic volumes on the modelled surface road network, not by the tunnel ventilation outlets
- For air quality, some metrics (one hour NO_2 and 24 hour PM_{10}), exceedances of the criteria were predicted to occur both with and without the project. However, where this was the case the total numbers of receptors with exceedances decreased slightly with the project and in the cumulative scenarios
- Where increases in pollutant concentrations at receptors were predicted, these were mostly small. A very small proportion of receptors were predicted to have larger increases. However, at the affected locations the concentrations were considered to be unrealistically high (the reasons for this are explained in the report)
- The spatial changes in air quality as a result of the project were quite complex, reflecting the complexity of changes in traffic on the road network. For example:
  - Marked reductions in pollutant concentration were predicted along Dobroyd Parade / City West Link and Parramatta Road to the south-east of the Parramatta Road ventilation facility. In the 2023 Do Minimum 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, reducing emissions of pollutants from those surface roads
  - A substantial reduction in pollutant concentrations was predicted along the Victoria Road corridor south of Iron Cove at Rozelle, due to traffic being diverted through the Iron Cove Link tunnel
  - There would also be reductions in pollutant concentrations along General Holmes Drive, Princes Highway and the M5 East Motorway
  - However, there would be additional traffic (and an increase in pollutant concentrations) to the north of Iron Cove Link and near Anzac Bridge as a result of the general increase in traffic due to the project
  - Pollutant concentrations were also predicted to increase along Canal Road, which would be used to access the St Peters interchange, and other roads associated with the Sydney Gateway project
- Annual mean $PM_{2.5}$ was taken as the indicator for the operational effects of Option B for project construction. The effects of Option B were not significantly different from those for Option A.

More detailed pollutant-specific conclusions are presented in the report.

E.6 Ambient air quality (expected traffic, elevated receptors)

Concentrations at two elevated receptor heights (10 metres and 30 metres) were assessed for annual mean and 24 hour $PM_{2.5}$. It should be noted that, for the 10 metre and 30 metre heights, it was not necessarily the case that there were existing buildings at these heights at the RWR receptor locations.

The results are summarised as follows:

- The influence of surface roads was clearly reduced at 10 metres compared with at ground level, and was negligible at 30 metres. At a height of 30 metres the increases in concentration were larger than at 10 metres, but they were much more localised around the ventilation outlets. This was due to some of the grid points at 30 metres being very close to the ventilation outlets
- For all receptor locations, the changes in $PM_{2.5}$ concentration at 10 metres are likely to be acceptable. This assumes that the changes in $PM_{2.5}$ concentration for heights between ground level and 10 metres are also acceptable

- Future developments to a height of 10 metres should be possible at all locations in the GRAL domain
- The predicted concentrations do not indicate the need for any restrictions on future developments to 30 metres height, except in the vicinity of ventilation outlets at Campbell Road ventilation facility. The ventilation outlets would not adversely impact any existing receptors, as there are no existing buildings 30 metres or higher located close to the proposed ventilation facilities. Planning controls should be developed in the vicinity of St Peters to ensure future developments at heights about 10 metres are not adversely impacted by the ventilation outlets, A building height of 10 metres was selected because the screening analysis was only done at 10 and 30 metres and predictions for concentrations between these heights was undertaken. Development of planning controls would need to be support3d by detailed modelling addressing all relevant pollutants and averaging periods.

E.7 Ambient air quality (regulatory worst case)

The regulatory worst case only applied to the ambient air quality impacts of the tunnel ventilation outlets. For CO, PM_{10} and $PM_{2.5}$ only the 2033 Do Something Cumulative scenario was used, as this was shown to result in the highest concentrations during some initial modelling. In the case of NO_2 it was not possible to know beforehand which scenario would result in the highest concentrations, and therefore all scenarios were modelled.

The concentrations from the ventilation outlets in the regulatory worst case scenarios were, of course, higher than those for the expected traffic scenarios in all cases, and the following points are noted in relation to the regulatory worst case scenarios:

- The maximum one hour CO concentration was negligible, especially taking into account the CO concentrations are well below the NSW impact assessment criterion (30 milligrams per cubic metres (mg/m^3)). For example, the maximum one hour ventilation outlet contribution in the regulatory worst case scenario (0.50 mg/m^3) was a very small fraction of the criterion. The maximum background one hour CO concentration (3.27 mg/m^3) was also well below the criterion. Exceedances of the criterion due to the ventilation outlets are therefore highly unlikely
- For PM_{10} the maximum contribution of the ventilation facility outlets was small. The annual mean and maximum 24 hour PM_{10} contributions from the ventilation outlets were less than 10 per cent of the respective criteria (25 micrograms per cubic metre ($\mu g/m^3$) and 50 $\mu g/m^3$). Exceedances of the criteria due to the ventilation outlets alone would therefore be unlikely
- The ventilation outlet contributions were most significant for $PM_{2.5}$, with the maximum contributions equating to 13 per cent and 18 per cent of the annual mean and 24 hour criteria (8 $\mu g/m^3$ and 15 $\mu g/m^3$ respectively). However, exceedances of the criteria due to the ventilation outlets alone would again be unlikely
- A detailed analysis was conducted for one hour NO_2. In some cases the ventilation outlet contributions appeared to be substantial. However, as the background and surface road contributions (and hence total NOx) increase, there is a pronounced reduction in the outlet contribution to NO_2. The analysis showed that the maximum outlet contribution occurred when other contributions were low, such that overall NO_2 concentrations were well below the criterion or even the predicted maximum. Exceedances of the criteria due to the ventilation outlets alone would therefore be unlikely
- Peak in-tunnel concentrations for all traffic scenarios, including the capacity traffic at different speeds, were well within the in-tunnel concentrations associated with the regulatory worst case scenarios. It therefore follows that the predicted ventilation outlet contributions to ambient concentrations for any in-tunnel traffic scenario would be lower than those used in the regulatory worst case assessment.

It can be concluded that emissions from the project's ventilation outlets, even in the regulatory worst case scenarios, would be unlikely to result in significant impacts on local ambient air quality.

The potential regional impacts of the project on air quality were assessed through consideration of the changes in emissions across the road network (as a proxy), and the capacity of the project to influence ozone production. Overall, it is concluded that the regional impacts of the project would be negligible, and undetectable in ambient air quality measurements at background locations.

E.8 Management of impacts

E.8.1 Construction impacts

A range of measures for the management of construction impacts has been provided in the report. Most of the recommended measures are routinely employed as ‘good practice’ on construction sites. A Construction Air Quality Management Plan will be produced to cover all construction phases of the project. This should contain details of the site-specific mitigation measures to be applied.

E.8.2 Operational impacts

The report has provided a review of the measures that are available for improving tunnel-related air quality (both in-tunnel and ambient), and then describes their potential application in the context of the project. The measures that would be adopted for the project are summarised below.

Tunnel design

The project design provisions to reduce pollutant emissions and concentrations within the tunnel would include:

- Maximum limits on gradients. The mainline tunnels would have a maximum gradient of less than four per cent
- Large mainline tunnel cross-sectional area to reduce the pollutant concentration for a given emission into the tunnel volume, and to permit greater volumetric air throughput. The mainline tunnels would have widths varying between 10.5 to 16.0 metres and be higher than most previous tunnels
- Increased height to reduce the risk of incidents involving high vehicles blocking the tunnel and disrupting traffic. This would reduce the risk of higher pollutant concentrations associated with flow breakdown.

Ventilation design and control

The project ventilation system has been designed and would be operated so that it would achieve some of the most stringent standards in the world for in-tunnel air quality, and would be effective at maintaining local and regional ambient air quality. The design of the ventilation system would ensure zero portal emissions.

The ventilation system would be automatically controlled using real-time traffic data covering both traffic mix (composition in terms of vehicle types) and speed, and feedback from air quality sensors in the mainline tunnels, to ensure in-tunnel conditions are managed effectively in accordance with the criteria that have been specified in the conditions of approval for other recent tunnel projects. Furthermore, specific ventilation modes would be developed to manage breakdown, congestion and emergency situations.

Air treatment

The provision of a tunnel filtration system does not represent a feasible and reasonable mitigation measure and is not being proposed. The reasons for this are as follows:

- In-tunnel air pollutant levels, which are comparable to best practice and accepted elsewhere in Australia and throughout the world, would be achieved without filtration
- Emissions from the ventilation outlets of the M4-M5 Link tunnel would have a negligible impact on existing ambient pollutant concentrations

- Of the systems that have been installed, the majority have subsequently been switched off or are currently being operated infrequently. Where the operation of in-tunnel air treatment systems have been discontinued or reduced, the reasons have been that the technology has proved to be less effective than predicted, the forecast traffic volumes have not eventuated, or there have been reductions in vehicle emissions
- Incorporating filtration with the ventilation outlets would require a significant increase in the size of the tunnel facilities to accommodate the equipment. It would result in increased project size, community footprint, and capital cost. The energy usage would also be substantial and does not represent a sustainable approach.

If in-tunnel air quality criteria could not be achieved with the proposed ventilation system, the most effective solution would be the introduction of additional ventilation outlets and additional air supply locations. This is a proven solution and more sustainable and reliable than tunnel filtration systems.

1 Introduction

NSW Roads and Maritime Services (Roads and Maritime) is seeking approval to construct and operate the WestConnex M4-M5 Link (the project), which would comprise a new multi-lane road link between the M4 East Motorway at Haberfield and the New M5 Motorway at St Peters. The project would also include an interchange at Lilyfield and Rozelle (the Rozelle interchange) and a tunnel connection between Anzac Bridge and Victoria Road, east of Iron Cove Bridge (Iron Cove Link). In addition, construction of tunnels, ramps and associated infrastructure to provide connections to the proposed future Western Harbour Tunnel and Beaches Link project would be carried out at the Rozelle interchange.

Together with the other components of the WestConnex program of works and the proposed future Sydney Gateway, the project would facilitate improved connections between western Sydney, Sydney Airport and Port Botany and south and south-western Sydney, as well as better connectivity between the important economic centres along Sydney's Global Economic Corridor and local communities.

Approval is being sought under Part 5.1 of the *Environmental Planning and Assessment Act 1979* (NSW) (EP&A Act) for the project. A request has been made for the NSW Minister for Planning to specifically declare the project to be State significant infrastructure and also critical State significant infrastructure. An environmental impact statement (EIS) is therefore required.

1.1 Overview of WestConnex and related projects

The M4-M5 Link is part of the WestConnex program of works. Separate planning applications and assessments have been completed for each of the approved WestConnex projects. Roads and Maritime has commissioned Sydney Motorway Corporation (SMC) to deliver WestConnex, on behalf of the NSW Government. However, Roads and Maritime is the proponent for the project.

In addition to linking to other WestConnex projects, the M4-M5 Link would provide connections to the proposed future Western Harbour Tunnel and Beaches Link, the Sydney Gateway (via the St Peters interchange) and the F6 Extension (via the New M5).

The WestConnex program of works, as well as related projects, are shown in **Figure 1-1** and described in **Table 1-1**.

Table 1-1 WestConnex and related projects

Project	Description	Status
WestConnex program of works		
M4 Widening	Widening of the existing M4 Motorway from Parramatta to Homebush.	Planning approval under the EP&A Act granted on 21 December 2014. Open to traffic.
M4 East	Extension of the M4 Motorway in tunnels between Homebush and Haberfield via Concord. Includes provision for a future connection to the M4-M5 Link at the Wattle Street interchange.	Planning approval under the EP&A Act granted on 11 February 2016. Under construction.
King Georges Road Interchange Upgrade	Upgrade of the King Georges Road interchange between the M5 West and the M5 East at Beverly Hills, in preparation for the New M5 project.	Planning approval under the EP&A Act granted on 3 March 2015. Open to traffic.

Project	Description	Status
New M5	Duplication of the M5 East from King Georges Road in Beverly Hills with tunnels from Kingsgrove to a new interchange at St Peters. The St Peters interchange allows for connections to the proposed future Sydney Gateway project and an underground connection to the M4-M5 Link. The New M5 tunnels also include provision for a future connection to the proposed future F6 Extension.	Planning approval under the EP&A Act granted on 20 April 2016. Commonwealth approval under the *Environment Protection and Biodiversity Conservation Act 1999* (Commonwealth) granted on 11 July 2016. Under construction.
M4-M5 Link (the project)	Tunnels connecting to the M4 East at Haberfield (via the Wattle Street interchange) and the New M5 at St Peters (via the St Peters interchange), a new interchange at Rozelle and a link to Victoria Road (the Iron Cove Link). The Rozelle interchange also includes ramps and tunnels for connections to the proposed future Western Harbour Tunnel and Beaches Link project.	The subject of this EIS.
Related projects		
Sydney Gateway	A high-capacity connection between the St Peters interchange (under construction as part of the New M5 project) and the Sydney Airport and Port Botany precinct.	Planning underway by Roads and Maritime and subject to separate environmental assessment and approval.
Western Harbour Tunnel and Beaches Link	The Western Harbour Tunnel component would connect to the M4-M5 Link at the Rozelle interchange, cross underneath Sydney Harbour between the Birchgrove and Waverton areas, and connect with the Warringah Freeway at North Sydney. The Beaches Link component would comprise a tunnel that would connect to the Warringah Freeway, cross underneath Middle Harbour and connect with the Burnt Bridge Creek Deviation at Balgowlah and Wakehurst Parkway at Seaforth. It would also involve the duplication of the Wakehurst Parkway between Seaforth and Frenchs Forest.	Planning underway by Roads and Maritime and subject to separate environmental assessment and approval.
F6 Extension	A proposed motorway link between the New M5 at Arncliffe and the existing M1 Princes Highway at Loftus, generally along the alignment known as the F6 corridor.	Planning underway by Roads and Maritime and subject to separate environmental assessment and approval.

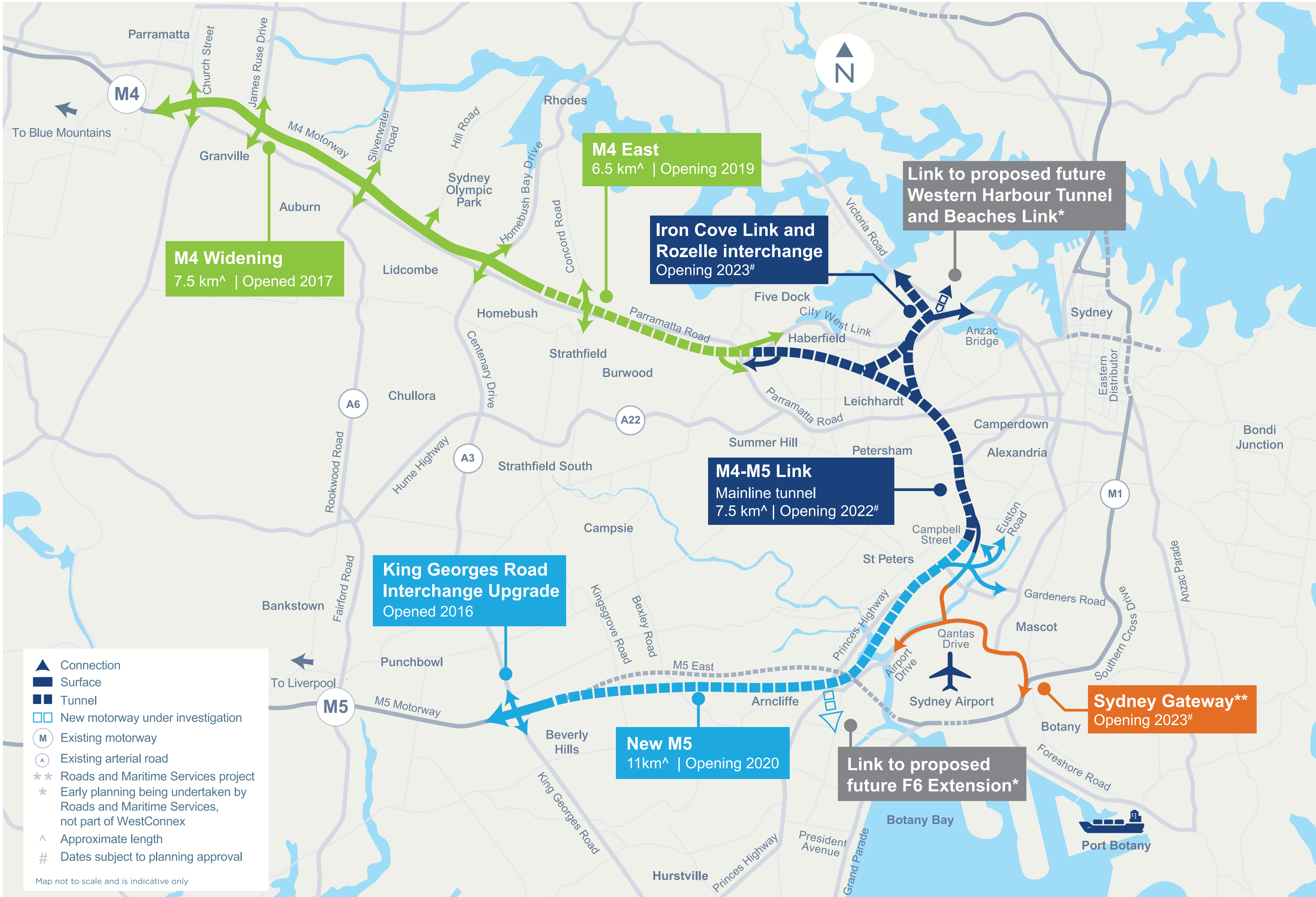

Figure 1-1 Overview of WestConnex and related projects

1.2 Purpose of this report

The general purpose of this report is to address the requirements of the air quality section of the revised Secretary's Environmental Assessment Requirements (SEARs) for the project (SSI 7485), issued on 3 May 2017.

Broad stakeholder and community confidence in the effective management of air quality within and around tunnels is critical to community acceptance of road tunnels as an effective transport solution, including those forming part of WestConnex, (WestConnex Strategic Environmental Review, Sydney Motorways Project Office (SMPO) 2013; and Update to Strategic Environmental Review, Roads and Maritime, 2015) (Strategic Environmental Review).

In recent years, urban road tunnels in Australia have been subjected to considerable scrutiny, with the following being areas of community focus: in-tunnel air quality, emissions from tunnel portals, and ambient air quality. Specific emphasis has therefore been placed on the assessment and management of these in the report:

- In-tunnel air quality:
  - The report demonstrates that the proposed ventilation system and management approaches would achieve some of the most stringent standards in the world for operational in-tunnel air quality
- Portal emissions:
  - User and community-related air pollution issues associated with the Sydney M5 East tunnel led to approval conditions for the M5 East tunnel, including the prohibition of portal emissions, being retained for subsequent tunnels. No portal emissions are proposed for the M4-M5 Link project, and the report demonstrates that the design of the ventilation system would achieve this
- Ambient air quality:
  - The potential for ambient air quality impacts during project construction is assessed in the report, and a comprehensive range of management measures is recommended
  - The potential for ambient air quality impacts during project operation is assessed in detail, and the report demonstrates that the proposed ventilation system would be effective at maintaining ambient air quality.

It is important to ensure that the context and implications of the project are well understood. Road traffic is a major contributor to air pollution in urban areas such as Sydney. An appreciation of the sources and dispersion pathways of road traffic pollution, including the role of tunnels, is crucial to its control and improvement. This report summarises the existing literature and guidance in a number of different areas, such as road vehicle emissions, air quality standards, and in-tunnel pollution.

The operational air quality assessment for the project has followed a series of logical steps:

- Understanding the existing conditions
- Characterising the changes in traffic
- Characterising the tunnel ventilation
- Quantifying in-tunnel pollution
- Estimating impacts on ambient air quality.

At each step, the best possible use has been made of existing information, and appropriate methods and models have been used. Significant improvements have been made to several methods and models for the explicit purpose of the project assessment, and these developments would be beneficial to future air quality assessments in NSW.

The following impacts of the project were outside the scope of work and have not been addressed in this report:

- Air quality inside buildings or vehicles. This is because air quality criteria apply to outdoor locations, and ambient air quality monitoring is conducted at such locations
- Health risks associated with air quality (refer to **Chapter 11** (Human health risk) and **Appendix K** (Technical working paper: Human health risk assessment) of the EIS
- Greenhouse gas emissions (assessed in **Chapter 22** (Greenhouse gas) of the EIS).

1.3 SEARs

Table 1-2 displays the sections of the SEARs that are specific to air quality, and also provides a cross-reference to the sections of this report which address these requirements.

Table 1-2 Requirements of SEARs addressed in this report

Requirement of SEARs (air quality)	Section where requirement is addressed
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.	**Section 9** (management of impacts).
1. The Proponent must undertake an air quality impact assessment (AQIA) for construction and operation of the project in accordance with the current guidelines. · Approved Methods for the Modelling and Assessment of Air Pollutants in New South Wales (NSW EPA, 2016) · Approved Methods for the Sampling and Analysis of Air Pollutants in NSW (DEC, 2007) · Technical Framework - Assessment and Management of Odour from Stationary Sources in NSW (DEC, 2006) · In-Tunnel Air Quality (Nitrogen Dioxide) Policy (ACATAQ, 2016).	**Section 8** (construction impacts) **Section 8** (operational impacts) **Annexure L** (ventilation report).
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 Operations (Clean Air) Regulation 2010*;	**Section 4.4.5** (tunnel ventilation outlets).
(b) the identification of all potential sources of air pollution and an assessment of potential emissions of PM_{10}, $PM_{2.5}$, CO, NO_2 and other nitrogen oxides and volatile organic compounds (eg BTEX);	**Section 3** (air quality issues) **Section 8** (operational impacts) **Annexure A** (traffic pollutants and their effects).
(c) consider the impacts from the dispersal of these air pollutants on the ambient air quality along the proposal route, proposed ventilation outlets and portals, surface roads, ramps and interchanges and the alternative surface road network;	**Section 8** (operational impacts).
(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 worst case design maximum traffic flow scenario (variable	**Annexure L** (Ventilation report).

Requirement of SEARs (air quality)		Section where requirement is addressed
	speed).and worst case breakdown scenario, and discussion of the likely occurrence of each;	
(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 (i.e. ventilation outlets and air inlets) including details of proposed air quality monitoring (including frequency and criteria);	**Section 9** (management of impacts).
(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, New M5 project and the In-Tunnel Air Quality (Nitrogen Dioxide) Policy;	**Annexure L** (Ventilation report) **Section 5** (assessment criteria) **Section 8** (operational impacts).
(g)	consideration of any advice from the Advisory Committee on Tunnel Air Quality on the project, particularly in relation to assessment methodology;	Advice provided by the Advisory Committee for the NorthConnex, M4 East and New M5 projects was taken into account when developing the assessment methodology.
(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 emission of air pollutants and their dispersal, and safety procedures;	**Section 9** (management of impacts), and specifically **section 9.2.3**.
(i)	details of in-tunnel air quality control measures considered, including air filtration, and justification of the proposed measures;	**Section 9** (management of impacts), and specifically **section 9.2.3**.
(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	**Section 9** (management of impacts).
(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.	**Section 8** (operational impacts) In-tunnel air quality is addressed in **Annexure L** (Ventilation report).

1.4 Structure of this report

The remainder of the report is structured as follows:

- **Section 2** describes the project, including its construction and the main elements of the proposed ventilation strategy
- **Section 3** identifies key air quality issues for the project, such as the relevance of motor vehicles and road tunnels to air quality in general, and the experience with Sydney tunnels to date

- **Section 4** summarises the regulation of emissions, air pollution and exposure. It addresses the control of road vehicle emissions and fuel quality, in-tunnel pollution limits, and ambient air quality standards
- **Section 5** provides an overview of the air quality assessment methodology, outlining key documents, guidelines and policies, summarising previous major road and tunnel project assessments, and introducing specific aspects of the approach. These aspects include the general methods that were used for assessing the impacts of project construction and operation, and the scenarios that were evaluated
- **Section 6** describes the existing environment in the area of Sydney affected by the project, with specific reference to terrain, meteorology, emissions and ambient air quality
- **Section 7** describes the assessment of the construction impacts of the project using a semi-quantitative risk-based approach
- **Section 8** describes the assessment of the operational impacts of the project, including the cumulative impacts with the M4 East and New M5 projects, as well as other associated projects. The section deals with emission modelling, in-tunnel air quality, and dispersion modelling for ambient air quality
- **Section 9** provides a review of air quality mitigation measures, and recommendations on measures to manage any impacts of the project. This section deals with both the construction and the operation of the project
- Annexures which address various technical aspects of the air quality assessment. In particular, the report on the ventilation requirements for the project is provided in **Annexure L**.

At the start of each section the most important aspects that are covered are briefly summarised.

2 The project

2.1 Project location

The project would be generally located within the City of Sydney and Inner West local government areas (LGAs). The project is located about two to seven kilometres south, south-west and west of the Sydney central business district (CBD) and would cross the suburbs of Ashfield, Haberfield, Leichhardt, Lilyfield, Rozelle, Annandale, Stanmore, Camperdown, Newtown and St Peters. The local context of the project is shown in **Figure 2-1.**

2.2 Overview of the project

Key components of the project are shown in **Figure 2-1** and would include:

- Twin mainline motorway tunnels between the M4 East at Haberfield and the New M5 at St Peters. Each tunnel would be around 7.5 kilometres long and would generally accommodate up to four lanes of traffic in each direction
- Connections of the mainline tunnels to the M4 East project, comprising:
  - A tunnel-to-tunnel connection to the M4 East mainline stub tunnels east of Parramatta Road near Alt Street at Haberfield
  - Entry and exit ramp connections between the mainline tunnels and the Wattle Street interchange at Haberfield (which is currently being constructed as part of the M4 East project)
  - Minor physical integration works with the surface road network at the Wattle Street interchange including road pavement and line marking
- Connections of the mainline tunnels to the New M5 project, comprising:
  - A tunnel-to-tunnel connection to the New M5 mainline stub tunnels north of the Princes Highway near the intersection of Mary Street and Bakers Lane at St Peters
  - Entry and exit ramp connections between the mainline tunnels and the St Peters interchange at St Peters (which is currently being constructed as part of the New M5 project)
  - Minor physical integration works with the surface road network at the St Peters interchange including road pavement and line marking
- An underground interchange at Leichhardt and Annandale (the Inner West subsurface interchange) that would link the mainline tunnels with the Rozelle interchange and the Iron Cove Link (see below)
- A new interchange at Lilyfield and Rozelle (the Rozelle interchange) that would connect the M4-M5 Link mainline tunnels with:
  - City West Link
  - Anzac Bridge
  - The Iron Cove Link (see below)
  - The proposed future Western Harbour Tunnel and Beaches Link
- Construction of connections to the proposed future Western Harbour Tunnel and Beaches Link project as part of the Rozelle interchange, including:
  - Tunnels that would allow for underground mainline connections between the M4 East and New M5 motorways and the proposed future Western Harbour Tunnel and Beaches Link (via the M4-M5 Link mainline tunnels)
  - A dive structure and tunnel portals within the Rozelle Rail Yards, north of the City West Link / The Crescent intersection

- Entry and exit ramps that would extend north underground from the tunnel portals in the Rozelle Rail Yards to join the mainline connections to the proposed future Western Harbour Tunnel and Beaches Link
- A ventilation outlet and ancillary facilities as part of the Rozelle ventilation facility (see below)

· Twin tunnels that would connect Victoria Road near the eastern abutment of Iron Cove Bridge and Anzac Bridge (the Iron Cove Link). Underground entry and exit ramps would also provide a tunnel connection between the Iron Cove Link and the New M5 / St Peters interchange (via the M4-M5 Link mainline tunnels)

· The Rozelle surface works, including:
  - Realigning The Crescent at Annandale, including a new bridge over Whites Creek and modifications to the intersection with City West Link
  - A new intersection on City West Link around 300 metres west of the realigned position of The Crescent, which would provide a connection to and from the New M5/St Peters interchange (via the M4-M5 Link mainline tunnels)
  - Widening and improvement works to the channel and bank of Whites Creek between the light rail bridge and Rozelle Bay at Annandale, to manage flooding and drainage for the surface road network
  - Reconstructing the intersection of The Crescent and Victoria Road at Rozelle, including construction of a new bridge at Victoria Road
  - New and upgraded pedestrian and cyclist infrastructure
  - Landscaping, including the provision of new open space within the Rozelle Rail Yards

· The Iron Cove Link surface works, including:
  - Dive structures and tunnel portals between the westbound and eastbound Victoria Road carriageways, to connect Victoria Road east of Iron Cove Bridge with the Iron Cove Link
  - Realignment of the westbound (southern) carriageway of Victoria Road between Springside Street and the eastern abutment of Iron Cove Bridge
  - Modifications to the existing intersections between Victoria Road and Terry, Clubb, Toelle and Callan streets
  - Landscaping and the establishment of pedestrian and cycle infrastructure

· Five motorway operations complexes; one at Leichhardt (MOC1), three at Rozelle (Rozelle West (MOC2), Rozelle East (MOC3) and Iron Cove Link (MOC4)), and one at St Peters (MOC5). The types of facilities that would be contained within the motorway operations complexes would include substations, water treatment plants, ventilation facilities and outlets, offices, on-site storage and parking for employees

· Tunnel ventilation systems, including ventilation supply and exhaust facilities, axial fans, ventilation outlets and ventilation tunnels

· Three new ventilation facilities, including:
  - The Rozelle ventilation facility at Rozelle
  - The Iron Cove Link ventilation facility at Rozelle
  - The Campbell Road ventilation facility at St Peters

· Fitout (mechanical and electrical) of part of the Parramatta Road ventilation facility at Haberfield (which is currently being constructed as part of M4 East project) for use by the M4-M5 Link project

· Drainage infrastructure to collect surface and groundwater for treatment at dedicated facilities. Water treatment would occur at
  - Two operational water treatment facilities (at Leichhardt and Rozelle)

- The constructed wetland within the Rozelle Rail Yards
- A bioretention facility for stormwater runoff within the informal car park at King George Park at Rozelle (adjacent to Manning Street). A section of the existing informal car park would also be upgraded, including sealing the car park surface and landscaping

· Treated water would flow back to existing watercourses via new, upgraded and existing infrastructure

· Ancillary infrastructure and operational facilities for electronic tolling and traffic control and signage (including electronic signage)

· Emergency access and evacuation facilities, including pedestrian and vehicular cross and long passages and fire and life safety systems

· Utility works, including protection and/or adjustment of existing utilities, removal of redundant utilities and installation of new utilities. A Utilities Management Strategy has been prepared for the project that identifies management options for utilities, including relocation or adjustment. Refer to **Appendix F** (Utilities Management Strategy) of the EIS.

The project does not include:

· Site management works at the Rozelle Rail Yards. These works were separately assessed and determined by Roads and Maritime through a Review of Environmental Factors under Part 5 of the EP&A Act (refer to **Chapter 2** (Assessment process) of the EIS)

· Ongoing motorway maintenance activities during operation

· Operation of the components of the Rozelle interchange which are the tunnels, ramps and associated infrastructure being constructed to provide connections to the proposed future Western Harbour Tunnel and Beaches Link project.

Temporary construction ancillary facilities and temporary works to facilitate the construction of the project would also be required.

2.2.1 Staged construction and opening of the project

It is anticipated the project would be constructed and opened to traffic in two stages (as shown in **Figure 2-1**).

Stage 1 would include:

· Construction of the mainline tunnels between the M4 East at Haberfield and the New M5 at St Peters, stub tunnels to the Rozelle interchange (at the Inner West subsurface interchange) and ancillary infrastructure at the Darley Road motorway operations complex (MOC1) and Campbell Road motorway operations complex (MOC5)

· These works are anticipated to commence in 2018 with the mainline tunnels open to traffic in 2022. At the completion of Stage 1, the mainline tunnels would operate with two traffic lanes in each direction. This would increase to generally four lanes at the completion of Stage 2, when the full project is operational.

Stage 2 would include:

· Construction of the Rozelle interchange and Iron Cove Link including:

- Connections to the stub tunnels at the Inner West subsurface interchange (built during Stage 1)
- Ancillary infrastructure at the Rozelle West motorway operations complex (MOC2), Rozelle East motorway operations complex (MOC3) and Iron Cove Link motorway operations complex (MOC4)
- Connections to the surface road network at Lilyfield and Rozelle
- Construction of tunnels, ramps and associated infrastructure as part of the Rozelle interchange to provide connections to the proposed future Western Harbour Tunnel and

Beaches Link project

- Stage 2 works are expected to commence in 2019 with these components of the project open to traffic in 2023.

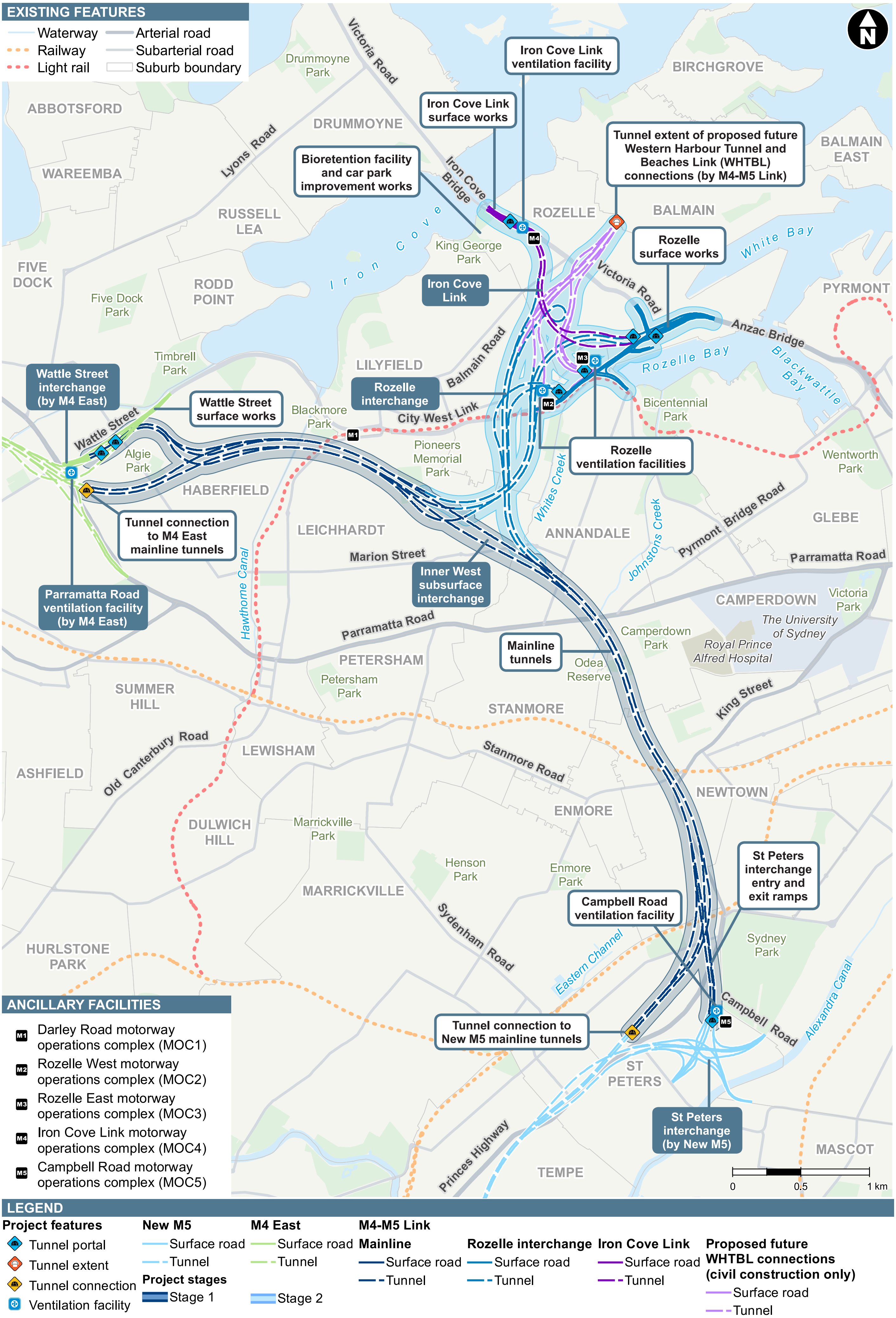

Figure 2-1 Overview of the project

2.3 Construction activities

An overview of the key construction features of the project is shown in **Figure 2-2**. These would generally include:

- Enabling and temporary works, including provision of construction power and water supply, ancillary site establishment including establishment of acoustic sheds and construction hoarding, demolition works, property adjustments and public and active transport modifications (if required)
- Construction of the road tunnels, interchanges, intersections and roadside infrastructure
- Haulage of spoil generated during tunnelling and excavation activities
- Fitout of the road tunnels and support infrastructure, including ventilation and emergency response systems
- Construction and fitout of the motorway operations complexes and other ancillary operations buildings
- Realignment, modification or replacement of surface roads, bridges and underpasses
- Implementation of environmental management and pollution control facilities for the project.

A more detailed overview of construction activities is provided in **Table 2-1**.

Table 2-1 Overview of construction activities

Component	Typical activities
Site establishment and enabling works	· Vegetation clearing and removal · Utility works · Traffic management measures · Install safety and environmental controls · Install site fencing and hoarding · Establish temporary noise attenuation measures · Demolish buildings and structures · Carry out site clearing · Heritage salvage or conservation works (if required) · Establish construction ancillary facilities and access · Establish acoustic sheds · Supply utilities (including construction power) to construction facilities · Establish temporary pedestrian and cyclist diversions.
Tunnelling	· Construct temporary access tunnels · Excavation of mainline tunnels, entry and exit ramps and associated tunnelled infrastructure and install ground support · Spoil management and haulage · Finishing works in tunnel and provision of permanent tunnel services · Test plant and equipment.
Surface earthworks and structures	· Vegetation clearing and removal · Topsoil stripping · Excavate new cut and fill areas · Construct dive and cut-and-cover tunnel structures · Install stabilisation and excavation support (retention systems) such as sheet pile walls, diaphragm walls and secant pile walls (where required) · Construct required retaining structures · Excavate new road levels.
Bridge works	· Construct piers and abutments · Construct headstock · Construct bridge deck, slabs and girders · Demolish and remove redundant bridges.
Drainage	· Construct new pits and pipes

Component	Typical activities
	· Construct new groundwater drainage system · Connect drainage to existing network · Construct sumps in tunnels as required · Construct water quality basins, constructed wetland and bioretention facility and basin · Construct drainage channels · Construct spill containment basin · Construct onsite detention tanks · Adjustments to existing drainage infrastructure where impacted · Carry out widening and naturalisation of a section of Whites Creek · Demolish and remove redundant drainage.
Pavement	· Lay select layers and base · Lay road pavement surfacing · Construct pavement drainage.
Operational ancillary facilities	· Install ventilation systems and facilities · Construct water treatment facilities · Construct fire pump rooms and install water tanks · Test and commission plant and equipment · Construct electrical substations to supply permanent power to the project.
Finishing works	· Line mark to new road surfaces · Erect directional and other signage and other roadside furniture such as street lighting · Erect toll gantries and other control systems · Construct pedestrian and cycle paths · Carry out earthworks at disturbed areas to establish the finished landform · Carry out landscaping · Closure and backfill of temporary access tunnels (except where these are to be used for inspection and/or maintenance purposes) · Site demobilisation and preparation of the site for a future use.

Twelve construction ancillary facilities are described in this EIS (as listed below). To assist in informing the development of a construction methodology that would manage constructability constraints and the need for construction to occur in a safe and efficient manner, while minimising impacts on local communities, the environment, and users of the surrounding road and other transport networks, two possible combinations of construction ancillary facilities at Haberfield and Ashfield have been assessed in this EIS. The construction ancillary facilities that comprise these options have been grouped together in this EIS and are denoted by the suffix a (for Option A) or b (for Option B).

The construction ancillary facilities required to support construction of the project include:

- Construction ancillary facilities at Haberfield (Option A), comprising:
  - Wattle Street civil and tunnel site (C1a)
  - Haberfield civil and tunnel site (C2a)
  - Northcote Street civil site (C3a)
- Construction ancillary facilities at Ashfield and Haberfield (Option B), comprising:
  - Parramatta Road West civil and tunnel site (C1b)
  - Haberfield civil site (C2b)
  - Parramatta Road East civil site (C3b)
- Darley Road civil and tunnel site (C4)
- Rozelle civil and tunnel site (C5)

- The Crescent civil site (C6)
- Victoria Road civil site (C7)
- Iron Cove Link civil site (C8)
- Pyrmont Bridge Road tunnel site (C9)
- Campbell Road civil and tunnel site (C10).

The number, location and layout of construction ancillary facilities would be finalised as part of detailed construction planning during detailed design and would meet the environmental performance outcomes stated in the EIS and the Submissions and Preferred Infrastructure Report and satisfy criteria identified in any relevant conditions of approval.

The construction ancillary facilities would be used for a mix of civil surface works, tunnelling support, construction workforce parking and administrative purposes. Wherever possible, construction sites would be co-located with the project footprint to minimise property acquisition and temporary disruption. The layout and access arrangements for the construction ancillary facilities are based on the concept design only and would be confirmed and refined in response to submissions received during the exhibition of this EIS and during detailed design.

2.3.1 Construction program

The total period of construction works for the project is expected to be around five years, with commissioning occurring concurrently with the final stages of construction. An indicative construction program is shown in **Table 2-2**.

Table 2-2 Indicative construction program

Construction activity	Indicative construction timeframe																							
	2018				2019				2020				2021				2022				2023			
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Mainline tunnels																								
Site establishment and establishment of construction ancillary facilities			■	■	■	■	■	■	■	■														
Utility works and connections			■	■	■	■	■	■																
Tunnel construction				■	■	■	■	■	■	■	■	■	■											
Portal construction				■	■	■	■	■																
Construction of permanent operational facilities												■	■	■	■	■								
Mechanical and electrical fitout works														■	■	■								
Establishment of tolling facilities															■	■								
Site rehabilitation and landscaping																■	■	■	■					
Surface road works																	■	■	■					
Demobilisation and rehabilitation																			■	■				
Testing and commissioning																■	■	■	■	■				

Construction activity	Indicative construction timeframe																							
	2018				2019				2020				2021				2022				2023			
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Rozelle interchange and Iron Cove Link																								
Site establishment and establishment of construction ancillary facilities				■	■	■	■	■	■															
Utility works and connections and site remediation				■	■	■	■	■																
Tunnel construction									■	■	■	■	■	■	■	■	■							
Portal construction						■	■	■	■															
Construction of surface road works						■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■			
Construction of permanent operational facilities						■	■	■	■	■	■	■	■	■	■	■								
Mechanical and electrical fitout works													■	■	■	■	■	■	■	■				
Establishment of tolling facilities																		■	■					
Site rehabilitation and landscaping																			■	■	■			
Demobilisation and rehabilitation																						■	■	
Testing and commissioning																			■	■	■	■	■	

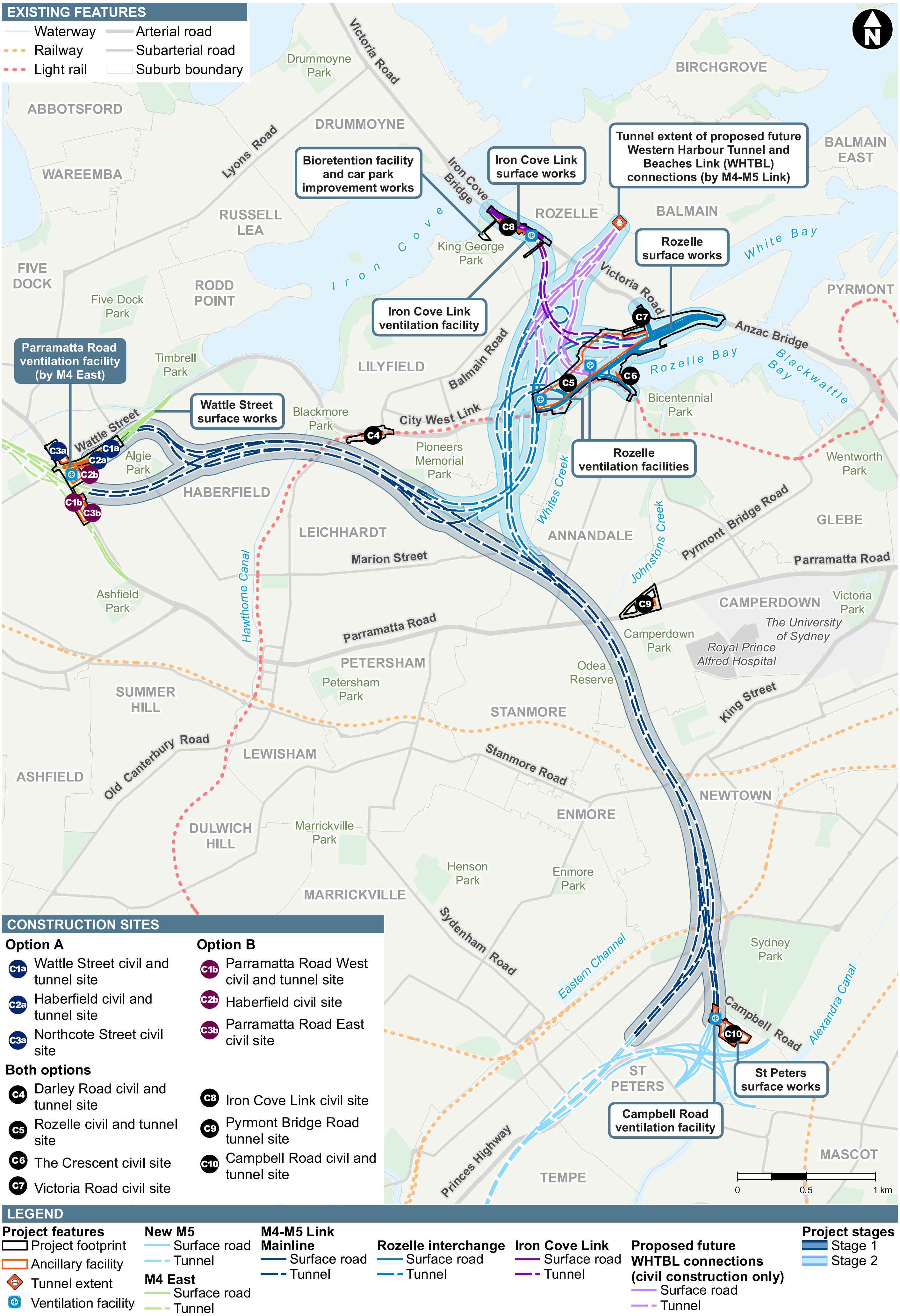

Figure 2-2 Overview of project footprint and ancillary facilities

2.4 Specific aspects of design relating to in-tunnel and ambient air quality

2.4.1 Overview

The project's ventilation system has been designed to:

- Safeguard the health and amenity of motorists using the mainline tunnels during normal operation and emergency conditions
- Meet the current in-tunnel, ventilation outlet and ambient air quality criteria relevant to the project (**section 4.4.4**)
- Operate automatically to manage air quality
- Meet the requirements of the Australian Government's Civil Aviation Safety Authority with respect to emissions to the atmosphere and potential aviation hazards
- Minimise the consumption of energy and other resources where doing so would not compromise the health and amenity of motorists using the mainline tunnels or the achievement of applicable air quality criteria.

Details of the design and operation of the project's ventilation system are provided in the following sections.

The tunnel ventilation system would comprise ventilation facilities and jet fans. Equipment to monitor and measure air quality (both inside and outside the tunnels) and the safety of tunnel users would be incorporated into the project. During normal operation, the ventilation system would draw fresh air into the tunnels through the tunnel portals and emit air from the tunnels only via ventilation facilities.

2.4.2 Tunnel ventilation facilities and outlets

All tunnel ventilation facilities that were inside the GRAL domain (excluding the Cross City Tunnel outlet) were included in the air quality assessment. The Cross City Tunnel outlet was excluded because it was very close to the eastern boundary of the domain, because of the relatively low volumes of traffic in the tunnel, and because of the distance between the outlet and the receptors included in the assessment. It was therefore considered the Cross City Tunnel outlet would not have material impact on the results of the assessment.

The ventilation facilities – and, more importantly in terms of ambient air quality, the associated air outlets – are summarised in **Table 2-3**. Some facilities would have more than one outlet.

A proposed F6 Extension from Arncliffe to Kogarah is currently being investigated by Roads and Maritime, and would connect the New M5 to the southern and bayside suburbs of Sydney, and the proposed F6 Motorway. Outlet M would provide the outlet for the southbound F6 Extension tunnel (Arncliffe to Kogarah). It would not require any construction as part of the project. Construction, fit-out and commissioning would occur as part of the construction of F6 Extension (if approved). For the purposes of cumulative assessments for this project, it is assumed that the F6 Extension would provide a connection to President Avenue in the south. Depending on the outcome of investigations by Roads and Maritime, the project would undergo route and design development. For the purpose of the air quality assessment, an approximate location of the outlet was used, subject to a separate environmental assessment and approval process.

In total, 14 separate tunnel ventilation outlets (A to N) were included in the assessment. For outlets D, E and K, four exhaust sub-outlets would be provided to improve dispersion of the exhaust air and assist in meeting the Civil Aviation Safety Authority and Sydney Airport's requirements. The ventilation outlets that would be specific to the M4-M5 Link are G, I, J, K and L. The remaining outlets (A, B, C, D, E, F, H, M and N) were included to assess potential cumulative impacts only.

Further details of the ventilation facilities, including the locations and surrounding environments, are provided in **Chapter 5** (Project description) of the EIS.

The control of air flows through the tunnels and ventilation outlets is described in **Annexure L**. Cross-references to the relevant sections and figures in **Annexure L** are provided in **Table 2-4**. Details of the ventilation outlets that were of specific interest to the air quality assessment are provided in **section 8** and **Annexure I**.

Table 2-3 Tunnel ventilation facilities and outlets included in the assessment

Project	Facility location	Outlet(s)	Function of outlet
Existing ventilation facility			
M5 East	Turrella.	**Outlet A**	Single point of release of air from the M5 East tunnel.
Ventilation facilities currently under construction for M4 East and New M5			
M4 East (Parramatta Road)	On the north-east corner of the Wattle Street (City West Link) and Parramatta Road interchanges at Haberfield.	**Outlet B**	Exhaust from the M4 East mainline eastbound tunnel, and from the Wattle Street (City West Link) and Parramatta Road eastbound off-ramps.
M4 East (Underwood Road)	Within the existing M4 Motorway reserve near Underwood Road, Homebush.	**Outlet C**	Exhaust from the westbound tunnel of the M4 East.
New M5 (SPI)	St Peters motorway operations complex, adjacent to the Princes Highway/Canal Road intersection.	**Outlet D**	Exhaust from the second section of the eastbound New M5 tunnel (Arncliffe to St Peters).
New M5 (Arncliffe)	The Arncliffe motorway operations complex located near the southwestern corner of the Kogarah Golf Course.	**Outlet E**	Exhaust from the first section of eastbound traffic of the New M5 tunnel (Kingsgrove to Arncliffe)[(a)].
New M5 (Kingsgrove)	Between Wolli Creek and the M5 East Motorway, Kingsgrove.	**Outlet F**	Exhaust from the westbound traffic of the New M5 tunnel (St Peters to Kingsgrove).
Proposed ventilation facilities for WestConnex M4-M5 Link (subject of this EIS)			
M4-M5 Link (Parramatta Road)[(b)]	On the north-east corner of the Wattle Street (City West Link) and Parramatta Road interchange, Haberfield.	**Outlet G**	Exhaust from the westbound traffic of the M4-M5 Link between Rozelle and Haberfield.
M4-M5 Link, Iron Cove Link and Western Harbour Tunnel and Beaches Link (Rozelle)[(c)]	Within the Rozelle Rail Yards.	**Outlet H**[(d)]	Exhaust from the southbound tunnel of the WHT.
		Outlets I and J	Exhaust from the M4-M5 Link and Iron Cove Link projects, taking air from the southbound Iron Cove Link and the northbound ramps connecting the mainline tunnels to Rozelle interchange

Project	Facility location	Outlet(s)	Function of outlet
			and Anzac Bridge off-ramp.
Iron Cove Link	Rozelle, near Iron Cove Bridge, over the exit portal to Victoria Road.	**Outlet L**	Exhaust from the northbound tunnel of the Iron Cove Link.
M4-M5 Link Campbell Road	St Peters interchange.	**Outlet K**	Exhaust from the eastbound traffic to the M4-M5 Link (Arncliffe to St Peters)[(e)].
Proposed ventilation facilities for the future proposed F6 Extension			
F6 Extension (Arncliffe)[(f)]	The Arncliffe motorway operations complex located near the southwestern corner of the Kogarah Golf Course.	**Outlet M**	Exhaust from the northbound F6 Extension tunnel (Kogarah to Arncliffe).
F6 Extension (Rockdale)[(f)]	Indicative location if President Avenue but subject to further project development and design.	**Outlet N**	Exhaust from the southbound tunnel of the F6 Extension.

(a) This facility would also provide the ventilation supply facility for the second section of the eastbound New M5 tunnel (Arncliffe to St Peters).

(b) This facility is being constructed as part of M4 East and the outlet is being fitout by the M4-M5 Link project. The M4-M5 Link outlet would not operate unless the proposed M4-M5 Link is approved.

(c) This facility would incorporate three outlets (H, I and J). Ventilation supply facilities would also be provided at Rozelle for the northbound Western Harbour Tunnel and Beaches Link traffic and the southbound tunnel connections from Western Harbour Tunnel and Beaches Link to the M4-M5 Link.

(d) This outlet would be constructed as part of the M4-M5 Link, but would not operate until the opening of the WHT project, if that project is approved.

(e) The facility would also provide the ventilation supply facility to the northbound M4-M5 Link (St Peters to Rozelle).

(f) This facility is being constructed as part of New M5, and would not operate until the opening of the proposed F6 Extension, if that project is approved.

Table 2-4 References to air flow diagrams for tunnel ventilation outlets

Ventilation outlet	Air flow diagrams (Annexure L)
A	-
B	Figures E.0.4 and 3.4
C	Figure E.0.4
D	Figures E.0.4 and 3.3
E	Figures E.0.4 and 3.5
F	Figure E.0.4
G	Figures E.0.4 and 3.4
H	Figures E.0.4 and 3.1
I	Figures E.0.4 and 3.1
J	Figures E.0.4 and 3.1
K	Figures E.0.4 and 3.3
L	Figures E.0.4 and 3.1
M	Figure E.0.4 and 3.5
N	Figure E.0.4

2.4.3 Operating modes

Ventilation operations

The tunnel ventilation system would operate in two modes:

- Normal traffic conditions, including worst case and low speed traffic
- Major incident (emergency) conditions including major accident and fire scenarios.

In-tunnel air quality, traffic volumes and average traffic speeds through the project tunnels would be constantly monitored by operators in the Motorway Control Centre and decisions about the operation of the project's ventilation system made in real time. Operating procedures would be developed and applied to the operation of the ventilation system, including triggers for intervention in the case of elevated concentrations of vehicle emission in the project tunnels, congested traffic conditions or incidents, breakdowns or emergencies. The operating procedures would include:

- Actions to manage the operation of the ventilation system, including increased ventilation rates by the use of jet fans within the tunnel, and potential introduction of additional fresh air into the tunnels through the ventilation supply facilities
- Actions to manage traffic volumes and average traffic speeds through the project tunnels if required for in-tunnel air quality reasons or during incidents, breakdowns or emergencies within or downstream of the project tunnels
- Incident, breakdown and emergency response actions.

Normal traffic conditions

Under normal traffic conditions (ie when traffic flow within the tunnel is at capacity and travelling at the posted speed limit of 80 kilometres per hour), the main alignment tunnels would be longitudinally ventilated. Fresh air would be drawn into the main alignment tunnels from the entry portals and from vehicles travelling through the tunnel, generating a 'piston' effect (the suction created behind a moving vehicle, pulling air through the tunnel) pushing air towards the tunnel exit portals. Under normal traffic conditions, the tunnels would effectively 'self-ventilate', as the piston effect generated from moving vehicles exceeds the fresh air demand, thereby removing the need for mechanical ventilation to move air through the tunnels.

Under these conditions, all air would be discharged from the tunnel via the ventilation outlets as described in **section 2.4.2** with no portal emissions. At the ventilation facility offtake points, tunnel air would be drawn upwards into ventilation facilities by large fans prior to discharge to the atmosphere. The locations and heights of the various ventilation outlets are provided in **section 8.4.6** (**Table 8-15**). The air would then be discharged from each ventilation facility to the atmosphere at velocities that would achieve effective dispersion of the tunnel air, while also meeting the Australian Government's Civil Aviation Safety Authority requirements.

Portal emissions are prevented by using the ventilation system to draw the air back against the flow of traffic at the exit ramps and directing the air through the exhaust outlets.

Low-speed traffic conditions

Where low speed conditions persist within the tunnels (ie when traffic speeds slow towards 40 kilometres per hour or less, typically as a result of a traffic incident), the piston effect associated with traffic movement would be reduced. Traffic management measures (such as reducing speed limits, ramp and lane closures) would be imposed to manage the incident and restore as far as practicable free flowing traffic. Under these conditions, longitudinal ventilation may require mechanical support to move air through the tunnels. Mechanical support would be provided using jet fans, which would operate by moving air in the same direction that the traffic is flowing (except at exit portals) to provide the fresh air demand required to meet the relevant air quality criteria.

Additional fresh air may be injected into the mainline tunnels via supply facilities located at Rozelle, Haberfield and St Peters interchange.

Emergency conditions

During a major incident, when traffic is stopped in the tunnel, the jet fans would be used to increase the air flow to protect vehicle occupants and emergency services personnel from a build-up of emissions. Drivers would be requested, via the public address system, to turn off vehicle engines to reduce emissions if there is an extended delay while the incident is cleared.

In the case of a fire, the incident carriageway would be closed to incoming traffic and traffic downstream of the fire would exit the tunnel. Jet fans would be used to propel the smoke downstream to the nearest ventilation outlet, or exit portal(s), depending on the location of the fire. This would prevent smoke flowing backwards from the fire source over any vehicles that are stationary behind the fire and jet fans upstream of the fire. Further details of the smoke control system are provided in **section 5.8.2** of the EIS.

2.4.4 Iterative approach to design

The design of the proposed M4-M5 Link project has been undertaken using an iterative approach, with changes being made to various aspects – such as ventilation outlet locations and dimensions – and testing to ensure that impacts on in-tunnel and ambient air quality have been adequately managed to meet air quality goals and criteria. The design on which this report is based has been developed using this approach, to minimise potential impacts.

3 Air quality considerations for the M4-M5 Link project

3.1 Overview of section

This section:

- Summarises the main aspects of traffic-related emissions and air pollution, including the air quality issues that are associated specifically with road tunnels
- Provides contextual information on topics such as the main traffic pollutants and their effects, the processes affecting air pollution, and air pollution in and around tunnels
- Identifies the key air quality considerations for the project.

3.2 Roads, tunnels and air quality

3.2.1 Significance of road traffic pollution

Road traffic is the main source of several important air pollutants in Australian cities. The pollutants released from motor vehicles have a variety of effects on amenity, health, ecosystems and cultural heritage (refer to **Annexure A**). Traffic pollution also has impacts on wider geographical scales. The main focus of concern is currently on the short-term and long-term effects of road transport pollution on human health. For example, these effects account for the majority of the costs to society associated with the impacts of air pollution. The health costs of air pollution in Australia are estimated to be in the order of $11.1 billion to $24.3 billion annually, solely as a result of mortality (Begg et al., 2007; Access Economics, 2008). Road transport is a significant contributor; the health costs of emissions from road transport in Australia have been estimated to be $2.7 billion per year (Bureau of Transport and Regional Economics (BTRE), 2005). The Organisation for Economic Co-operation and Development (OECD) has estimated that about half of the economic cost of air pollution in its member countries is specifically attributable to road transport, and in Australia in 2010 this equated to around ($2.9 billion) (OECD, 2014). However, more work is needed to provide a robust estimate of the road transport share.

A discussion of the risks to human health in relation to the project is provided in **Appendix K** (Technical working paper: Human health risk assessment) of the EIS.

3.2.2 Pollutants

Many different air pollutants are associated with road vehicles. Pollutants that are emitted directly into the air are termed 'primary' pollutants. With regard to local air quality and health, as well as the quantity emitted, the most significant primary pollutants from road vehicles are:

- Carbon monoxide (CO)
- Oxides of nitrogen (NO_X). By convention, NO_X is the sum of nitric oxide (NO) and nitrogen dioxide (NO_2), and is stated as NO_2-equivalents
- Particulate matter (PM). The two metrics that are most commonly used are PM_{10} and $PM_{2.5}$, which are particles with an aerodynamic diameter of less than 10 µm and 2.5 µm respectively.
- Hydrocarbons (HC). The term 'hydrocarbons' covers a wide range of compounds which contain carbon and hydrogen. In the context of vehicle emissions, the term 'volatile organic compounds' (VOC) is also often used, particularly when there is a reference to fuel evaporation. The terms VOC and total hydrocarbons (THC) are used interchangeably in this report. Where reference is made to a source document or model, the original term used has been retained.

Other pollutants, notably ozone (O_3) and important components of airborne particulate matter, are formed through chemical reactions in the atmosphere. These are termed 'secondary' pollutants. Most of the NO_2 in the atmosphere is also secondary in nature.

The characteristics, health effects and environmental effects of the main primary and secondary transport-related pollutants are summarised in **Annexure A**. The specific pollutants and metrics that were addressed in this assessment are identified in **section 5**.

3.2.3 Impact pathways

The links between road traffic, air pollution and health are complex, involving a multi-step impact pathway. The pathway begins with the initial formation of pollutants, and the formation processes for traffic-derived pollutants are explained in **Annexure B**. The processes that lead to emissions of primary pollutants are:

- Combustion, which results in CO, HC, NO_X and PM being emitted from vehicle exhaust
- Evaporation of VOCs from fuel
- Abrasion resulting in PM emissions from tyre wear, brake wear and road surface wear
- Resuspension, which results in particulate matter on the road surface being entrained in the atmosphere.

For a given road section, the total mass of a pollutant that is emitted from the traffic depends on several factors, including:

- The volume, composition and operation (eg speed) of the traffic
- The road gradient
- The length of the road section.

The emitted pollutants are then dispersed in the ambient air according to the local topography and meteorology, and are transformed into secondary pollutants through chemical reactions. The dispersion and transformation of traffic-derived pollutants are summarised in **Annexure B**.

The main direct impacts of primary traffic pollutants are near the point of emission; further away concentrations decrease rapidly as a result of dispersion and dilution. Because of the time required for their formation, the concentrations of secondary pollutants are not always highest near the emission source. An example of this is the formation of NO_2 from NO emissions.

The resulting effects of road traffic pollution on the health of a given population are influenced by the concentration to which the population is exposed, the duration of the exposure, and the susceptibility of the population to the relevant pollutants. The situation is complicated by numerous factors, such as combinations of pollutants having synergistic effects on health.

The overall exposure of individuals to air pollutants is dependent upon the types of activity in which they are engaged, the locations of those activities, and the pollutant concentrations at those locations. In principle, an understanding of the amount of time spent in different types of environment (such as outdoors in the street, indoors at home, in transit, at the workplace, etc), and the pollutant concentrations in those environments, allows the calculation of 'integrated' personal exposure (Duan, 1982). However, the calculation of such an integral is often not possible because the pollutant concentrations in the different microenvironments are generally not known. The term 'average exposure' is therefore commonly used, and this is typically taken to mean the pollutant concentration over a specified period (eg annual mean) at an outdoor location which is broadly representative of where people are likely to spend time. This approach is reflected in the regulation of ambient air quality.

Once the pollutant has crossed a physical boundary within the body, the concept of 'dose' is used (Ott, 1982). The dose is the mass of material absorbed or deposited in the body for an interval of time, and depends on the respiratory activity of the individuals concerned. Responses to doses – the actual health effects - can also vary from person to person, depending on physiological conditions.

3.2.4 Air pollution in and around road tunnels

In-tunnel pollution

The principles of exposure also apply inside road tunnels, where impacts on health are related to the concentration of pollutants in the tunnel and the amount of time spent in the tunnel. The more time spent travelling in a tunnel with elevated pollutant concentrations, the greater the exposure time which, in turn, would increase the risk of effects (National Health and Medical Research Council (NHMRC), 2008; Longley et al. 2010). Ensuring that in-tunnel air quality remains within acceptable levels is the key consideration for tunnel ventilation design. Visibility is also a significant safety concern for tunnel design. Visibility is reduced by the scattering and absorption of visible light by airborne particles. The amount of scattering or absorption is dependent upon particle size, composition and density (Permanent International Association of Road Congresses (PIARC), 2012).

Portal emissions

In most road tunnels around the world emissions are released from the portals. One of the potential advantages of tunnels is the opportunity to site portals so that emissions in sensitive areas are avoided. However, this can often be challenging in densely populated urban settings (Longley, 2014b). In Sydney, several urban tunnels have therefore been designed in such a way that portal emissions are avoided, and examples of this approach are provided in **section 3.3**. In line with this approach, the M4-M5 Link project would also be designed so that there are no emissions from the tunnel portals during normal operations.

Ventilation outlet emissions

Tunnel portal emissions are avoided through the extraction of air via elevated ventilation outlets, and these provide an effective means of dispersing the polluted air from a tunnel.

Ventilation outlets work by taking advantage of the turbulent mixing in the atmosphere, and the fact that wind speed generally increases with height (Longley, 2014a). The concentrations of pollutants at locations of potential exposure are determined by the emission rates of the pollutants and the effectiveness of the ventilation system at harnessing the dispersive capacity of the atmosphere. The concentrations of pollutants at ground level are progressively reduced as the height of the outlet increases. A combination of the design height of the outlet and the amount of fresh air that is mixed with the polluted air from the tunnel can be used to ensure appropriate dilution before the exhaust plume makes contact with the ground, and good design can ensure compliance with local air quality standards, (PIARC, 2008). The temperature of the air leaving tunnel ventilation outlets is also an important determinant of the dispersion of pollutants. Plumes with higher temperatures have higher buoyancy, which generally means that the plume is carried higher into the atmosphere, resulting in improved dispersion. The temperature of the plume is influenced by the number of vehicles moving through the tunnels, as some of the heat from the vehicle exhaust would be carried through to the ventilation outlets.

To achieve zero emissions from a portal, the polluted air from the section of tunnel between a ventilation outlet and the portal must be extracted from the ventilation outlet. This requires that the air in the tunnel section is drawn back against air flow induced by vehicle aerodynamic drag (the so-called ‘piston effect’). Given this requirement for pushing air in the opposite direction to the traffic flow, positioning ventilation outlets close to tunnel exit portals has been found to be the most cost-effective and energy-efficient approach, as this minimises the distance over which this ‘reverse flow’ is needed. However, the use of ventilation outlets to avoid portal emissions does have implications:

- An increase in the required throughput of ventilation air, which can increase the design size and capital cost of the ventilation system.
- An increase in the operational cost (and energy use) of the ventilation system, as it must be operated continuously regardless of traffic or pollutant levels in the tunnel.

Ventilation outlets can also be deliberately sited away from dense residential areas to address community concern about the impact. However, this can considerably increase the construction, maintenance and running costs of a tunnel for no significant gain in air quality, and such designs are very rare outside Australia (Longley, 2014a).

Studies suggest that the greatest impacts from an outlet occur some distance from the outlet, and also largely restricted to directions which are downwind of the outlet in the most frequent local wind directions, and there may be effectively zero impact in many directions. However, outlets are designed so that even these peak concentrations do not lead to any significant or measurable impact on the local community, as predicted by modelling and frequently confirmed by monitoring (Longley, 2014a). Nevertheless, the potential air quality impacts of the ventilation outlets themselves are often the focus of community attention in relation to tunnel projects. A consideration of ventilation outlets therefore needs to be included in any detailed air quality assessment (SMPO, 2013; Roads and Maritime, 2015). The air quality assessment informs the ventilation outlet design and operating conditions to ensure that good air quality is maintained.

3.3 Sydney tunnels and air quality

NHMRC (2008) described the history of road tunnels in Sydney, and highlighted the importance of accurate modelling at the design stage to ensure that air quality is properly managed.

Since the opening of the Eastern Distributor tunnel in 1999, the major road tunnels constructed in Sydney have all been designed to avoid portal emissions[2], and the tunnel air is discharged from elevated ventilation outlets. This approach was initially required by the Conditions of Approval for the M5 East tunnel as a precautionary measure to protect residents around the tunnel portals, and was subsequently retained for the Cross City Tunnel and Lane Cove Tunnel (LCT). It also applies to the recently approved NorthConnex, M4 East and New M5 tunnels.

The M5 East Tunnel (four kilometres long) carries a large volume of traffic (around 110,000 vehicles per day), and is subject to frequent congestion. High levels of in-tunnel pollution and poor visibility were initially reported (NSW Parliament, 2002). NHMRC noted that the emission factors used to design the tunnel ventilation underestimated emissions from the local fleet, and that traffic in the tunnel quickly exceeded the design assumptions. It has also been observed that there was a failure to model the effects of emissions from traffic travelling at low speeds (NSW Department of Planning, 2005). On the other hand, ambient air quality continues to be monitored at five locations in the vicinity of the ventilation outlet for the M5 East Tunnel and, since opening in December 2001, the tunnel has been operating within the ambient air quality goals set in the approval for the project (SMPO, 2013; Roads and Maritime, 2015).

Conversely, for the Cross City Tunnel (2.1 kilometre long) there was a significant overestimation of the traffic volume at opening. This has been attributed to toll avoidance and a reversal of surface road changes designed to encourage tunnel use. Although pollutant concentrations reported inside the Cross City Tunnel are low, the ventilation system was expensive to build and operate (Manins, 2007).

The Lane Cove Tunnel (3.6 kilometres long) connects the M2 Motorway at North Ryde with the Gore Hill Freeway at Artarmon, and is designed to relieve congestion on Epping Road. The tunnel is ventilated by one outlet at each end. Extensive air quality monitoring was conducted in the vicinity of the ventilation outlets and alongside Epping Road. Concentrations of air pollutants decreased alongside Epping Road after the opening of the tunnel, and no exceedances of air pollution standards were attributed to air discharged from the tunnel ventilation outlets (Holmes et al., 2011).

3.4 Advisory Committee on Tunnel Air Quality

Given the community concerns about road tunnels in Sydney, and the scale of projects such as NorthConnex and WestConnex, the NSW Government established an Advisory Committee on Tunnel Air Quality (ACTAQ). The Committee is chaired by the NSW Chief Scientist and Engineer, and includes representatives from several government departments, including Roads and Maritime, NSW Department of Health (NSW Health), NSW Department of Planning and Environment (DP&E), the NSW Office of Environment and Heritage (OEH) and NSW Environment Protection Authority (NSW EPA). The main role of ACTAQ is to provide the NSW Government with an understanding of the

[2] This approach is not unique to Sydney. For example, each of Brisbane's road tunnels (North South Bypass Tunnel, Airport Link and Northern Link) has been designed to operate without portal emissions (SMPO, 2013).

scientific and engineering issues concerning tunnel ventilation design and operation based on NSW, national and international experience. Between 2014 and 2016 ACTAQ released a number of reports on motor vehicle emissions, air quality and tunnels[3]. These reports were consulted as part of the assessment for the project.

3.5 WestConnex Strategic Environmental Review

The Strategic Environmental Review (SMPO, 2013) and Update to Strategic Environmental Review (Roads and Maritime, 2015) for the whole of WestConnex identified the major potential benefits and challenges associated with the scheme, and considered how the latter could be avoided, managed and/or mitigated during project development and delivery. Issues and strategies were identified in consultation with the key government agencies. These documents thus set the scene for subsequent project-specific environmental impact assessments.

Six priority issues were identified, one of which was air quality. A strategic air quality assessment was undertaken to evaluate the potential impacts of WestConnex on regional and local air quality, as well as in-tunnel air quality. The main findings of this assessment were as follows:

- Regional air quality is unlikely to change as a result of WestConnex
- Transferring vehicles from surface roads into tunnels is likely to improve the air quality along existing surface roads where traffic is reduced. However, local effects on air quality would need to be determined more accurately through detailed assessments
- The tunnel ventilation systems for WestConnex would be designed and operated to meet stringent in-tunnel criteria and ambient air quality standards. In-tunnel air quality criteria would be developed in consultation with NSW EPA, NSW Health, and DP&E based on a review of current international practice and experience from NSW motorway tunnels
- Locating ventilation outlets close to the tunnel portals would substantially minimise the costs and energy use for the system
- Filtration of tunnel emissions is not an efficient or effective mechanism to address in-tunnel, local or regional air quality. The most effective way to manage air quality both in and around tunnels is through vehicle fleet emission reductions
- The results of monitoring of earlier tunnel projects and detailed air quality modelling would be used to demonstrate how the proposed approach would protect air quality
- The number of people using road tunnels would increase substantially with WestConnex. However, the maximum time spent in any tunnel should decrease due to improved traffic flow across the network.

3.6 Summary of key air quality considerations

To summarise the previous sections, the key air quality considerations are likely to be as follows:

- Understanding in-tunnel air quality, and the short-term exposure of tunnel users to elevated pollutant concentrations. This relates not only to the exposure of M4-M5 Link tunnel users, but also to the cumulative exposure of users of multiple Sydney tunnels, and notably the M4 East and New M5
- Understanding the ambient air quality impacts of tunnel ventilation outlets and changes to the surface road network. This includes:
  - Potential improvement in air quality alongside existing surface roads which would have a decrease in traffic volume
  - Potential deterioration in air quality alongside new and upgraded/widened surface roads

[3] http://www.chiefscientist.nsw.gov.au/reports.

- Potential deterioration in air quality alongside existing roads which would have an increase in traffic volume
- Potential deterioration in air quality in the vicinity of tunnel ventilation outlets
- The combined impacts of multiple road infrastructure projects in Sydney

· Accurate modelling of air quality to inform tunnel ventilation design and management

· Public understanding of air quality and the magnitude of any project impacts

· The impacts of the construction of the project.

There was therefore a need for a detailed assessment of the potential impacts of the project on air quality (both adverse and beneficial) and this report presents this assessment. This report also informs the design of the tunnel ventilation system, including the location, design and operation of the outlets for polluted air.

4 Regulation of emissions, air pollution and exposure

4.1 Overview of section

A number of legislative instruments and guidelines apply to air pollution from road transport in general, and road tunnels specifically. This section:

- Summarises key legislative instruments and guidelines in relation to the project, and covers:
  - National emission standards that apply to new vehicles
  - Emission regulations, checks and policies that apply to in-service vehicles
  - Fuel quality regulations
  - In-tunnel limits on pollutant concentrations for tunnel ventilation design and operational control
  - Ambient air quality standards and assessment criteria, which define levels of pollutants in the outside air that should not be exceeded during a specific time period to protect public health
- Compares the regulations in Australia and NSW with those in force elsewhere.

The regulations, guidelines and criteria in Australia and NSW are summarised in the following sections. More detailed information, including an international context for some of the aspects, is provided in **Annexure C**.

4.2 Policies and regulations for road vehicle emissions

4.2.1 National emission standards for new vehicles

Under the *Motor Vehicle Standards Act 1989* (Commonwealth), new road vehicles must comply with certain safety and emissions requirements as set out in Australian Design Rules (ADRs). The specific emission limits that apply to exhaust emissions from light-duty and heavy-duty vehicles, and their timetable for adoption in the ADRs, are listed on the Australian Government website[4], and further information is provided in **Annexure C**. Some examples, showing the reduction in the allowable emissions with time, are shown in **Figure 4-1** and **Figure 4-2**.

The evaporation of fuel from petrol vehicles constitutes a significant fraction of the total on-road mobile VOC emissions in the NSW Greater Metropolitan Region (GMR) (NSW EPA, 2012b). The limits for evaporative emissions in Australia are also given in **Annexure C**.

The non-exhaust processes that lead to PM emissions from road vehicles are not regulated. Denier van der Gon et al. (2013) concluded that there is an urgent need for a comprehensive research program to properly quantify non-exhaust emissions and assess their health relevance. The EU Particle Measurement Programme is evaluating the options for the measurement of non-exhaust particles[5]. Although there is an intention to develop standardised methodologies, there is currently no plan to regulate non-exhaust PM in Europe.

[4] http://www.infrastructure.gov.au/roads/environment/emission/.

[5] Informal Group for the Particle Measurement Programme, Session 35, Brussels, 4-5 Mar 2015; http://www.globalautoregs.com/meetings/709.

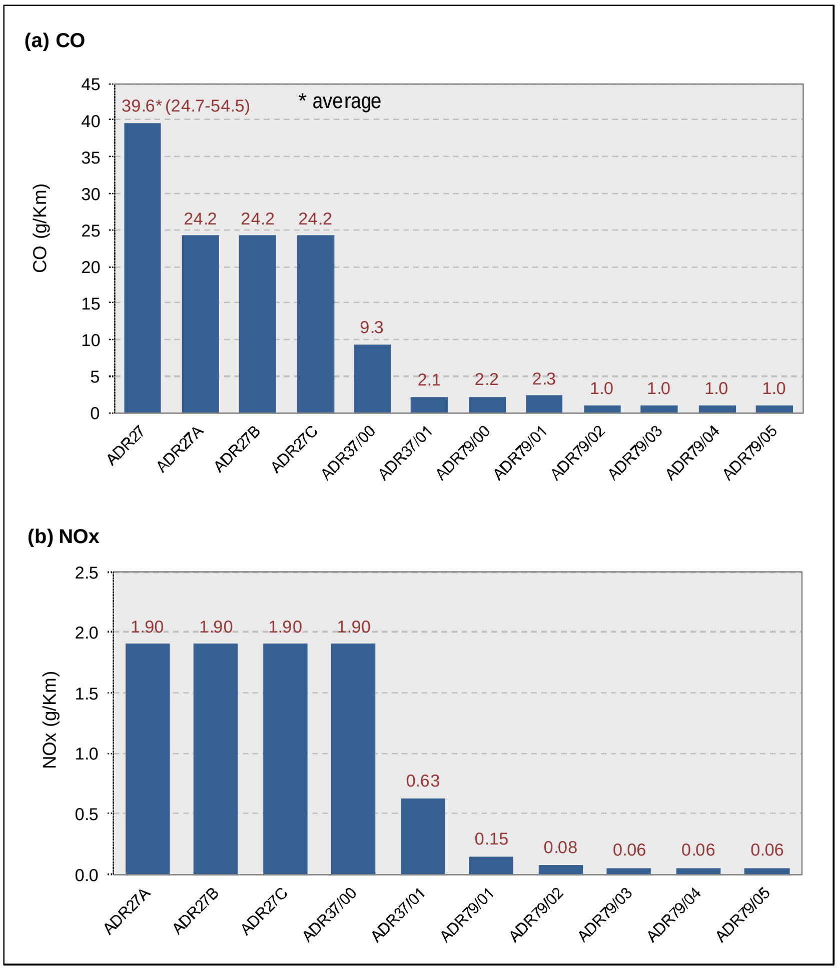

Figure 4-1 Exhaust emission limits for CO and NO_X applicable to new petrol cars in Australia

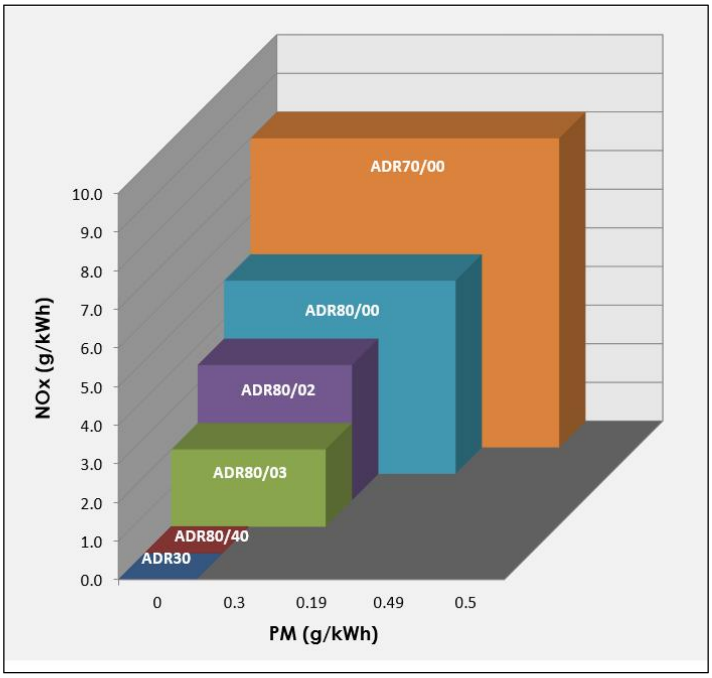

Figure 4-2 Exhaust emission limits for NO_X and PM applicable to heavy-duty vehicles in Australia

4.2.2 Checks on in-service vehicles

The *National Environment Protection (Diesel Vehicle Emissions) Measure 2001* establishes a range of strategies that state and territory governments can employ to manage emissions from diesel vehicles.

In NSW the owners of private vehicles that are more than five years old are required to obtain an 'e-Safety Check' prior to registration renewal, but the only requirements for in-service emissions testing in the NSW regulations[6] are for modified vehicles and LPG conversions.

The OEH has, in conjunction with the then NSW Roads and Traffic Authority (RTA) (now Roads and Maritime), established a diesel vehicle retrofit program which involves retrofitting engines with pollution-reduction devices, primarily to reduce PM emissions. The program commenced in 2005 and, as of 2011, more than 70 vehicle fleets (covering 520 vehicles) had participated (DSEWPC, 2011).

Specific measures have also been introduced to improve air quality in the M5 East tunnel. An Air Quality Improvement Plan was launched in 2006 in response to community concern about the large numbers of smoky heavy vehicles using the tunnel. The Plan included the installation of additional jet fans and a smoky vehicle camera/video system in the tunnel. A trial of air filtration technologies was also undertaken (refer to **section 9**). A subsequent review of the AQIP led to the implementation of a stronger suite of measures in the 2012 Air Quality Improvement Program. These measures included upgrading the smoky vehicle camera system, increasing fines for smoky vehicles detected in the M5 East tunnel and expanding the diesel retrofit program to reduce NO_2 and PM concentrations, both in the M5 East tunnel and across the broader Sydney road network.

4.3 Fuel quality regulations

The *Fuel Quality Standards Act 2000* (Commonwealth) provides a framework for the setting of national automotive fuel quality standards. The first national standards for petrol and diesel were introduced in the *Fuel Standard (Petrol) Determination 2001* and the *Fuel Standard (Automotive Diesel) Determination 2001*. These Standards prohibited the supply of leaded petrol and reduced the level of sulfur in diesel fuel. The regulation of fuel quality continued with the development of standards for LPG, biodiesel and ethanol.

More recent improvements in fuel quality have focused on reducing sulfur content further, as low-sulfur fuel is a prerequisite for modern exhaust after-treatment devices. Australia adopted a Euro 3-equivalent sulfur limit for petrol (150 ppm) in 2005, and a Euro 4-equivalent sulfur limit for diesel (50 ppm) in 2006, to support the introduction of the equivalent vehicle emission standards. From January 2008, a 50 ppm limit was applied to higher octane grades of unleaded petrol to support Euro 4 petrol vehicles. Since January 2009 the sulfur limit in diesel has been further reduced to 10 ppm, primarily to support the introduction of new emissions standards for heavy-duty vehicles; certain vehicle technologies that are employed to meet emission standards are sensitive to sulfur (DIT, 2010).

The Australian Government is currently in the process of reviewing the *Fuel Quality Standards Act 2000* (Commonwealth).

4.4 In-tunnel pollution limits

4.4.1 Gaseous pollutants

An understanding of in-tunnel pollutant concentrations is required for three main reasons:

- To design and control ventilation systems
- To manage in-tunnel exposure to air pollution

[6] The only relevant in-service emission test is the DT80 which is incorporated into the National Vehicle Standards as Rule 147A. However, NSW has not adopted Rule 147A.

- To manage external air pollution.

For many tunnels, the ventilation requirements have been determined according to guidelines from the World Road Association (PIARC, 2012), and the relevant criteria are presented in **Annexure C**. The fresh air requirements for tunnel ventilation design and control purposes in Australia have traditionally been based upon the in-tunnel CO concentration, given that:

- CO emissions have historically been dominated by road transport
- CO is the only traffic-related pollutant with a short-term (15 minute) World Health Organization (WHO) health-based guideline
- CO is relatively resistant to physical or chemical change during the timescales of its atmospheric residence in a road tunnel (NHMRC, 2008).

In the past, most of the CO was emitted by petrol vehicles. However, following the introduction and refinement of engine management and exhaust after-treatment systems, CO emissions from such vehicles are now rather low. This has given rise to significant reductions in overall CO emissions and ambient concentrations. The increased market penetration of diesel vehicles in passenger car fleets (more so in Europe than in Australia) has meant that some countries are now considering the use of NO_2 concentrations for tunnel ventilation design. This is partly in response to health concerns relating to short-term exposure to NO_2 (eg Svartengren et al., 2000), and partly to ensure compliance with ambient air quality standards outside the tunnel. This shift in emphasis is also supported by evidence of the increase in primary NO_2 emissions from road vehicles (Carslaw and Beevers, 2004; Carslaw, 2005).

A policy paper on in-tunnel NO_2 was produced by ACTAQ (2016). This stated that all new road tunnels over one kilometre in length shall be designed and operated so that the tunnel-average NO_2 concentration is less than 0.5 ppm measured using a rolling 15-minute average.

4.4.2 Visibility and PM

Another important consideration for tunnel ventilation design is visibility. Consideration of visibility criteria in the design of the tunnel ventilation system is required due to the need for visibility levels that exceed the minimum vehicle stopping distance at the design speed (PIARC, 2012). Visibility is reduced by the scattering and absorption of light by PM suspended in the air. The principle for measuring visibility in a tunnel (using opacity meters) is based on the fact that a light beam decays in intensity as it passes through the air. The level of decay can be used to determine the opacity of air. For tunnel ventilation it has become customary to express visibility by the extinction coefficient K.

The amount of light scattering or absorption is dependent upon the particle composition (dark particles, such as soot, are particularly effective), diameter (particles need to be larger than around 0.4 μm), and density. Particles causing a loss of visibility also have an effect on human health, and so monitoring visibility also provides the potential for an alternative assessment of the air quality and health risk within a tunnel. However, such an assessment is limited by the short duration of exposure in tunnels compared with the longer exposure times (24 hours and one year) for which the health effects of ambient particles have been established. Moreover, there is no established safe minimum threshold for particles, and so visibility cannot reliably be used as a criterion for health risk (NHMRC, 2008).

It is worth adding that the nature of PM emitted by road vehicles is changing with time. Diesel exhaust particles have normally been taken as the reference for visibility. Non-exhaust PM is becoming more important in terms of the mass emitted, but wear particles and resuspended particles have characteristics that are different from those of exhaust particles. The evidence suggests that non-exhaust particles are generally larger than exhaust particles, and may have less of an impact on visibility.

4.4.3 Other considerations

In addition to controlling pollution, tunnel ventilation systems must also be capable of responding to emergency incidents involving vehicle fires and smoke release. Demands on smoke control or dilution of chemical releases may mean that the ventilation system has to move larger volumes of air than those required for the dilution of exhaust gases, and this aspect of design must also be considered. The design requirements for smoke control are defined by NFPA-502 (NFPA, 2017).

4.4.4 Limit values

The three pollutants assessed in-tunnel are nitrogen dioxide (NO_2), carbon monoxide (CO) and particulate matter (PM) which is measured as an optical extinction coefficient. The operational in-tunnel limits for CO and NO_2 in several Sydney road tunnels are shown in **Table 4-1.** With the current pollution limits, and for the assessment years of the WestConnex project, NO_2 would be the pollutant that determines the required air flows and drives the design of ventilation for in-tunnel pollution.

Table 4-1 Operational limits for CO, NO_2 and visibility in Sydney road tunnels

Tunnel	CO concentration (ppm, rolling average)			NO_2 concentration (ppm)	Visibility (extinction coefficient, m^{-1})
	3-min	15-min	30-min	15-min	
Cross City Tunnel	200	87	50	N/A	0.005-0.012
Lane Cove Tunnel	-	87	50	N/A	0.005-0.012
M5 East Tunnel	200	87	50	N/A	0.005-0.012
NorthConnex M4 East New M5	200[(a)]	87[(b)]	50[(b)]	0.5[(b)]	0.005[(c)]

(a) In-tunnel single point exposure limit

(b) In-tunnel average limit along tunnel length

(c) In-tunnel limit at any location along tunnel length, rolling 15-minute average

Sources: NHMRC (2008), Longley (2014c), PIARC (visibility), NSW Government (2015, 2016a, 2016b)

In February 2016, the NSW Government ACTAQ issued a document entitled 'In-tunnel air quality (nitrogen dioxide) policy' (ACTAQ, 2016). That document further consolidated the approach taken earlier for the NorthConnex, M4 East and New M5 projects. The policy wording requires tunnels to be '*designed and operated so that the tunnel average nitrogen dioxide (NO_2) concentration is less than 0.5 ppm as a rolling 15 minute average*'.

For M4-M5 Link and the associated integrated analysis of WestConnex, the 'tunnel average' has been interpreted as a 'route average', being the 'length-weighted average pollutant concentration over a portal-to-portal route through the system'. Tunnel average NO_2 has been assessed for every possible route through the system under all circumstances, and the calculation of this is outlined in section 7.3 of **Annexure L.** The path with the highest average NO_2 concentration is reported.

With the predicted maximum CO levels falling well below the 'tunnel average' requirement, the complexity of evaluating 'tunnel average' CO criteria has been simplified and assessed as an in-tunnel maximum criterion throughout the project. The tunnel ventilation system would be designed and operated so that the in-tunnel air quality limits are not exceeded. The limits used for tunnels in other countries are summarised in **Annexure C**.

4.4.5 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 4-2**. The SEARs for the M4-M5 Link refer to the *Protection of the Environment Operations Act 1997* (NSW) and the Protection of the Environment Operations (Clean Air) Regulation 2010. Although the Regulations specify in-stack concentration limits, these are designed primarily for industrial activities and the limit values are much higher than those imposed for road tunnels in Sydney[7].

Table 4-2 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
NO_2	2.0	1 hour	Dry, 273 K, 101.3 kPa
CO	40	Rolling 1 hour	Dry, 273 K, 101.3 kPa
VOC (as propane)	4.0[(a)]	Rolling 1 hour	Dry, 273 K, 101.3 kPa

(a) Stated as 1.0 in the Conditions of Approval for NorthConnex.

Sources: NSW Government (2015, 2016a, 2016b)

4.5 Tunnel portal emission restrictions

As noted in **section 3.3**, a key operating restriction for tunnels in Sydney 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.

4.6 Ambient air quality standards and criteria

Compliance with ambient air quality standards is a major consideration during road project design and operation. An ambient air quality standard defines a metric relating to the concentration of an air pollutant in the ambient air. Standards are usually designed to protect human health, including sensitive populations such as children, the elderly, and individuals suffering from respiratory disease, but may 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. Each metric is often combined with a goal, such as a requirement for the limit to be achieved by a specified date.

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[7] See for example, Schedule 4 of the Protection of the Environment Operations (Clean Air) Regulation 2010, which specifies standards of in-stack concentration for general activities and plant. These standards have values of at least 50 mg/m^3 for total particles, at least 350 mg/m^3 for NO_X, and at least 125 mg/m^3 for CO.

Air pollutants are often divided into ‘criteria’ pollutants and ‘air toxics’. Criteria pollutants tend to be ubiquitous and emitted in relatively large quantities, and their health effects have been studied in some detail. 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, carcinogenic or highly persistent in the environment, so as to be a hazard to humans, plants or animal life.

The health effects of criteria pollutants and some specific air toxics are summarised in **Annexure A**, and further information on standards and impact assessment criteria is provided below.

NB: The actual impact assessment criteria that were applicable to the project are summarised in **section 5.5.3**.

4.6.1 Criteria pollutants

In 1998 Australia adopted a *National Environment Protection (Ambient Air Quality) Measure* (AAQ NEPM) that established national standards for six criteria pollutants (NEPC, 1998):

- Carbon monoxide (CO)
- Nitrogen dioxide (NO_2)
- Sulfur dioxide (SO_2)
- Lead (Pb)
- Photochemical oxidants as ozone (O_3)
- Particulate matter with an aerodynamic diameter of less than 10 µm (PM_{10}).

The AAQ NEPM was extended in 2003 to include advisory reporting standards for PM with an aerodynamic diameter of less than 2.5 µm ($PM_{2.5}$) (NEPC, 2003). 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 µg/m^3 was established
- An aim to move to annual average and 24 hour $PM_{2.5}$ standards of 7 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 form of the 24 hour $PM_{2.5}$ and PM_{10} standards was replaced with an exceptional event rule.

The NEPM is a national monitoring and reporting protocol. The NEPM standards are applicable to urban background monitoring sites which are broadly representative of population exposure. The use of any NEPM air quality criteria in relation to the assessment of projects and developments is outside the scope of the NEPM itself, and is decided by the jurisdictions. The criteria for air quality assessments for projects/developments in NSW are contained in the Approved Methods (see below). However, should the Approved Methods be revised it is possible that they would take into account the new NEPM standards, but they may not necessarily take exactly the same form. Nevertheless, the project would be designed so that any increases in $PM_{2.5}$ concentrations due to emissions from the ventilation outlets are minimal.

The Australian States and Territories manage emissions and air quality in relation to particular types of source (eg landfills, quarries, crematoria, and coal mines). The jurisdictions have legislation or guidance which includes design goals, licence conditions or other instruments for protecting local communities from ground-level impacts of pollutants in residential areas outside site boundaries. Where this is the case, the AAQ NEPM standards are often used for air quality assessments. In NSW, the *Approved Methods for the Modelling and Assessment of Air Pollutants in NSW* (NSW EPA, 2016) (NSW Approved Methods) sets out the approaches and criteria to be used. The NSW Approved

Methods are designed mainly for the assessment of industrial point sources, and do not contain specific information on the assessment of, for example, transport schemes and land use changes. Air quality must be assessed in relation to standards[8] and averaging periods for specific pollutants that are taken from several sources, notably the AAQ NEPM.

The metrics, criteria and goals set out for criteria pollutants in the NSW Approved Methods are provided in **Annexure C**.

4.6.2 Air toxics

In recognition of the potential health problems arising from the exposure to air toxics, the *National Environment Protection (Air Toxics) Measure* (Air Toxics NEPM) (NEPC, 2011a) identifies 'investigation levels' for five priority pollutants: benzene, formaldehyde, toluene, xylenes and benzo(a)pyrene (as a marker for polycyclic aromatic hydrocarbons). These are not compliance standards but are for use in assessing the significance of the monitored levels of air toxics with respect to the protection of human health.

The NSW Approved Methods specify air quality impact assessment criteria and odour assessment criteria for many other substances (mostly hydrocarbons), including air toxics, and these are too numerous to reproduce here. The SEARs for the project require an evaluation of BTEX compounds: benzene, toluene, ethylbenzene, and xylenes.

The investigation levels in the Air Toxics NEPM and the impact assessment criteria in the NSW Approved Methods for priority air toxics and BTEX compounds are given in **Annexure C**.

[8] In this Assessment Report the term 'standard' is used to refer to the numerical value of the concentration for a given pollutant in legislation. The NSW Approved Methods refer to 'impact assessment criteria', and this terminology is also used in the Report.

5 Overview of assessment methodology

5.1 Overview of section

This section:

- Identifies the key guidelines and policies that were relevant to the air quality assessment for the project
- Reviews recent air quality assessments for major road projects in Australia and New Zealand in order to inform the methodology and to ensure that the assessment was conducted in line with Australian and international best practice
- Describes the general approaches that were used to assess the impacts of the project on air quality, including:
  - Construction
  - Operation – emissions
  - Operation – in-tunnel air quality
  - Operation – ambient air quality (local and regional)
- Defines the scenarios that were assessed
- Explains why certain pollutants and metrics were included in the air quality assessment, and why others were excluded
- Explains the terminology used in the air quality assessment
- Discusses the accuracy and conservatism of the assessment process.

5.2 Key documents, guidelines and policies

The following documents, guidelines and policies were relevant to the air quality assessment:

- The NSW Air Emissions Inventory. This quantifies emissions from all sources of air pollution – domestic, commercial, industrial, off-road mobile and on-road mobile
- The National Environment Protection Measure for Ambient Air Quality (AAQ NEPM). This sets the national health-based air quality standards for six air pollutants
- Approved Methods for the Modelling and Assessment of Air Pollutants in NSW (NSW EPA, 2016)
- Air Quality in and Around Traffic Tunnels by NHMRC (2008)
- Guidance for the Management of Air Quality in Road Tunnels in New Zealand (Longley et al., 2010), and the document which has largely superseded it, the New Zealand Transport Agency's Guide to road tunnels (NZTA, 2013)
- Guidance from the World Road Association (PIARC), and in particular:
  - Road tunnels: a guide to optimising the air quality impact upon the environment (PIARC, 2008)
  - Road tunnels: vehicle emissions and air demand for ventilation (PIARC, 2012)
- Dispersion modelling guidance, such as the New Zealand Ministry for the Environment's Good Practice Guide for Atmospheric Dispersion Modelling (NZMfE, 2004)
- Guidance on the assessment of dust from demolition and construction ((UK) Institute of Air Quality Management (IAQM) 2014). This provides guidance on how to assess the sensitivity of receptors and the risk of impact on those receptors due to the various components of the project construction.

5.3 Consultation with government agencies and committees

Roads and Maritime consulted the following government agencies and bodies during the development and production of the methodology and the air quality assessment report:

- NSW EPA
- NSW Health
- NSW Chief Scientist & Engineer
- ACTAQ.

5.4 Previous road and tunnel project assessments

A number of recent air quality assessments for surface roads and tunnels in Australia and New Zealand were reviewed in order to identify where the methodologies, tools and findings could inform the M4-M5 Link assessment. These previous assessments are summarised in **Annexure D**. The summary includes details of the pollutants considered, the sources of emission factors, the dispersion models applied, and the approaches used to assess construction impacts. The findings can be summarised as follows:

- Assessments have focussed on the following pollutants and metrics: CO (rolling eight hour), NO_2 (one hour and annual mean) and PM_{10} (24 hour and annual mean). Some studies also included $PM_{2.5}$ (24 hour and annual mean), VOCs, and specific air toxics such as benzene and PAHs
- The averaging periods for pollutants are typically based on criteria from the USEPA and the AAQ NEPM, as well as NSW EPA
- Studies have generally used a 'do nothing' scenario as a baseline and have compared the impacts of the proposed project in a specified future year. In some cases, multiple scenarios for the project have been considered (eg 10 and 20 years after the project completion). Some studies have modelled different tunnel ventilation options (eg one outlet, two outlets, and different locations)
- For baseline scenarios background air quality data have typically been collected from representative monitoring stations in urban areas
- Several studies have used international emission factors (eg PIARC), and weighted these according to the local fleet, rather than using emission factors that are specific to Australian/NZ. Local vehicle emission factors have been used in some cases (eg NSW GMR inventory)
- Some studies have assumed no future improvements in vehicle technology or fuel, and have modelled emissions based on fleet-average emission factors
- Traffic data have either been taken from models such as the strategic Sydney traffic model, or based on surveys by local authorities or government agencies (eg Roads and Maritime in NSW).
- Air quality impacts have typically been predicted using meteorological processors such as TAPM[9] or CALMET[10], in combination with dispersion models such as CALPUFF for tunnel ventilation outlets and CALINE[11]-based models for surface roads. CALINE is considered to be more accurate than CALPUFF for simulating turbulence close to roads. Others models have also been used, including TRAQ[12], GRAL[13] and AUSPLUME
- The number of sensitive receptors assessed has been dependent on the scale of the project. For instance, the NorthConnex project assessed around 7,000 discrete receptors

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[9] TAPM = The Air Pollution Model

[10] CALMET is a meteorological model that is a component of CALPUFF modelling system

[11] CALINE = California Line Source Dispersion Model

[12] Tool for Roadside Air Quality (TRAQ), an air pollution screening tool developed by Roads and Maritime

[13] GRAL = Graz Lagrangian Model

- The impacts of project construction have generally been assessed qualitatively, and in some cases estimated using emissions factors.

5.5 General approach for M4-M5 Link

5.5.1 Construction assessment

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.

There are other potential impacts of demolition and construction, such as the release of heavy metals, asbestos fibres or other pollutants during the demolition of certain buildings such as former chemical works, or the removal of contaminated soils. The release of certain fungal spores during the demolition of old buildings can give rise to specific concerns if immune-compromised people are likely to be exposed, for example, close to an oncology unit of a hospital. These issues need to be considered on a site-by-site basis. Very high levels of soiling can also damage plants and affect the health and diversity of ecosystems (IAQM, 2014).

Dust emissions can occur during the preparation of the land (eg demolition and earth moving) and during construction itself, and can vary substantially from day to day depending on the level of activity, the specific operations being undertaken, and the weather conditions. A significant portion of the emissions results from site plant and road vehicles moving over temporary roads and open ground. If mud is allowed to get onto local public roads, dust levels can increase at some distance from the construction site (IAQM, 2014).

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 quantify dust emissions from construction activities reliably. 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. Moreover, mitigation should be straightforward, as most of the necessary measures are routinely employed as ‘good practice’ on construction sites. It is therefore usual to provide a more qualitative type of assessment of potential construction dust impacts.

A semi-quantitative[14], risk-based approach has been used for the M4-M5 Link assessment, and the impacts of construction have not been specifically modelled. The approach followed the guidance

[14] The phrase ‘semi-quantitative’ as been used as some aspects of the assessment are quantified (eg prevailing PM_{10} concentrations) whereas others are based more on judgement (eg receptor sensitivity) or coarse classifications.

published by the United Kingdom (UK) Institute of Air Quality Management (IAQM, 2014), the aim of which is to identify risks and to recommend appropriate mitigation measures.

The assessment of construction impacts using the IAQM procedure is presented in **section 7**.

5.5.2 Operational assessment – in-tunnel air quality

For in-tunnel air quality, the project has been modelled as an integral part of the complete WestConnex motorway network, incorporating coordinated ventilation system operation across project boundaries. The project was then assessed against the in-tunnel air quality criteria. The tunnel system was sub-divided into three models which were aerodynamically separate:

- M4-M5 Link (M4 Motorway to M5 Motorway direction)
- M4-M5 Link (M5 Motorway to M4 Motorway direction)
- Western Harbour Tunnel and Beaches Link.

The ventilation system is designed for coordinated operation with adjacent tunnel projects (ie the M4 East and New M5, the proposed future Western Harbour Tunnel and Beaches Link and future proposed F6 Extension), with complete or partial air exchange across project boundaries when necessary to ensure in-tunnel air quality is maintained across the network.

The ventilation system is designed to have a complete exchange of tunnel air between Western Harbour Tunnel and Beaches Link and the project at the Rozelle ventilation facility. The Western Harbour Tunnel and Beaches Link is run 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 flow, pollution levels, and temperature for the project were modelled using the IDA Tunnel software[15]. The criteria, scenarios, data and detailed method that were used in the tunnel ventilation simulation are provided in full in **Annexure L**. The modelling scenarios for expected traffic were the same as those used in the ambient air quality modelling (refer to **section 5.5.3** for the definition of these). The regulatory demand and worst case traffic scenarios were specific to traffic conditions within the tunnel.

Expected traffic (24 hour) scenarios

These scenarios represented the 24 hour operation of the tunnel ventilation system under day-to-day conditions of expected traffic demand in 2023 and 2033. Vehicle emissions were based on the design fleets in the corresponding years, with the results being presented for both in-tunnel air quality and for outlet emissions for use in the ambient air quality assessment.

In the cumulative scenarios, emissions from the adjacent tunnel projects were also considered.

Regulatory demand (24 hour) traffic scenarios

To compensate for the possibility that the expected traffic was under-predicted, the traffic was scaled up to maximum capacity and modelling undertaken to demonstrate that the in-tunnel air quality criteria would be met. Simulations using the regulatory demand traffic were completed for the 2023-DM, 2033-DS, 2033-DM and 2033-DS scenarios, and these are presented in **Annexure L**.

Worst case traffic scenarios

These simulations demonstrated the most onerous traffic conditions for the ventilation system, based on traffic conditions between 20 and 80 kilometres per hour that included:

- Congestion (down to 20 kilometres per hour on average)
- Breakdown or minor incident

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

- Free-flowing traffic at maximum capacity.

Normal operations for the ventilation system include the ‘expected traffic’, the ‘regulatory demand’ and ‘worst case traffic’ scenarios.

Emergency operations are ventilation modes needed for fire situations.

Travel route scenarios

An additional series of calculations dealt with a worst case trip scenario for in-tunnel exposure to NO_2.

All possible travel routes through the M4-M5 Link and the adjoining tunnels were identified for each direction of travel, and these were assessed against the in-tunnel criterion for NO_2. The details of the mathematical formulae and grid models used are provided in section 7.3 in **Annexure L**. Tables 7.8 and 7.9 in **Annexure L** 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 Western Harbour Tunnel, the route-average NO_2 was calculated as beginning or ending at the respective interface plant with the M4-M5 Link. This required the Western Harbour Tunnel ventilation system to achieve a route-average NO_2 concentration that was lower than the criterion for all routes starting or ending at the M4-M5 Link interface plant. 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 also meet, or be better than, the air quality criterion. Similarly, routes including the F6 Extension were assessed on the basis of starting or ending at President Avenue, and so the F6 Extension ventilation system would be required to achieve the same criterion for upstream or downstream routes.

5.5.3 Operational assessment – local air quality

The operational ambient air quality assessment was based upon the use of the GRAMM-GRAL model system. The model system consists of two main modules: a prognostic wind field model (Graz Mesoscale Model – GRAMM) and a dispersion model (GRAL). This section summarises the main elements of the approach; the rationale for the selection of the model, and full details of the methodology, are presented in **section 8**.

Definition of modelling domains

Separate domains were required for the meteorological modelling and dispersion modelling, and these domains are shown relative to the project in **Figure 5-1**.

The GRAMM domain (also referred to as the ‘study area’ in places) for the modelling of meteorology is shown by the red boundary in **Figure 5-1**. The domain covered a substantial part of Sydney, extending 23 kilometres in the east–west (x) direction and 23 kilometres in the north–south (y) direction.

The M4-M5 Link GRAL domain for dispersion modelling is shown by the black boundary in **Figure 5-1**. Every dispersion model run was undertaken for this domain, which extended 12 kilometres in the x direction and 15 kilometres in the (y) direction. The domain extended well beyond the project itself to allow for the traffic interactions between the M4-M5 Link, other WestConnex projects (M4 East and New M5) and other proposed future projects (Western Harbour Tunnel and Beaches Link, Sydney Gateway and F6 Extension). 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.

Modelling scenarios

Two types of scenario were considered for ambient air quality:

- Expected traffic scenarios
- Regulatory worst case scenarios.

These scenarios are described below.

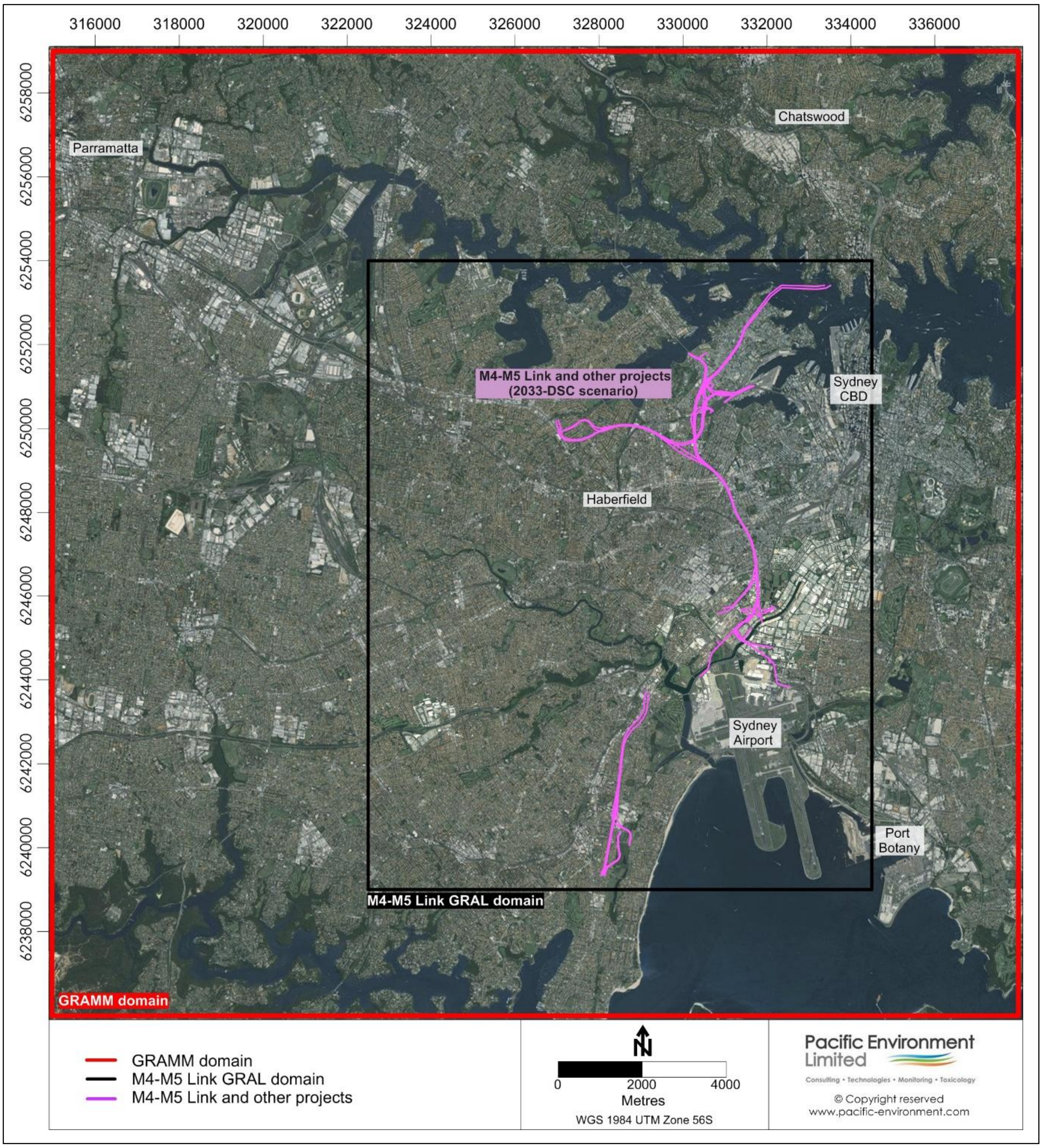

Figure 5-1 Modelling domains for GRAMM and GRAL (grid system MGA94)

Expected traffic scenarios

The seven expected traffic scenarios included in the operational air quality assessment are summarised in **Table 5-1**. The scenarios took into account future changes over time in the composition and performance of the vehicle fleet, as well as predicted traffic volumes and the distribution of traffic on the network and speed, as represented in the WestConnex Road Traffic Model (WRTM). The NorthConnex project was assumed to be operational in all of the future year scenarios. The objective of these scenarios was to demonstrate that the expected operation of the project would result in acceptable ambient air quality, and they are the main focus of this air quality assessment. The results from the modelling of these scenarios were also used in the health risk assessment for the project.

Table 5-1 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)]	WHT[(c)]	Beaches Link	F6 Extension	Sydney Gateway
2015-BY	2015 – Base Year (existing conditions)	ü	-	-	-	-	-	-	-	-	-
2023-DM	2023 – Do Minimum (no M4-M5 Link)	ü	ü	ü	ü	-	ü	-	-	-	-
2023-DS	2023 – Do Something (with M4-M5 Link)	ü	ü	ü	ü	ü	ü	-	-	-	-
2023-DSC	2023 – Do Something Cumulative (with M4-M5 Link and some other projects)	ü	ü	ü	ü	ü	ü	ü	-	-	ü
2033-DM	2033 – Do Minimum (no M4-M5 Link)	ü	ü	ü	ü	-	ü	-	-	-	-
2033-DS	2033 – Do Something (with M4-M5 Link)	ü	ü	ü	ü	ü	ü	-	-	-	-
2033-DSC	2033 – Do Something Cumulative (with M4-M5 Link and all other projects)	ü	ü	ü	ü	ü	ü	ü	ü	ü	ü

(a) Includes Iron Cove Link
(b) KGRIU = King Georges Road Interchange Upgrade
(c) Western Harbour Tunnel

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 primary year, and was considered to allow for the full ramp-up of traffic demand as travellers respond to the provision of the fully completed WestConnex and the associated tolls, as well as changes in the emission behaviour of the fleet with time.

The main scenarios are expanded upon below:

- 2015 Base Year. This represented the current road network with no new projects or upgrades (including WestConnex projects), 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. In this scenario it is assumed that the following projects would be open:
  - M4 Widening
  - M4 East
  - New M5
  - King Georges Road Interchange Upgrade.

  The M4-M5 Link and other projects (Western Harbour Tunnel (WHT), Beaches Link (BL), Sydney Gateway and F6 Extension) are not built. It is called 'do minimum' rather than 'do nothing' as it assumes that on-going 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. As for 2023 Do Minimum, but with the M4-M5 Link also completed
- 2023 Do Something Cumulative. As for 2023 Do Minimum, but with the M4-M5 Link and some other projects (Sydney Gateway and WHT) also completed
- 2033 Do Minimum. As for 2023 Do Minimum, but for 10 years after project opening
- 2033 Do Something. As for 2033 Do Minimum, including the M4-M5 Link completed, but for 10 years after project opening
- 2033 Do Something Cumulative. As for 2033 Do Minimum, with the M4-M5 Link, Sydney Gateway, WHT, BL and F6 Extension also completed.

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. This represented the theoretical maximum changes in air quality for all potential traffic operations in the tunnel, including unconstrained and worst case traffic conditions from an emissions perspective, as well as vehicle breakdown situations. Assuming that concentration limits are applied to the ventilation outlets, the results of the analysis would demonstrate the air quality performance of the project if it operates continuously at the limits. In reality, ventilation outlet concentrations would vary over a daily cycle due to changing traffic volumes and tunnel fan operation.

The RWC scenarios included in the assessment varied by pollutant, as shown in **Table 5-2**. The RWC scenarios were analogous to the 'with-project' scenarios in the expected traffic case. Tests showed that for annual mean $PM_{2.5}$ the RWC-2033-DSC scenario resulted in the highest predicted concentrations at receptors, and therefore only this scenario was used for the 'inert' pollutants (i.e. CO, PM_{10}, $PM_{2.5}$ and THC). For NO_2 the influence of atmospheric chemistry, and hence total NO_X from all sources, had to be considered. This meant that all four RWC had to be examined for NO_2, as the background and road traffic contributions to NO_X were also required.

The assumptions underpinning the regulatory worst case scenarios were very conservative, and resulted in contributions from project ventilation outlets that were much higher than those that could occur under any foreseeable operational conditions in the tunnel.

Table 5-2 Regulatory worst case scenarios

Scenario	Pollutant				
	CO	NO_2	PM_{10}	$PM_{2.5}$	THC
RWC-2023-DS	-	ü	-	-	-
RWC-2023-DSC	-	ü	-	-	-
RWC-2033-DS	-	ü	-	-	-
RWC-2033-DSC	ü	ü	ü	ü	ü

Ambient air quality criteria used in the assessment

Air quality in the M4-M5 Link domain was assessed in relation to the most relevant pollutants, and the criteria from the NSW Approved Methods and AAQ NEPM. The pollutants and criteria are summarised in **Table 5-3**. The long-term goals for $PM_{2.5}$ in the AAQ NEPM were considered but not formally used in the assessment of impacts, and these are shown in italics in the Table.

Table 5-3 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)
NO_2	246 mg/m^3	1 hour	NSW EPA (2016)
	62 mg/m^3	1 year	NSW EPA (2016)
PM_{10}	50 µg/m^3	24 hours	NSW EPA (2016)
	25 µg/m^3	1 year	NSW EPA (2016)
$PM_{2.5}$	25 µg/m^3	24 hours	NSW EPA (2016)
	20 µg/m^3 (goal by 2025)	*24 hours*	NEPC (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)	0.0004 mg/m^3	1 hour	NSW EPA (2016)
Formaldehyde	0.02 mg/m^3	1 hour	NSW EPA (2016)

Pollutant/metric	Concentration	Averaging period	Source
1,3-butadiene	0.04 mg/m^3	1 hour	NSW EPA (2016)

The application of the assessment criteria is described in the NSW Approved Methods, but the wording is not especially well suited to the assessment of road projects, especially in urban areas where there is an existing and complex spatial distribution of air pollutants.

For criteria pollutants the following steps must be applied:

- The predicted concentrations should be compared with the standards for the nearest existing or likely future 'off-site' sensitive receptor. In this assessment, this concept has been extended to include all potentially affected receptor locations outside the project footprint
- The incremental impact (predicted impacts due to the pollutant source alone) for each pollutant must be reported in units and averaging periods that are consistent with the air quality standards
- Background concentrations must be included using the procedures specified in Section 5 of the NSW Approved Methods
- The total impact (incremental impact plus background) must be reported as the 100th percentile in concentration units that are consistent with the standards, and compared with the relevant standards.

For air toxics, the steps mostly correspond to those above, with some slight differences. For example, the criteria for individual pollutants must be applied 'at and beyond the boundary of the facility', and incremental impacts must be reported for an averaging period of one hour and as the 100th percentile of model predictions for screening assessments or the 99.9th percentile of model predictions for more detailed assessments.

Change in annual mean $PM_{2.5}$

Appendix K (Human health risk assessment) of the EIS has adopted a risk level in excess of 10^{-4} (one chance in 10,000) as a point where risk is considered to be unacceptable. Although the Human Health Assessment considers a comprehensive range of health endpoints, the key metric that emerged during the assessment of the NorthConnex, M4 East and New M5 projects was the increase of risk in all-cause mortality for ages 30 and over. An increase in risk of all-cause mortality is related to the <u>change</u> in the annual mean $PM_{2.5}$ concentration ($\Delta PM_{2.5}$) (Boulter et al., 2015; Manansala et al., 2015). A risk of one in 10,000 equates to a value for $\Delta PM_{2.5}$ that varies depending on the baseline mortality, and is calculated as follows:

$$R = \beta \times \Delta PM_{2.5} \times B$$

Where, for the M4-M5 Link study area:

R	=	additional risk
β	=	slope coefficient for the % change in response to a 1 µg/m^3 change in exposure (β =0.0058 for $PM_{2.5}$ all-cause mortality ≥ 30 years) (Krewski et al., 2009)
$\Delta PM_{2.5}$	=	change in concentration in µg/m^3 at the point of exposure
B	=	baseline incidence of a given health effect per person (eg annual mortality rate) (976.6 per 100,000 for mortality all causes ≥ 30 years) (Golder Associates, 2013)

This equation can be rewritten as:

$$\Delta PM_{2.5} = R / (\beta \times B)$$

For the M4-M5 Link project, the value of $\Delta PM_{2.5}$ for a risk of one in 10,000 is:

$$\Delta PM_{2.5} = \frac{0.0001}{0.0058 \times 0.00976} = 1.8\ \mu g/m^3$$

Pollutants and metrics excluded from the assessment

The following pollutants/metrics were not considered to be relevant to the local air quality assessment of the project (and to road transport projects in general):

- Sulfur dioxide (SO_2). SO_2 is emitted from road vehicles, and results from the oxidation of the sulfur present in fuels during combustion. However, SO_2 emissions are directly proportional to the sulfur content of the fuel, and emissions have decreased considerably as a result of controls on fuel quality. For example, in 1999 the average sulfur content of diesel was 1,300 ppm. In December 2002, a new standard was introduced, reducing the maximum sulfur content of diesel to 500 ppm. Currently, the sulfur level in premium unleaded petrol is 50 ppm, and in diesel it is 10 ppm[16]. The emissions of SO_2 from road vehicles are therefore now very low, and SO_2 is no longer a major concern in terms of transport-related air quality
- Lead (Pb). In cities, motor vehicles operating on leaded petrol used to be the main source of lead in the atmosphere. However, as a result of the introduction of unleaded petrol in 1985, the progressive reduction of the lead content of leaded petrol, and reductions in emissions of lead from industry, there has been a significant fall in annual average concentrations of lead in ambient air throughout NSW (often to below the minimum detection limit) (DECCW, 2010). Since 2002 the lead content of petrol has been limited to 0.005 grams per litre. As a result, lead is no longer considered to be an air quality and health concern away from specific industrial activities (such as smelting)
- TSP. TSP is rather an old metric that is no longer the focus of health studies. For example, the USEPA replaced its TSP standard with a PM_{10} standard in 1987. For exhaust emissions from road transport, it can be assumed that TSP is equivalent to PM_{10} (and also $PM_{2.5}$). Although it is possible that a fraction of non-exhaust particles is greater than 10 µm in diameter, this is not well quantified
- Ozone (O_3). Because of its secondary and regional nature, ozone cannot practicably be considered in a local air quality assessment. Emissions of ozone precursors (NO_X and VOCs) are distributed unevenly in urban areas, and concentrations vary during the day. Complicating this further are the temporal and spatial variations in meteorological processes. Ozone formation is non-linear, so reducing or increasing NO_X or VOC emissions does not necessarily result in an equivalent decrease or increase in the ozone concentration. This non-linearity makes it difficult to develop management scenarios for ozone control (DECCW, 2010). Ozone was, however, considered in the regional air quality assessment (refer to **section 5.5.4**)
- 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.

The investigation levels in the Air Toxics NEPM were not included as they are not designed as impact assessment criteria.

It is also worth noting that in recent years a considerable amount of attention has focussed on ‘ultrafine’ particles (UFPs). These are particles with a diameter of less than 0.1 µm. Although there is some evidence particles in this size range are associated with adverse health effects, 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

[16] http://www.environment.gov.au/protection/publications/factsheet-sulfur-dioxide-so2

- 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
- The absence of air quality standards.

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'.

For the purpose of the project assessment, it has therefore been assumed that the effects of UFPs on health are adequately represented by those of $PM_{2.5}$.

Terminology

The concentration of a given pollutant at a given location/receptor has contributions from various different sources.

The following terms have been used in this assessment to describe the pollutant concentration at a given location and for a given averaging period:

- Background concentration. This is the contribution to the concentration of a pollutant from all sources other than the modelled surface road traffic (major roads only). It includes, for example, contributions from natural sources, industry and domestic activity, as well as minor roads
- Surface road concentration. This is the contribution from the main surface road network. It includes not only the contribution of the nearest road at the receptor, but the net contribution of the modelled road network at the receptor (excluding minor roads)
- Ventilation outlet concentration. This is the contribution from tunnel ventilation outlets
- Total concentration. This is the combination of the background, surface road, and ventilation outlet concentrations
- Change in concentration due to the project. This 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, amongst other things, how traffic is redistributed on the network as a result of the project.

These terms are relevant to both annual mean and short-term (eg one hour mean or 24 hour mean) ambient air quality criteria.

An example of the different contributions at a receptor for different scenarios is shown in **Figure 5-2**. The surface road and ventilation outlet concentrations would typically decrease between the base year and the future years as a result of improved emission controls. However, there is the potential for such reductions to be offset by traffic growth. In the example shown, the project has the effect of decreasing total traffic (surface road and ventilation outlet) emissions in the vicinity of the receptor. As the background is assumed to be constant with time (see below), the total concentration with the project in 2023 and 2033 is smaller than the total concentration without the project.

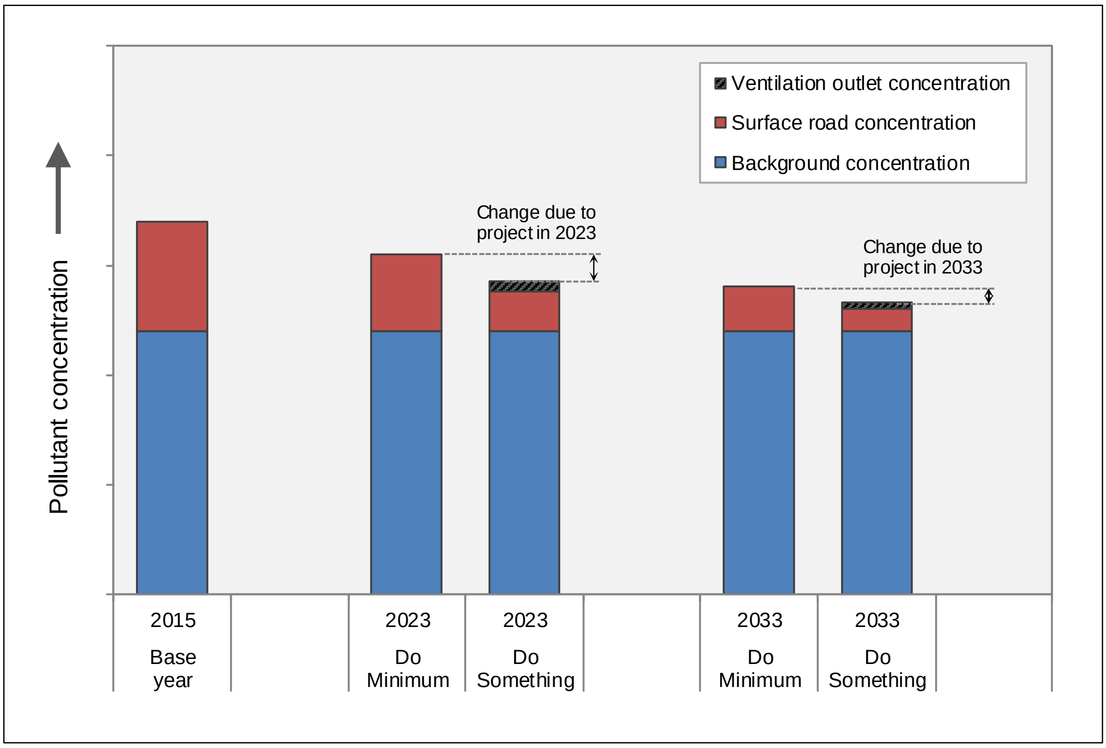

Figure 5-2 Contributions to total pollutant concentrations (example)

Determination of components in M4-M5 Link assessment

The different components in **Figure 5-2** 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). The approaches used to determine long-term and short-term background concentrations are explained in **Annexure F**. Background concentrations were assumed to remain unchanged in future years, given that trends over the last decade have generally shown them to be quite stable (or slightly decreasing)
- Surface road concentrations and ventilation outlet concentrations were estimated (separately) using a dispersion model (GRAL). The modelling of the road network gave non-zero concentrations at the locations of air quality monitoring stations, which introduced a small element of conservatism into the approach
- For all pollutants except NO_2, as the background concentration was the same with and without the project, 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 atmospheric chemistry in the roadside environment (see **Annexure G**).

Analysis and presentation of results

The following have been determined:

- The total pollutant concentration from all contributions (background, surface roads and ventilation outlets)
- The change in the total pollutant concentration with the project. Given the non-threshold nature of some air pollutants (notably PM), it was considered important to assess not only the total concentrations relative to the criteria, but also the incremental changes in concentration associated with the project

- The pollutant contribution from ventilation outlets alone. Although this is a somewhat artificial construct, as emissions from ventilation outlets do not occur without changes in emissions from the surface road network, it is often the focus of community interest.

The results have been presented as:

- Pollutant concentrations (and changes) at discrete receptors (in charts and tables) at receptor locations along the project corridor where people are likely to be present for some period of the day. The actual receptors included in the assessment are described in **section 8.4.6**
- Pollutant concentrations (and changes in concentration) across the entire GRAL modelling domain as contour plots. The concentrations were based on a Cartesian grid of points with an equal spacing of 10 metres in the x and y directions. This resulted in 1.8 million grid locations across the GRAL domain
- Pollutant concentrations (and changes) in the vicinity of the project tunnel ventilation outlets (as contour plots).

5.5.4 Operational assessment – regional air quality

The potential impacts of the project on air quality more widely across the across the Sydney region were assessed through consideration of the changes in emissions across the road network (as a proxy). The regional air quality impacts of a project can also be framed in terms of its capacity to influence ozone production. NSW EPA has recently developed a Tiered Procedure for Estimating Ground Level Ozone Impacts from Stationary Sources (ENVIRON, 2011). Although this procedure does not relate specifically to road projects, it was applied here to give an indication of the likely significance of the project’s effect on ozone concentrations in the broader Sydney region.

5.5.5 Operational assessment – odour

The project SEARs require the consideration of potential odour. Odours associated with motor vehicle emissions tend to be very localised and short-lived, and there are not expected to be any significant, predictable or detectable changes in odour as a result of the project.

For each of the RWR receptors, the change in the maximum 1 hour THC concentration as a result of the project was calculated. The largest change in the maximum 1 hour THC concentration across all receptors was then determined, and this was converted into an equivalent change for three of the odorous pollutants identified in the Approved Methods (toluene, xylenes, and acetaldehyde). These pollutants were taken to be representative of other odorous pollutants from motor vehicles.

5.6 Treatment of uncertainty

5.6.1 Accuracy and conservatism

There is generally a desire for a small amount of conservatism in air quality assessments, and conservatism has been built into the studies conducted for many other major infrastructure and development proposals in NSW and elsewhere. This approach:

- Allows for uncertainty. An assessment on the scale undertaken for the project is a complex, multi-step process which involves various different assumptions, inputs, models, and post-processing procedures. There is an inherent uncertainty in each of the methods used to estimate traffic volume, emissions and concentrations, and there are clearly limits to predicting future impacts accurately. Conservatism is built into some aspects of predictions to ensure that a margin of safety is applied (ie to minimise the risk that any potential impacts are underestimated)
- Provides flexibility. It is undesirable for the potential environmental impacts of a project to be defined too narrowly at this stage in the development process. A conservative assessment approach provides flexibility for ongoing design refinements and project implementation within an approved environmental envelope (AECOM, 2014b).

Conversely, it is recognised that excessive conservatism in an assessment risks overstating potential air quality impacts and associated human health risks. This, in turn, may lead to some potentially undesirable outcomes that need to be mitigated and managed, such as the following:

- It may unduly amplify community and stakeholder concerns about the impacts of the project
- It may lead to additional, or more stringent, conditions of approval than necessary, including the mitigation, monitoring and management of air quality
- Overstatement of vehicle contributions to local air quality may similarly 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' or '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. An example of this is the estimation of the maximum one hour NO_2 concentration during a given year. Any method which provides a 'typical' or 'average' one hour NO_2 concentration would tend to result in an underestimate of the likely maximum concentration, and therefore a more conservative approach is required.

However, the scale of the conservatism can often be difficult to define, and this can sometimes result in some assumptions being overly conservative. Skill and experience is required to estimate impacts that err on the side of caution but are not unreasonably exaggerated or otherwise skewed. 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). Excessive conservatism in modelling can also lead to potential improvements in air quality being overestimated.

5.6.2 Key assumptions

The key assumptions underpinning the assessment of operational impacts have been summarised in **section 8**. The different elements of the modelling chain for operational impacts (eg traffic model outputs, emission model predictions, dispersion model predictions, background concentrations, conversion factors) were assessed in terms of whether they were likely to be broadly accurate or broadly conservative, with quantitative data where possible.

5.6.3 Sensitivity tests

In the EISs for the M4 East and New M5 projects, several sensitivity tests were conducted for various model inputs (Boulter et al., 2015; Manansala et al., 2015). These included:

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

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

As the 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.

6 Existing environment

6.1 Overview of section

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 **section 8**.

6.2 Terrain

Terrain data for Sydney were obtained from the Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) website. **Figure 6-1** shows the terrain immediately surrounding the WestConnex project, based on 30-metre resolution data.

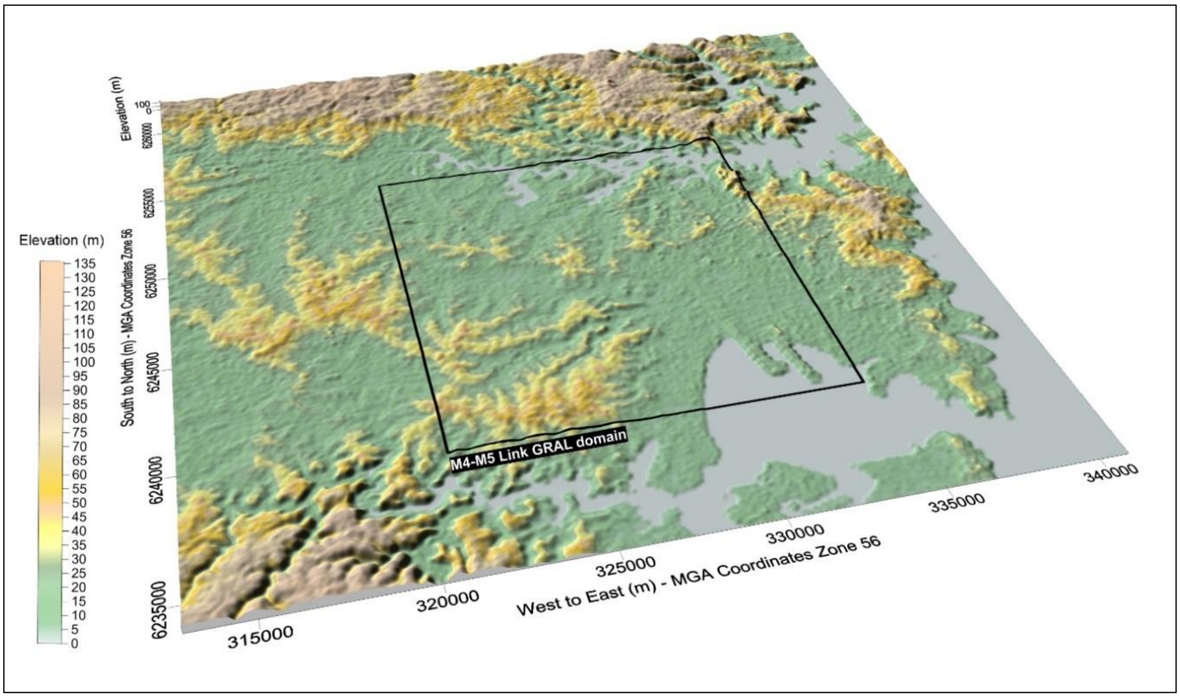

Figure 6-1 Terrain in the GRAMM domain (grid system MGA94)

The terrain within the GRAMM domain 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. 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 air flow throughout the GRAMM domain.

6.3 Land use

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.

6.4 Climate

Table 6-1 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 an 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 6-1 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

6.5 Meteorology

As noted in **Annexure B**, meteorology is an important factor affecting the dispersion of air pollution. Seven meteorological stations in the GRAMM domain were considered, and their locations are shown in **Figure 6-2**. Data relevant to the dispersion modelling such as wind speed, wind direction, temperature and cloud cover were obtained from these stations:

- OEH meteorological stations:
  - Chullora
  - Earlwood
  - Rozelle
- BoM meteorological stations:
  - Canterbury Racecourse
  - Fort Denison
  - Sydney Airport
  - Sydney Olympic Park AWS (Archery Centre).

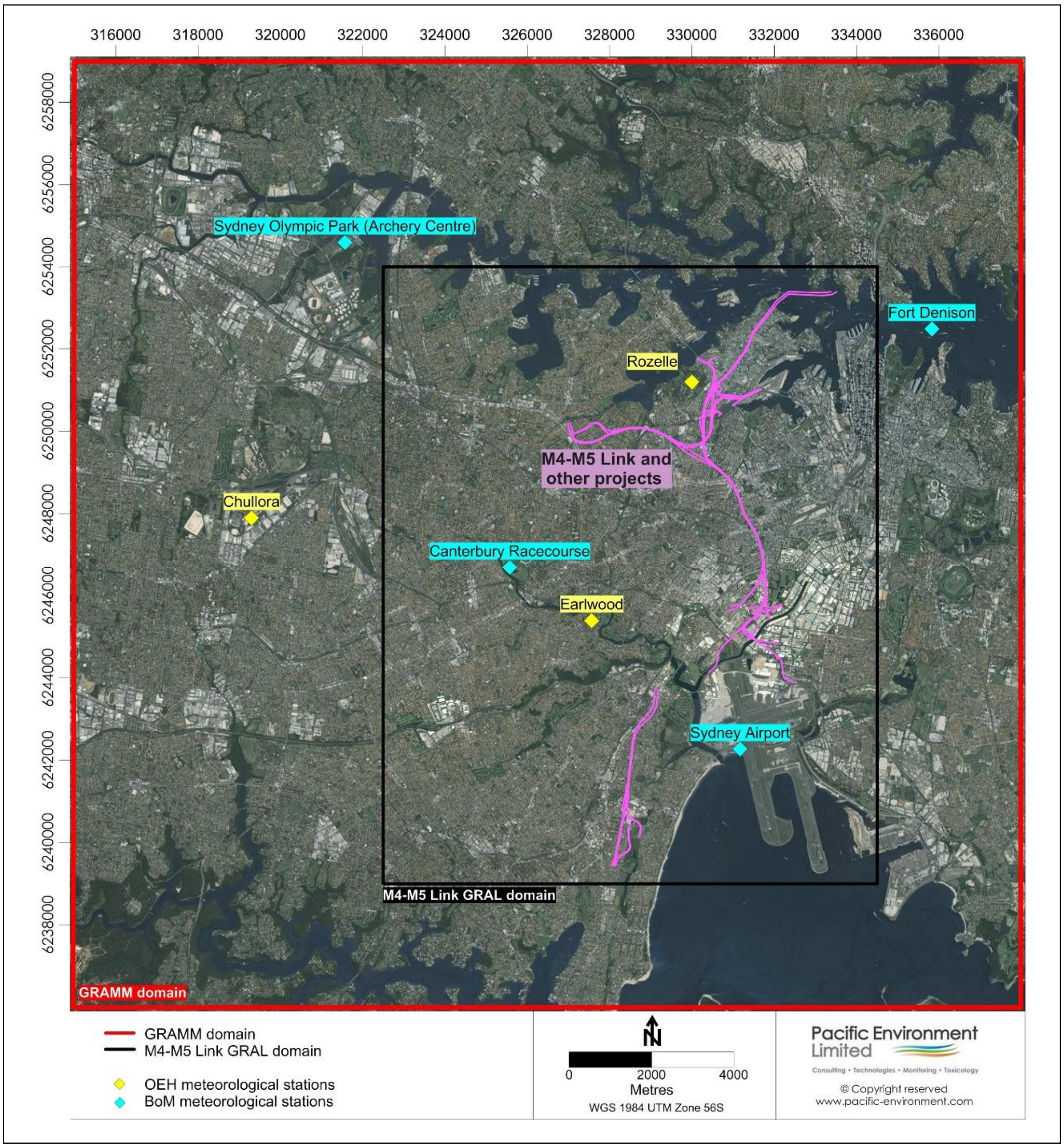

Figure 6-2 Meteorological stations in the model domains (grid system MGA94)

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 also summarised in **Annexure H**.

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). **Figure 6-3** shows annual and diurnal plots of wind speed and temperature from the Canterbury Racecourse site for 2015. The annual plots show a typical distribution of wind speed and temperature over the course of a year. The diurnal plots also show typical patterns, with higher wind speeds and temperatures during the day and lower wind speeds and temperatures at night and in the early morning.

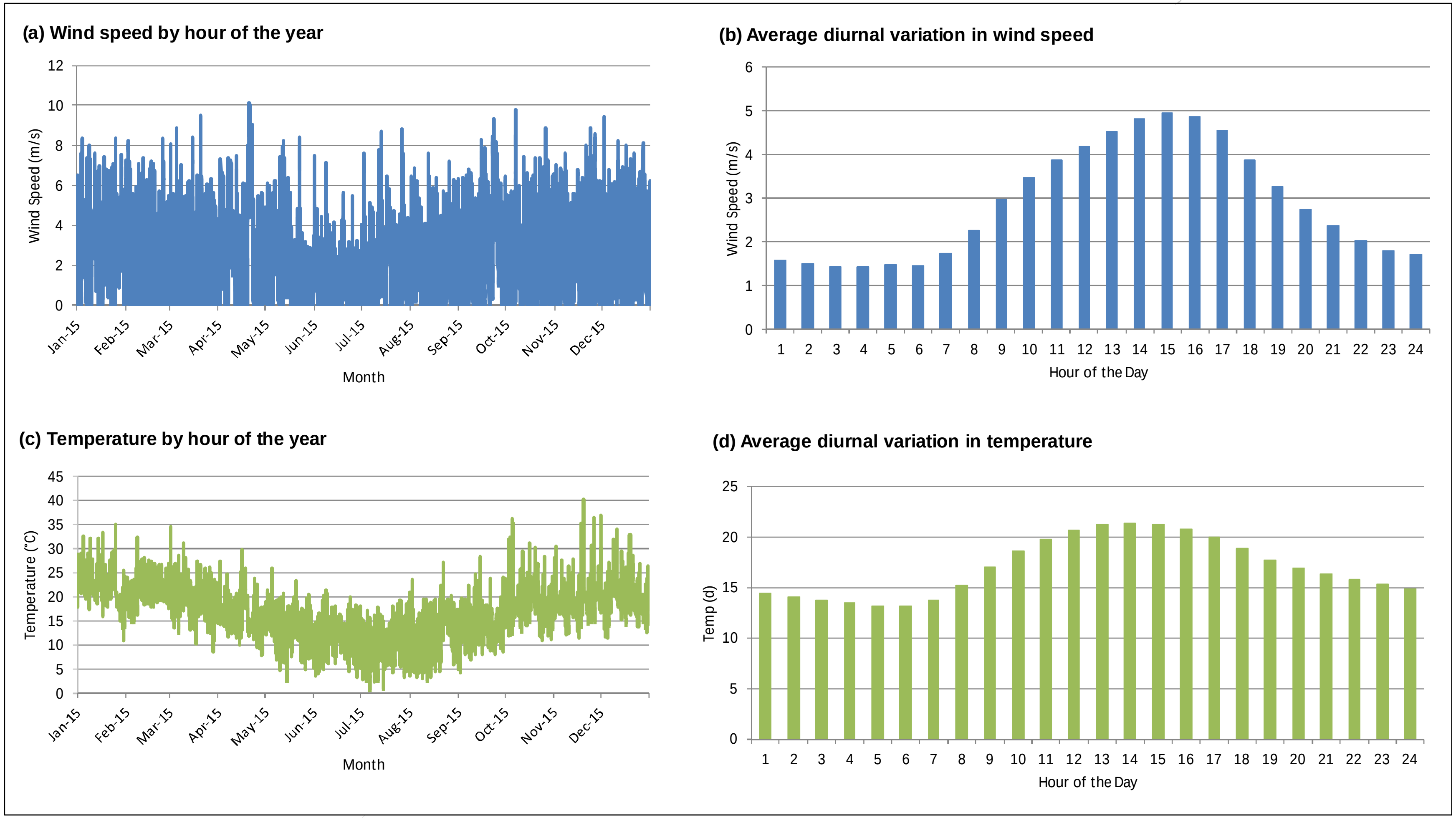

Figure 6-3 Annual and diurnal plots of wind speed and temperature for BoM Canterbury Racecourse (AWS 2015)

6.6 Air pollutant emissions

Calculations have established that 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 (BITRE, 2010). However, over the longer term, it is anticipated that emission levels would start to rise again, as increases in annual vehicle activity would start to offset the reductions achieved by the current emission standards and vehicle technologies (DIT, 2012).

The most detailed and comprehensive source of information on current and future emissions in the Sydney area is the emissions inventory[17] 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 2011, 2016, 2021, 2026, 2031 and 2036. The importance of road transport as a source of pollution in Sydney can be illustrated by reference to sectoral emissions. The data for anthropogenic and biogenic emissions in Sydney, as well as a detailed breakdown of emissions from road transport, were extracted from the inventory by NSW EPA[18] and are presented here. Emissions were considered for the most recent historical year (2011) and for the future years.

Figure 6-4 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 significant 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 important 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 marine aerosol, also contributed significantly to PM concentrations. Road transport contributed only two per cent of total SO_2 emissions in Sydney, reflecting the desulfurisation of 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 6-5** show that the road transport contribution to emissions CO, VOCs and NO_X is projected 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 6-6**. Petrol passenger vehicles (mainly cars) accounted for a large proportion of the vehicle kilometres travelled (VKT) in Sydney[19]. Exhaust emissions from these vehicles were responsible for 62 per cent of CO from road transport in Sydney in 2011, 45 per cent of NOx, and 76 per cent of SO_2. They were a minor source of PM_{10} (4 per cent) and $PM_{2.5}$ (9 per cent). Non-exhaust processes 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, say, most European countries, as there are relatively few diesel cars in Australia. It is also a cause for concern, as 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 to NOx 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 6-7**. 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. SO_2 emissions are proportional to fuel sulfur content, and this is assumed to remain constant in the inventory. The inventory also provides emissions of specific organic compounds, based on speciation profiles of petrol and diesel fuels.

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

[18] 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.

[19] 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).

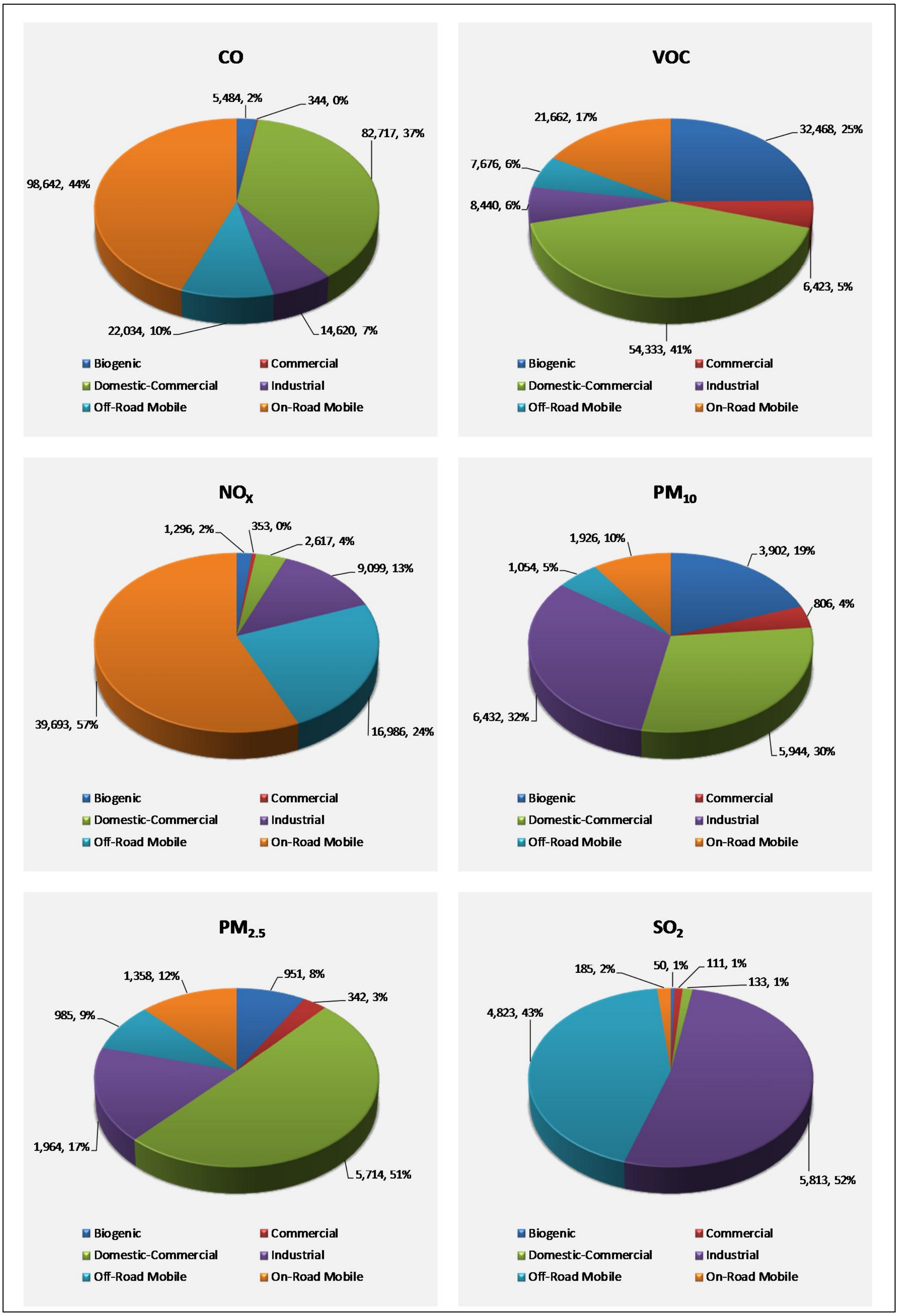

Figure 6-4 Sectoral emissions in Sydney, 2011 (tonnes per year and percentage of total)

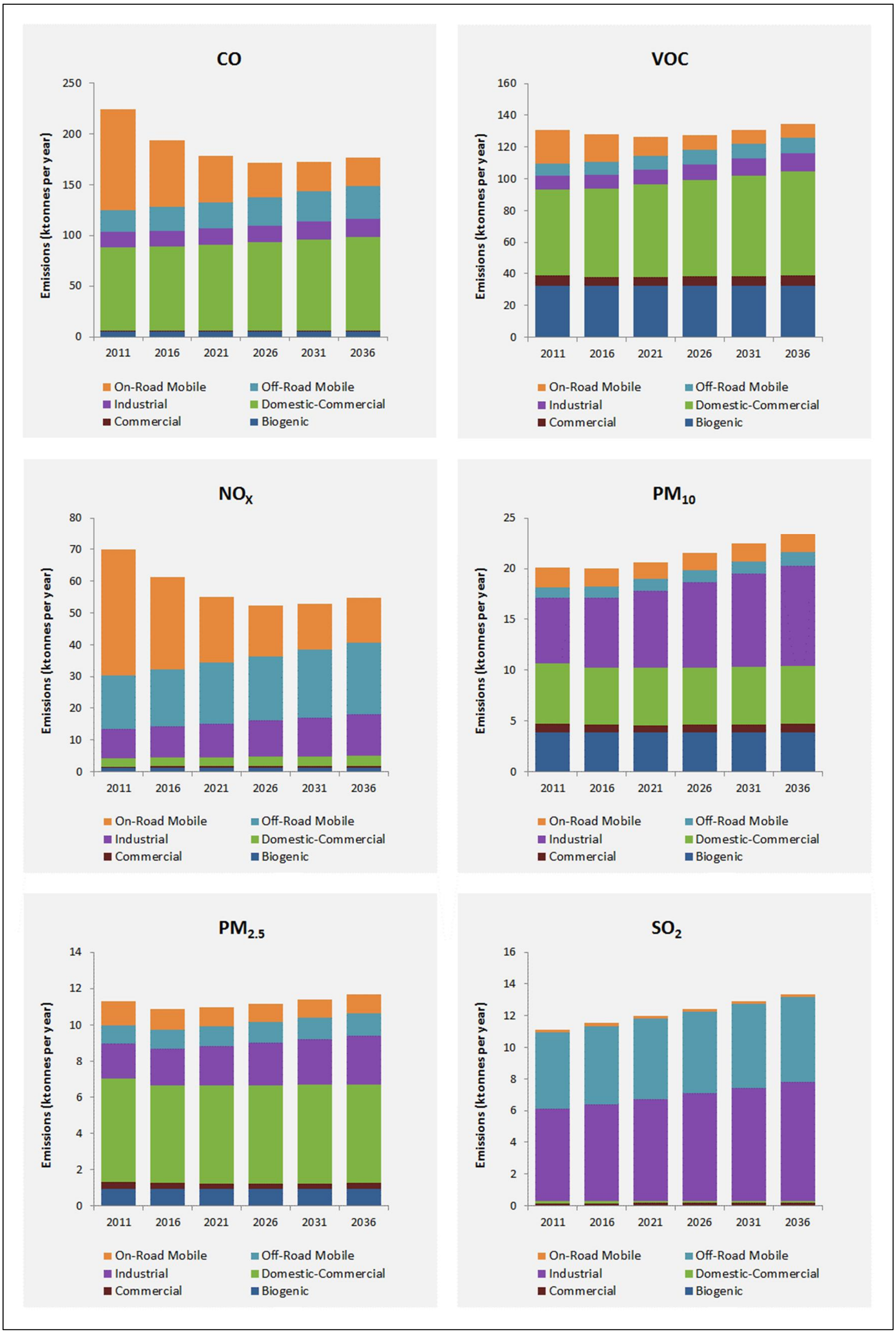

Figure 6-5 Projections of sectoral emissions – Sydney, 2011-2036

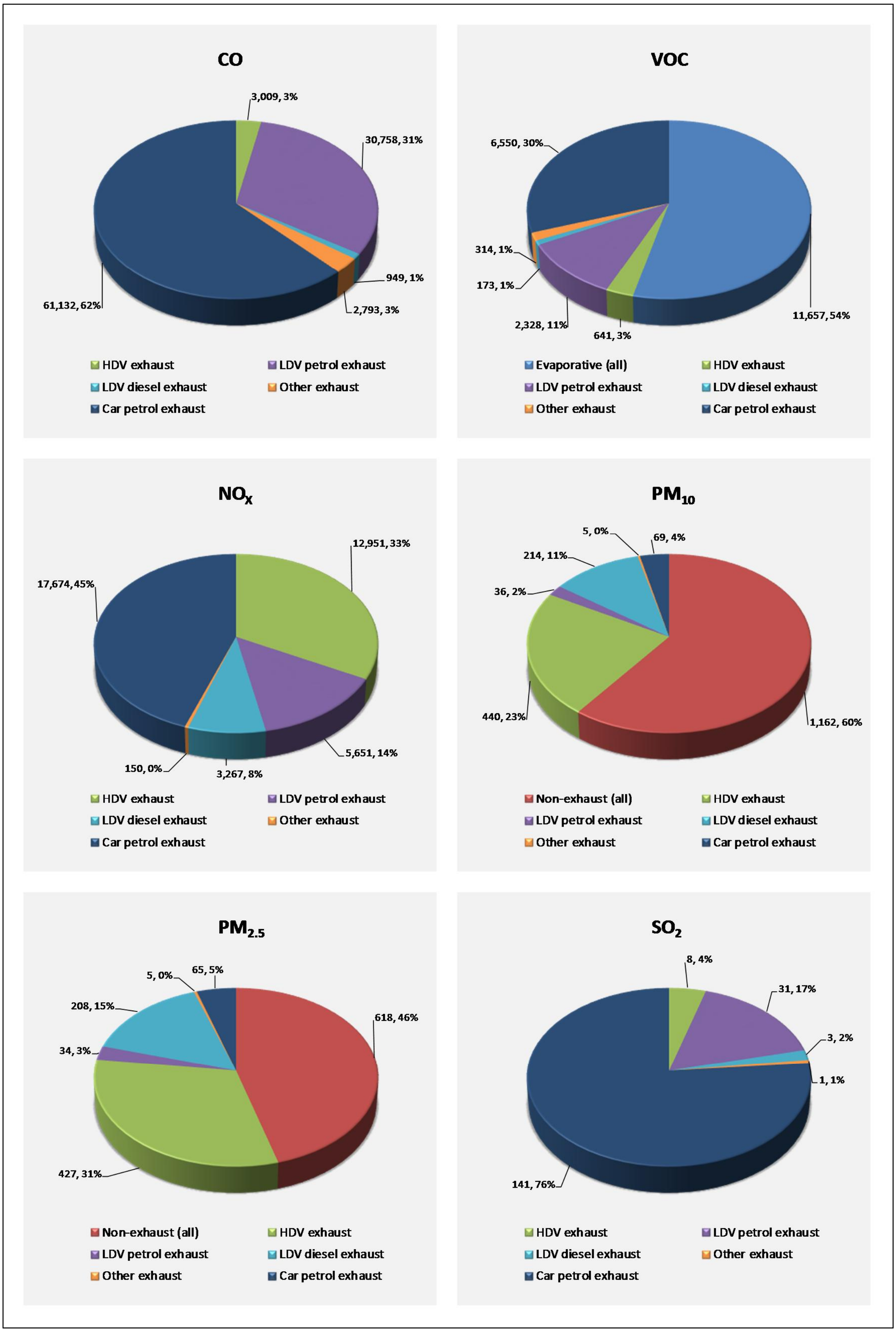

Figure 6-6 Breakdown of road transport emissions – Sydney, 2011 (tonnes per year and percentage of total)

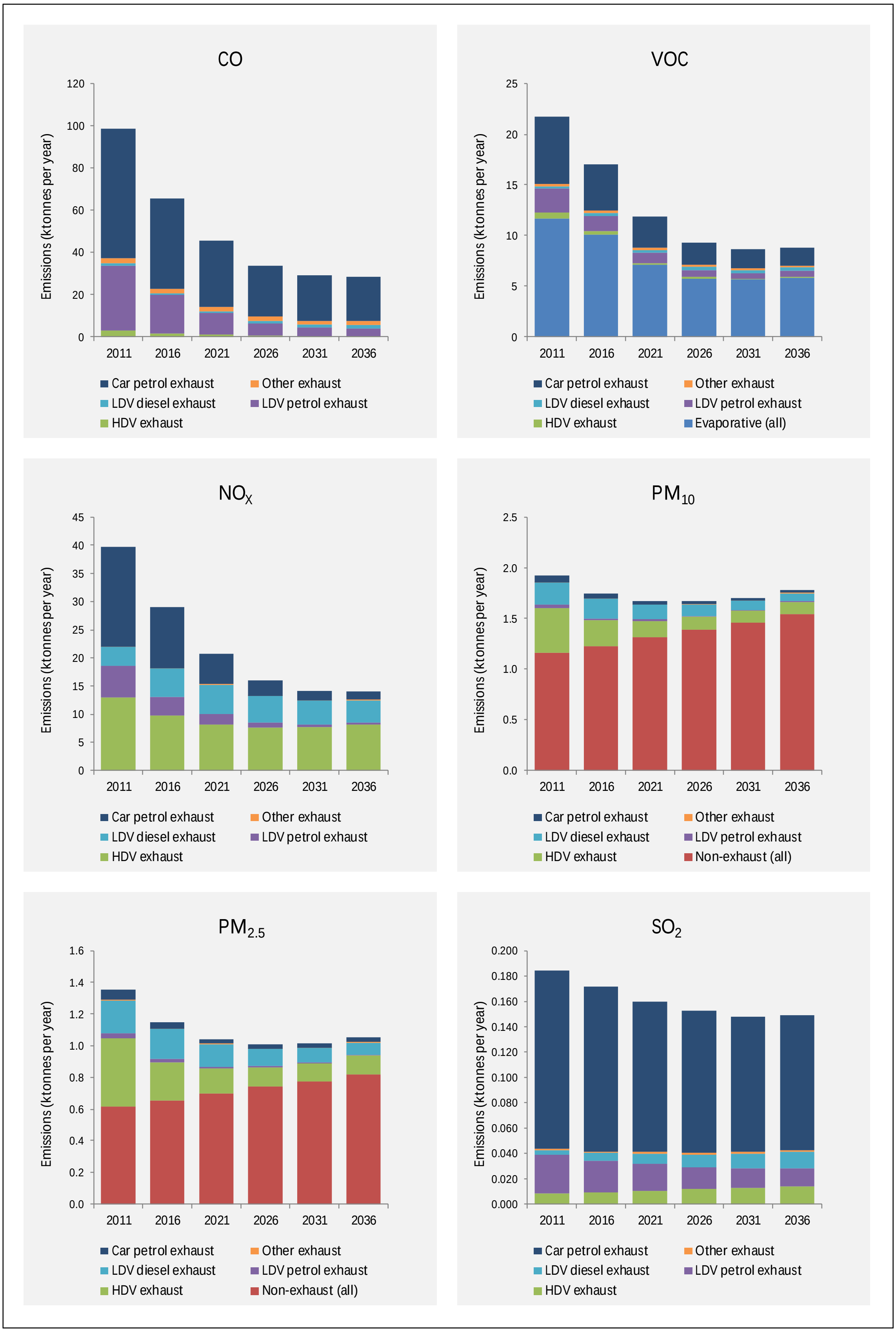

Figure 6-7 Projections of road transport emissions – Sydney, 2011-2036

6.7 In-tunnel air quality

Air quality is monitored continuously in all of 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. Some of the data are available on the websites of the tunnel operators[20,21], but the instruments typically only have a coarse resolution which is adequate for ventilation control but not for detailed scientific assessment. 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 these measurements have been used to support the ambient air quality assessment.

6.8 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 was essential. The following sections provide a brief overview of air quality in Sydney, and a summary of an extensive analysis of the data from the monitoring stations in the study area.

6.8.1 General characteristics of air quality on 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 (DECCW, 2009; 2010).

While levels of NO_2, SO_2 and CO continue to be below national standards, levels of ozone and particles (PM_{10} and $PM_{2.5}$) 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).

6.8.2 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**. The analysis was based on 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 (M5 East urban background)
  - CBMS, T1, U1, X1
- Roads and Maritime (M5 East roadside)
  - F1, M1.

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[20] http://www.lanecovemotorways.com.au/downloads.htm.

[21] http://www.crosscity.com.au/AirQuality.htm.

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 (8 hour), and quite stable at all sites between 2004 and 2015. In 2015 the maximum one hour concentrations were typically between around 2 and 3 mg/m^3, and the maximum eight hour concentrations were around 2 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, and hence around 10–20 µg/m^3 higher than those at the background sites. Even so, the concentrations at the roadside sites 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 varied NEPM
- 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 main reason for the increase was a change in the measurement method. 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 AAQ NEPM of 8 µg/m^3, and above the long-term goal of 7 µg/m^3
- Maximum 24 hour $PM_{2.5}$
  - There has been no systematic trend in the maximum 24 hour $PM_{2.5}$ concentration. As with the

annual mean $PM_{2.5}$ concentration, the maximum one hour concentrations were very close to or above the standard in the AAQ NEPM of 25 µg/m^3, and were generally above the long-term goal of 20 µg/m^3.

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

6.8.3 Project-specific air quality monitoring

A network of air quality monitoring stations has been established to support the 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. Pacific Environment operates and maintains the monitoring network.

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 presented in **Annexure F**. 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. The results are summarised below by pollutant.

- Carbon monoxide
  - Background sites

    The mean weekly concentrations at the OEH/Roads and Maritime sites were broadly comparable to those at the WestConnex sites. The 98th percentile and maximum concentrations were very close to those at the WestConnex sites. All the measured one hour CO concentrations were well below the criterion of 30 mg/m^3, and any differences between sites would not have had a material impact on the outcomes of the assessment for this pollutant
  - Roadside sites

    The data from the two Roads and Maritime roadside sites followed the general patterns in the WestConnex roadside data, in spite of the range of locations included. High wintertime concentrations and low summertime concentrations were well represented. Again, all the measured concentrations were well below the criterion of 30 mg/m^3
- Nitrogen oxides, nitrogen dioxide and ozone
  - Background sites

    NO_X concentrations at the WestConnex sites – and in particular the upper envelope of concentrations – were generally well represented by the OEH/Roads and Maritime data. The highest maximum and 98th percentile one hour NOx concentrations at the OEH/Roads and Maritime sites during the whole monitoring period were higher than the highest values at any of the WestConnex sites. NO_2 concentrations at the OEH/Roads and Maritime sites also generally covered the range of values at the WestConnex sites. In general, the results for ozone agreed well with those from the WestConnex sites
  - Roadside sites

    For NO_X and NO_2 there were some differences between the values at the Roads and Maritime sites and those at the WestConnex sites. These results would be influenced by site type and location, and the characteristics of the WestConnex sites are more varied than those of the Roads and Maritime sites. The highest mean concentrations were often measured at the WestConnex Concord Oval site (near Parramatta Road), whereas some of the other WestConnex sites are rather too far away from roads to be properly classified as 'roadside' and therefore the concentrations were considerably lower.

Prior to around the start of 2016 there were some marked differences between the mean NO_2 concentrations recorded at the different M4 East sites. Following the decommissioning of some of the M4 East sites in 2016 there was a slightly better general agreement between the Roads and Maritime and WestConnex data.

Ozone is not measured at any of the Roads and Maritime M5 East sites. Similar patterns in ozone concentration were recorded at the various WestConnex sites

- PM_{10} and $PM_{2.5}$

  - Background sites

    For PM_{10} and $PM_{2.5}$ the variation in the results from different sites would be influenced to some extent by the differences in measurement technique.

    The PM_{10} data from the OEH/Roads and Maritime background monitoring sites were broadly representative of the M4 East background site. However, prior to 2016 (during the winter of 2015), the concentrations at the New M5 sites were well above the upper envelope of the values from the OEH/Roads and Maritime sites. During 2016 the concentrations at all WestConnex sites had a better level of agreement, and were near the upper limit of the range of values at the OEH/Roads and Maritime sites. In the absence of a longer-term data set it is unclear whether the high values during 2015 at the New M5 sites was a specific winter-time phenomenon in the area.

    A similar pattern was evident in the $PM_{2.5}$ data; that is, high values at the New M5 sites during 2015, and a general convergence of concentrations across all sites during 2016

  - Roadside sites

    The PM_{10} concentrations at the WestConnex sites covered a wider range of values than those at the Roads and Maritime sites. Again, concentrations were markedly higher at some of the New M5 than at the other sites.

    $PM_{2.5}$ is not measured at any of the Roads and Maritime M5 East sites. Concentrations varied across the WestConnex sites, and were again distinctly higher at some of the New M5 sites.

7 Assessment of construction impacts

7.1 Overview of section

This section deals with the potential impacts of the construction phase of the project. The construction activities for the project were described in **section 2.3**.

The section:

- Identifies the project footprint and scenarios
- Describes the assessment procedure, which was based upon the guidance published by the UK Institute of Air Quality Management (IAQM, 2014). The IAQM guidance is designed primarily for use in the UK, although it may be applied elsewhere. Here, the guidance has been adapted for use in Sydney, taking into account factors such as the assessment criteria for ambient PM_{10} concentrations
- Identifies the measures that are recommended to manage any potential impacts of construction (these are listed in **section 9**)
- Discusses the significance of the identified risks.

7.2 Project footprint and scenarios

The project footprint comprises land required to construct and operate the project. This includes permanent operational infrastructure (including the tunnels), and land required temporarily for construction. An overview of the project footprint was provided in **Figure 2-2**. The above-ground construction activities would take place at a number of separate locations (with the work staggered in time), and these have been grouped into 12 distinct compounds (**Table 7-1**). However, two possible combinations of construction ancillary facilities at Haberfield and Ashfield have been assessed in this EIS, including compounds C1a/C2a/C3a (Option A) and C1b/C2b/C3b (Option B). Both have been assessed individually for this assessment. The number, location and layout of construction ancillary facilities would be finalised as part of detailed construction planning during detailed design.

Table 7-1 M4-M5 Link construction compounds

Compound	Description	Indicative construction period[(a)]
C1a	Wattle Street civil and tunnel site	Q3 2019 – Q4 2022
C2a/b	Haberfield civil and tunnel site / Haberfield civil 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
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
C8	Iron Cove Link civil site	Q4 2018 – Q3 2022
C9	Pyrmont Bridge Road tunnel site	Q3 2018 – Q4 2022
C10	Campbell Road civil and tunnel site	Q4 2018 – Q4 2022

(a) Quarters refer to the calendar year

Given that the construction activities in several of the compounds are expected to take place concurrently and in close proximity to one another, the assessment of each compound in isolation could have led to an underestimation of risk. For the assessment, the compounds were combined according to the six 'worst case' scenarios listed in **Table 7-2**.

Table 7-2 M4-M5 Link construction scenarios

Scenario	Compound(s) included
S1	C1a to C3a
S2	C1b to C3b
S3	C4
S4	C5, C6 and C7
S5	C8
S6	C9
S7	C10

7.3 Assessment procedure

The IAQM procedure for assessing risk from construction dust[22] is summarised in **Figure 7-1**.

If an initial screening step shows that an assessment is required, construction activities are divided into four types to reflect their different potential impacts, and the potential for dust emissions is assessed for each activity that is likely to take place. These activities are:

- Demolition. This is any activity that involves the removal of existing structures. This may also be referred to as de-construction, specifically when a building is to be removed a small part at a time
- Earthworks. This covers the processes of soil stripping, ground levelling, excavation and landscaping. Earthworks would primarily involve excavating material, haulage, tipping and stockpiling
- Construction. This is any activity that involves the provision of new structures, modification or refurbishment. A structure would include a residential dwelling, office building, retail outlet and road
- Track-out. This involves the transport of dust and dirt by heavy-duty vehicles (HDVs) from the work sites onto the public road network, where it may be deposited and then re-suspended by other vehicles.

The assessment methodology considers three separate dust impacts:

- Annoyance due to dust soiling
- The risk of health effects due to an increase in exposure to PM_{10}
- Harm to ecological receptors.

The assessment is used to define appropriate mitigation measures to ensure that there would be no significant effect.

The assessment steps, as they were applied to the M4-M5 Link project, are summarised in the following sections. Professional judgement was required at some stages, and where the justification for assumptions could not be fully informed by data a precautionary approach was adopted.

[22] It was assumed that exhaust emissions from on-site plant and site traffic would be unlikely to have a significant impact on local air quality.

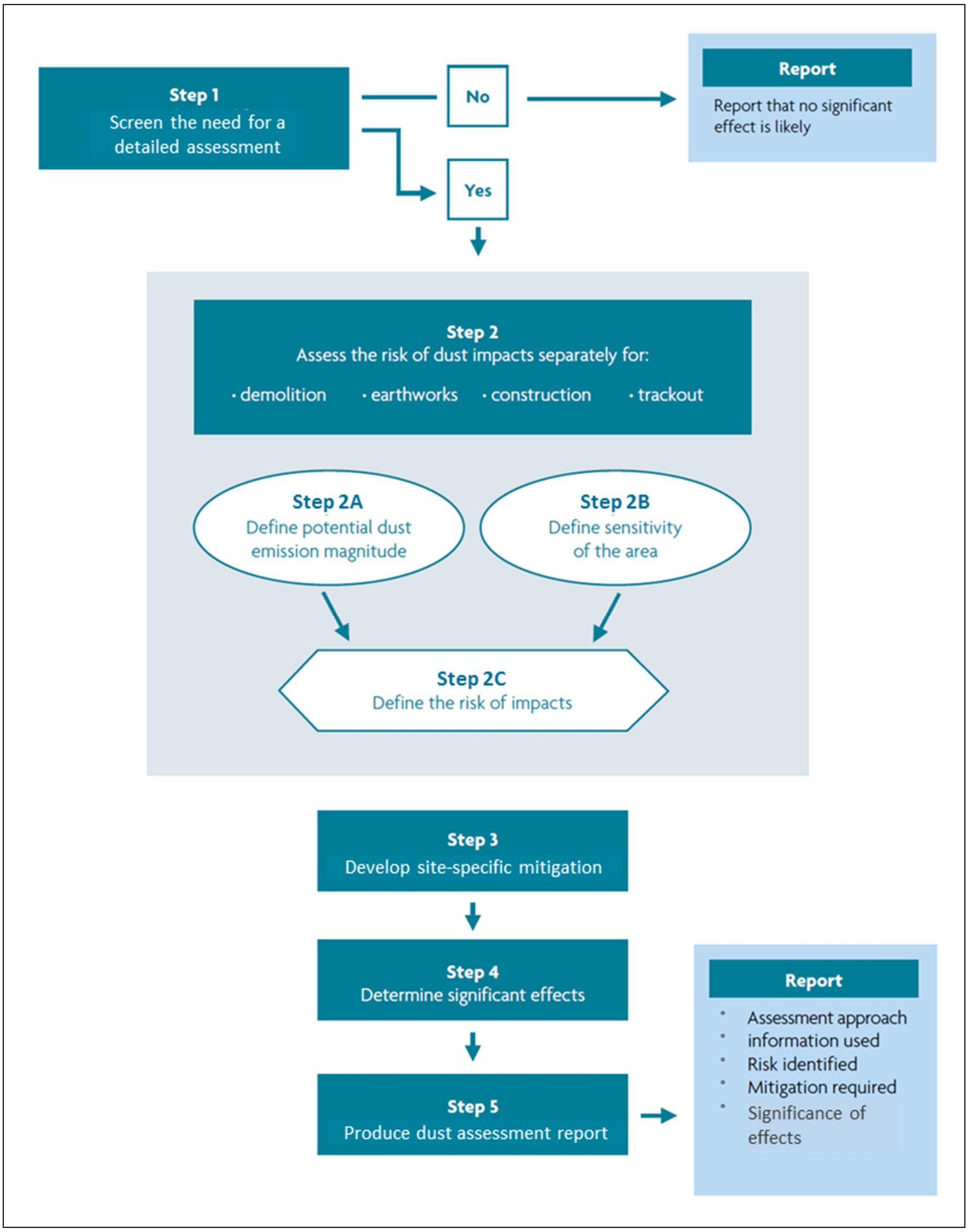

Figure 7-1 Steps in an assessment of construction dust (IAQM, 2014)

For some major construction excavation activities (such as landfill sites for the New M5 project) can cause potential odour issues during excavation. For the M4-M5 Link project no landfills require excavation or disturbance, and so odours should not be a significant issue during construction. It is noted that there is always the potential for unexpected finds (eg localised contamination etc) and these would be dealt with accordingly in the Construction Air Quality Management Plan.

7.4 Step 1: Screening

Step 1 involved a screening assessment. A construction dust assessment is normally required where:

- There are human receptors within 350 metres of the boundary of the site and/or within 50 metres of the route(s) used by construction vehicles on the public highway, up to 500 metres from the site entrance(s)
- There are ecological receptors within 50 metres of the boundary of the site and/or within 50 metres of the route(s) used by construction vehicles on the public highway, up to 500 metres from the site entrance(s).

A 'human receptor', refers to any location where a person or property may experience the adverse effects of airborne dust or dust soiling, or exposure to PM_{10} over a time period that is relevant to air quality standards and goals. Annoyance effects would most commonly relate to dwellings, but may also refer to other premises such as buildings housing cultural heritage collections (eg museums and galleries), vehicle showrooms, food manufacturers, electronics manufacturers, amenity areas and horticultural operations (eg soft-fruit production). An 'ecological receptor' refers to any sensitive habitat affected by dust soiling. This includes the direct impacts on vegetation or aquatic ecosystems of dust deposition, and the indirect impacts on fauna (e.g. on foraging habitats) (IAQM, 2014).

In this screening stage the proposed construction work compounds were examined in combination. It can be seen from **Figure 7-2** that there were multiple off-site human receptors within 350 metres of the boundaries of the project construction sites. The areas potentially affected by construction dust also contained areas of ecological significance, and these were therefore included in the assessment.

7.5 Step 2: Risk assessment

In Step 2 the risk of dust arising in sufficient quantities to cause annoyance and/or health effects was determined separately for each scenario and each of the four activities (demolition, earthworks, construction, and track-out). Risk categories were assigned to the site based on two factors:

- The scale and nature of the works, which determines the magnitude of potential dust emissions. This is assessed in Step 2A
- The sensitivity of the area, including the proximity of sensitive receptors (i.e. the potential for effects). This is assessed in Step 2B.

These factors are combined in Step 2C to give the risk of dust impacts. Risks are categorised as low, medium or high for each of the four separate potential activities. Where there is risk of an impact, then site-specific mitigation would be required in proportion to the level of risk.

7.5.1 Step 2A: Potential for dust emissions

The criteria for assessing the potential scale of dust emissions based on the scale and nature of the works are shown in **Table 7-3**. Based on these criteria, the appropriate categories are shown in **Table 7-4**.

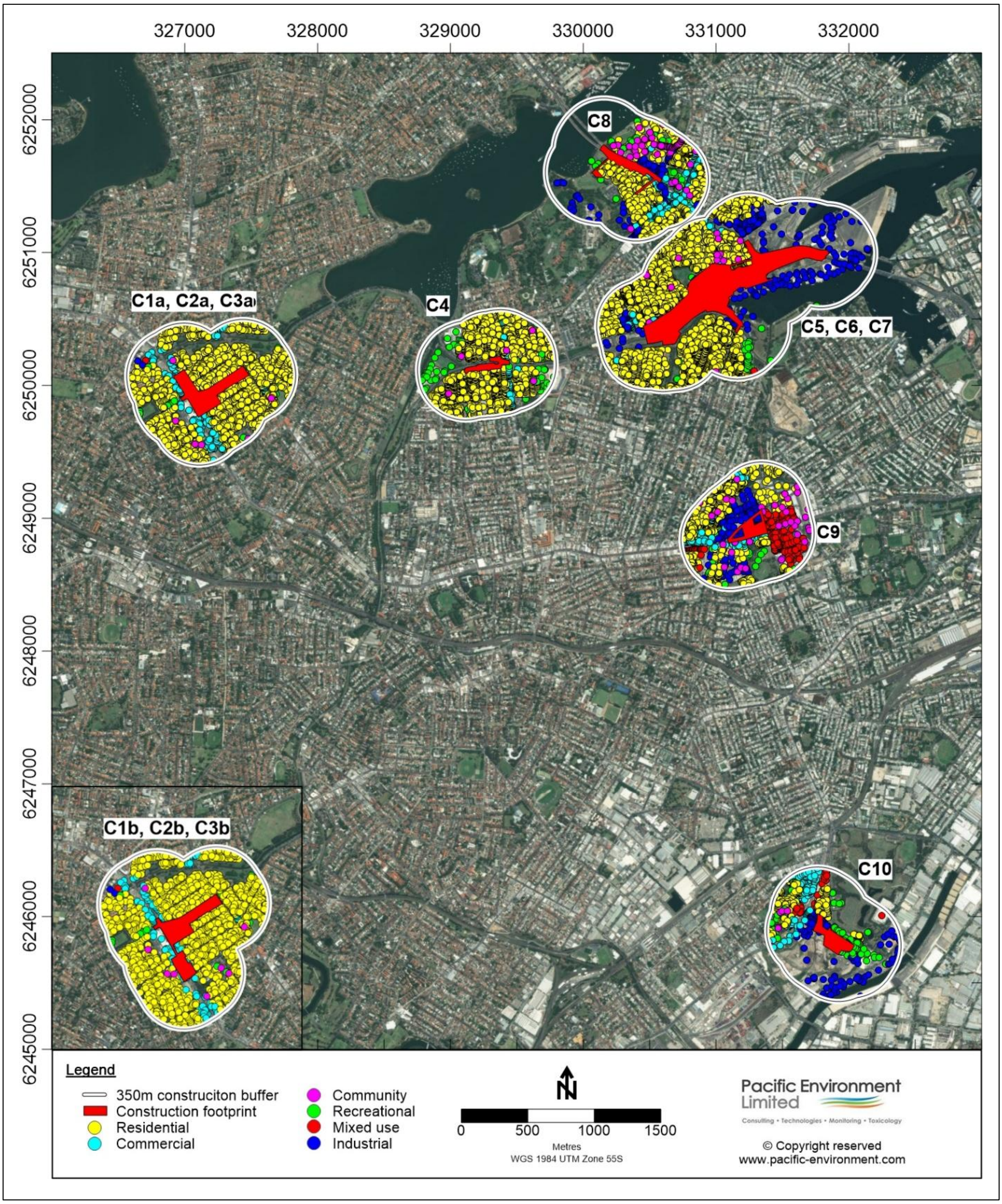

Figure 7-2 Screening assessment – receptors near the construction of the M4-M5 Link project

Table 7-3 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 (e.g. 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 (eg 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 7-4 Results of categorisation of compound 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

7.5.2 Step 2B: Sensitivity of area

The sensitivity of the area takes into account the specific sensitivities of local receptors, the proximity and number of the receptors, and the local background PM_{10} concentration. Dust soiling and health impacts are treated separately.

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 7-5**. 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 7-2**, being predominantly residences in addition to community centres, and in consideration of the IAQM guidance, the receptor sensitivity was assumed to be 'high'.

Table 7-5 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

The number of receptors in each distance band was estimated from land-use zoning of the site. The exact number of 'human receptors' is not required by the IAQM guidance. Instead, it is recommended that judgement is used to determine the approximate number of receptors within each distance band. For receptors that are not dwellings, professional judgement should be used to determine the number of human receptors.

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

- Commercial:
  - B1 – Neighbourhood Centre = 5
  - B2 – Local Centre = 5
- Mixed use:
  - B4 – Mixed Use = 3
- Commercial:
  - B6 – Enterprise Corridor = 5
  - 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 = 3
  - R2 – Low Density Residential = 3

- R3 – Medium Density Residential = 5
- R4 – High Density Residential = 50

· Recreation:
  - RE1 – Public Recreation = 20
  - RE2 – Private Recreation = 10
  - SP1 – Special Activities = 20
  - SP2 – Infrastructure = 20.

The numbers of receptors for each scenario and activity, and the resulting outcomes, are shown in **Table 7-6**. Based on the receptor sensitivity and the numbers of receptors within certain distances from activities, the sensitivity for all areas and all activities was determined to be 'high'.

Table 7-6 Results of sensitivity to dust soiling effects

Scenario	Activity	Receptor sensitivity	Number of receptors by distance from source (m)				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 7-7**. 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 (see **Annexure F**). 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 7-8**. The sensitivity for all areas and all activities was determined to be 'medium'.

Table 7-7 Criteria for sensitivity of area to health impacts

Receptor sensitivity	Annual mean PM_{10} conc. (µg/m^3) [(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

(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 7-8 Results for sensitivity of area to health impacts

Scenario	Activity	Receptor sensitivity	Annual mean PM_{10} conc. ($\mu g/m^3$)	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, C7)	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
	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 7-9**. 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 7-10**. All activities in Scenarios 4 and 5 were determined to have a 'medium' sensitivity to ecological impacts. All activities in Scenario 3 and 7 were determined to have a low sensitivity.

Table 7-9 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 7-10 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

7.5.3 Step 2C: Risk of dust impacts

The dust emission potential determined in Step 2A is combined with the sensitivity of the area determined in Step 2B to give the risk of impacts with no mitigation applied. The criteria are shown in **Table 7-11**.

Table 7-11 Risk categories

Type of activity	Sensitivity of area (from Step 2B)	Dust emission potential (from Step 2A)		
		Large	Medium	Small
Demolition	High	High Risk	Medium Risk	Medium Risk
	Medium	High Risk	Medium Risk	Low Risk
	Low	Medium Risk	Low Risk	Negligible
Earthworks	High	High Risk	Medium Risk	Low Risk
	Medium	Medium Risk	Medium Risk	Low Risk
	Low	Low Risk	Low Risk	Negligible
Construction	High	High Risk	Medium Risk	Low Risk
	Medium	Medium Risk	Medium Risk	Low Risk
	Low	Low Risk	Low Risk	Negligible
Track-out	High	High Risk	Medium Risk	Low Risk
	Medium	Medium Risk	Low Risk	Negligible
	Low	Low Risk	Low Risk	Negligible

The final results for the Step 2C risk assessment are provided in **Table 7-12**, 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.

7.6 Step 3: Mitigation

Step 3 involved determining mitigation measures for each of the four potential activities in Step 2. This was based on the risk of dust impacts identified in Step 2C. For each activity, the highest risk category was used. The suggested mitigation measures are discussed in **section 9.1**.

Table 7-12 Summary of risk assessment for the construction of the M4-M5 Link

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 Risk	Low Risk	N/Aa
	Earthworks	Small	High	Medium	N/A	Low Risk	Low Risk	N/A
	Construction	Medium	High	Medium	N/A	Medium Risk	Medium Risk	N/A
	Track-out	Large	High	Medium	N/A	High Risk	Medium Risk	N/A
Scenario 2 (C1b–C3b)	Demolition	Small	High	Medium	N/A	Medium Risk	Low Risk	N/A
	Earthworks	Small	High	Medium	N/A	Low Risk	Low Risk	N/A
	Construction	Medium	High	Medium	N/A	Medium Risk	Medium Risk	N/A
	Track-out	Large	High	Medium	N/A	High Risk	Medium Risk	N/A
Scenario 3 (C4)	Demolition	Large	High	Low	Low	High Risk	Medium Risk	Medium Risk
	Earthworks	Medium	High	Low	Low	Medium Risk	Low Risk	Low Risk
	Construction	Medium	High	Low	Low	Medium Risk	Low Risk	Low Risk
	Track-out	Large	High	Low	Low	High Risk	Low Risk	Low Risk
Scenario 4 (C5, C6, C7)	Demolition	Large	High	Medium	Medium	High Risk	High Risk	High Risk
	Earthworks	Large	High	Medium	Medium	High Risk	Medium Risk	Medium Risk
	Construction	Large	High	Medium	Medium	High Risk	Medium Risk	Medium Risk
	Track-out	Large	High	Medium	Medium	High Risk	Medium Risk	Medium Risk
Scenario 5 (C8)	Demolition	Medium	High	Medium	Medium	Medium Risk	Medium Risk	Medium Risk
	Earthworks	Large	High	Medium	Medium	High Risk	Medium Risk	Medium Risk
	Construction	Large	High	Medium	Medium	High Risk	Medium Risk	Medium Risk
	Track-out	Medium	High	Medium	Medium	Medium Risk	Low Risk	Low Risk
Scenario 6 (C9)	Demolition	Large	High	Medium	N/A	High Risk	High Risk	N/A
	Earthworks	Large	High	Medium	N/A	High Risk	Medium Risk	N/A
	Construction	Large	High	Medium	N/A	High Risk	Medium Risk	N/A
	Track-out	Large	High	Medium	N/A	High Risk	Medium Risk	N/A
Scenario 7 (C10)	Demolition	Small	High	Medium	Low	Medium Risk	Low Risk	Negligible
	Earthworks	Large	High	Medium	Low	High Risk	Medium Risk	Low Risk
	Construction	Large	High	Medium	Low	High Risk	Medium Risk	Low Risk
	Track-out	Large	High	Medium	Low	High Risk	Medium Risk	Low Risk

(a) N/A = not applicable

7.7 Step 4: Significance of risks

Once the risk of dust impacts has been determined in Step 2C, and the appropriate dust mitigation measures identified in Step 3, 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 will be 'not significant'.

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

8 Assessment of operational impacts

8.1 Overview of section

This section details the methods used to assess the operational impacts of the project on emissions and air quality, and presents the results of the assessment. The assessment took into account the emissions from both tunnel ventilation outlets and surface roads, and considered the cumulative impacts of these and background pollutant concentrations. The section describes the following:

- Emissions, including:
  - The emission models that were used and the reasons for their selection
  - Model inputs
  - Emission model evaluation
  - Results
- Ambient air quality, including:
  - The meteorological/dispersion models that were used and the reasons for their selection
  - Model set-up
  - Post-processing of dispersion model outputs
  - Meteorological and dispersion model evaluation
  - Results
- Key assumptions in the assessment, including a discussion of the level of conservatism associated with these assumptions where possible
- Sensitivity tests that were conducted.

8.2 Emissions

8.2.1 Introduction

For each scenario (expected traffic) a spatial emissions inventory was developed for road traffic sources in the WestConnex GRAL domain. The following components were treated separately:

- Emissions from existing and proposed tunnel ventilation outlets
- Emissions from the traffic on the surface road network, including any new roads associated with the project. These were calculated on a link-by-link basis.

The assessment was conducted assuming no emissions from any tunnel portals; that is, all emissions from the traffic in tunnels were assumed to be released to the atmosphere via ventilation outlets.

8.2.2 Tunnel ventilation outlets

Method

Emissions were determined for 14 different tunnel ventilation outlets, the locations of which are shown in **Figure 8-1**. 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 was very close to the eastern boundary[23] of the domain, because of the relatively low volumes of traffic in the tunnel, and because of the distance between the outlet and the receptors included in the assessment. It was therefore considered the Cross City Tunnel outlet would not have material impact on the results of the assessment.

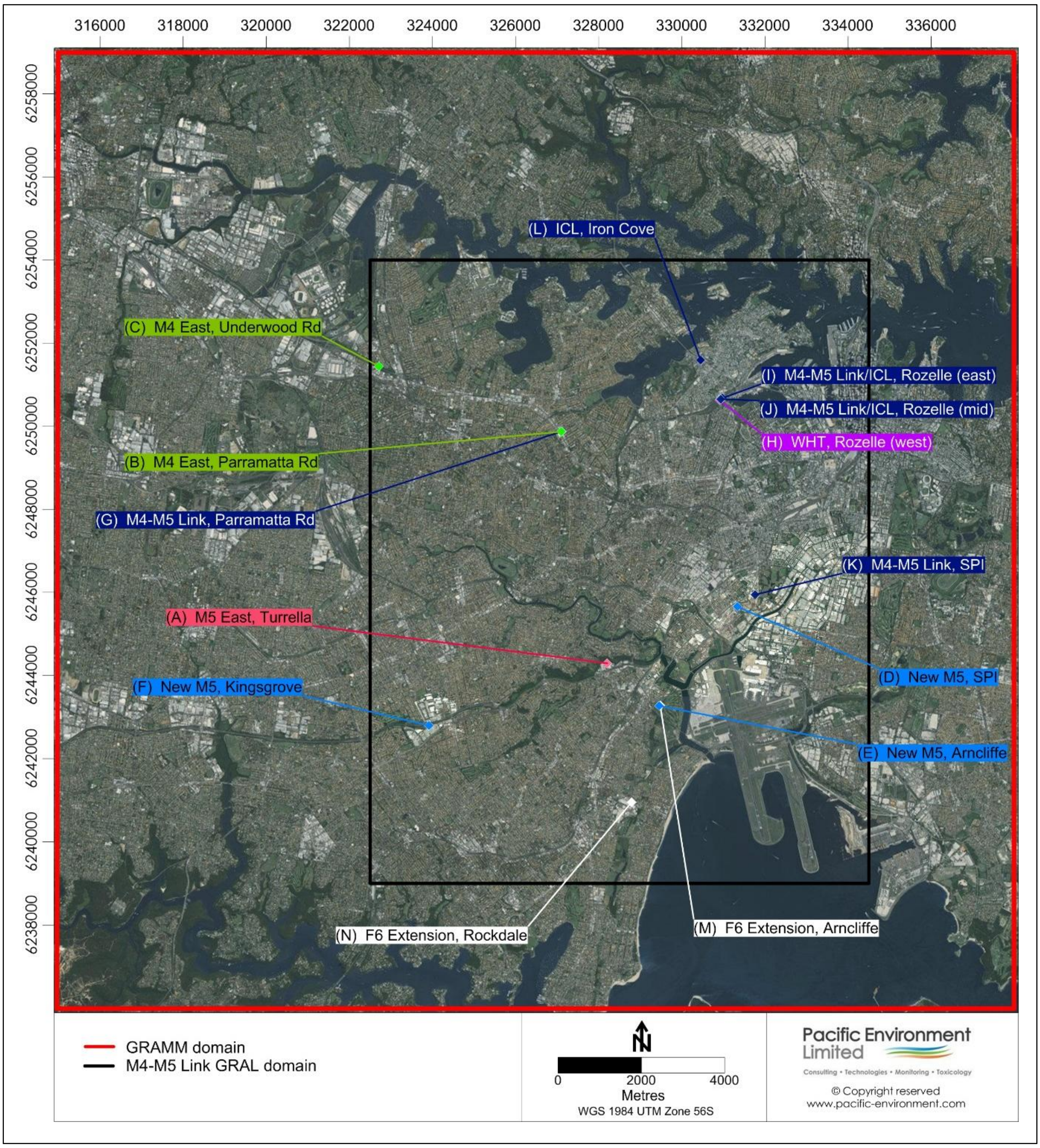

Figure 8-1 Locations of all tunnel ventilation outlets included in the assessment (grid system MGA94)

[23] 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).

The ventilation facilities and outlets were summarised in **Table 2-3**, and are listed below.

- Existing facility
  - Outlet A M5 East tunnel outlet at Turrella
- Facilities currently under construction for M4 East and New M5
  - Outlet B M4 East facility at Parramatta Road, Haberfield
  - Outlet C M4 East facility at Underwood Road, Homebush
  - Outlet D New M5 facility at St Peters interchange
  - Outlet E New M5 facility at Arncliffe
  - Outlet F New M5 facility at Kingsgrove
- Ventilation facilities for WestConnex M4-M5 Link (subject of this EIS)
  - Ventilation facility at Haberfield
    - Outlet G M4-M5 Link facility at Parramatta Road, Haberfield (under construction as part of the M4 East project)
  - Ventilation facility at Rozelle
    - Outlet H WHT facility at Rozelle (the M4-M5 Link project is constructing this outlet, although the fitout would be subject to separate assessment and approval under that project's EIS)
    - Outlets I and J M4-M5 Link/Iron Cove Link ('ICL' in **Figure 8-1**) facility at Rozelle
  - Ventilation facility at St Peters
    - Outlet K M4-M5 Link facility at Campbell Road at St Peters interchange
  - Ventilation facility at Iron Cove
    - Outlet L Iron Cove Link facility at Rozelle near Iron Cove
- Proposed ventilation facilities for the future proposed F6 Extension
  - Outlet M F6 Extension facility at Arncliffe
  - Outlet N F6 Extension facility at Rockdale.

The ventilation outlets that would be specific to the M4-M5 Link are G, I, J, K and L. The remaining outlets (A, B, C, D, E, F, H, M and N) were included to assess potential cumulative impacts only. Each ventilation outlet had either one physical outlet for air, or four 'sub-outlets' for air, depending on the configuration.

For the modelling of point sources in GRAL, emissions (in kilograms per hour) and exit velocities (in metres per second) are characterised as single annual average values. However, further temporal variation can be modelled through the use of source groups (refer to **section 8.4.3**). For each ventilation outlet, separate source groups were defined in GRAL to reflect different air flow regimes and emission rates, and the periods of the day associated with these source groups are given in **section 8.4.6**.

An average emission rate therefore had to be calculated for each outlet and source group, and hourly 'modulation factors' (ratios, relative to the average emission rate for each source group) were used in GRAL to replicate the variation in emissions within each time period. No seasonal variation was built into the emission rates. The approaches used for the existing M5 East tunnel and the proposed tunnels are summarised below.

Existing facility for M5 East tunnel

The M5 East tunnel outlet was the only existing one of note in the M4-M5 Link GRAL domain (as explained earlier, the Cross City Tunnel outlet was excluded). Emissions of NO_X, CO, PM_{10} and $PM_{2.5}$ from the outlet were calculated using hourly in-stack concentration and air flow measurements for 2014 supplied by Roads and Maritime. THC emissions were calculated using a method similar to that described below for the proposed outlets. Emission scaling factors for the future year scenarios were developed using the NSW EPA emission model and the WRTM outputs for the tunnel.

Proposed facilities for WestConnex tunnels and other projects

The method for determining emissions from the ventilation outlets is described in the tunnel ventilation report in **Annexure L**. The pollutants assessed for tunnel ventilation purposes were NO_X, NO_2, CO and $PM_{2.5}$. Emissions of PM_{10} and THC were also required for the ambient air quality assessment, and these were estimated using ratios based on calculations for a generic tunnel configuration using the NSW EPA model. The $PM_{2.5}$ emission rate from the tunnel ventilation work was multiplied by a $PM_{10}/PM_{2.5}$ ratio to determine PM_{10}. The THC emission rate was estimated using a THC/NO_X ratio. The ratios used are given in **Table 8-1**.

Table 8-1 Ratios used for estimating PM_{10} and THC emissions

Pollutant emission ratio	Value by year	
	2023	2033
PM_{10}:$PM_{2.5}$	1.46	1.53
THC:NO_X	0.06	0.04

Results

The diurnal profiles of outlet emission rates for each scenario and ventilation outlet, and the average emission factor for each source group, are given in **Annexure I**. The pollutant concentrations in the tunnel outlets, consistent with the assumptions in GRAL, are also provided in **Annexure I**.

8.2.3 Surface roads

Model selection

The following characteristics were considered to be desirable for the surface road emission model:

- Good availability and accessibility (eg readily able to accommodate future updates)
- A high level of detail and robustness (i.e. based on sound principles, taking into account all processes generating emissions and the most important factors determining emission rates, and including all relevant pollutants)
- A good level of maintenance (ie being up-to-date)
- A good representation of the vehicles and fuels used in Sydney
- A good representation of driving conditions in Sydney
- The inclusion of emission projections for future years.

When estimating emissions from road transport, it is important to distinguish between different types of vehicle, between vehicles using different types of fuel, and between vehicles conforming to different emission regulations. One of the most important factors is how vehicle operation (eg speed and acceleration are represented. Road gradient is also an important factor.

Various emission modelling approaches have been developed for the road transport sector. Most emission models are empirical in nature, being based on data from laboratory or real-world tests. A large number of emission models have been developed for surface roads. The most appropriate emission model for surface roads was considered to be the one developed by NSW EPA for the emissions inventory covering the Greater Metropolitan Region (GMR) (NSW EPA, 2012b). The main reasons for this choice were as follows:

- The model has been developed to a high standard; it is one of the most sophisticated models that has been developed for calculating emissions from road vehicles in NSW
- The model has been specifically designed for use in the NSW GMR, and takes into account:
  - The operation of vehicles on surface roads
  - The characteristics of vehicle fleets in the GMR
- Many of the emission factors have been derived using an extensive database of Australian measurements. They allow for the deterioration in emissions performance with mileage, the effects of tampering or failures in emission-control systems, and the use of ethanol in petrol
- The model includes emission factors for specific road types
- Emission projections for several future years are available, taking into account the technological changes in the vehicle fleet
- The model is up to date. The NSW GMR inventory was overhauled in 2012, with significant refinements to the road transport methodology
- The model includes cold-start emissions. These are not likely to be relevant to motorway tunnels such as the M4-M5 Link, but they do need to be considered for roads with a larger proportion of vehicles operating in cold-start mode
- The full inventory model is described in the report by NSW EPA (2012b). In 2012, a simplified version of the inventory model was developed by NSW EPA for use in the Roads and Maritime air quality screening model TRAQ. In January 2015 the NSW EPA provided Pacific Environment with revised algorithms, and these were implemented in the methodology for this assessment, along with a number of other refinements including emission factors for primary NO_2.

A more detailed description of the model used, including an evaluation, is provided in **Annexure E**.

The following models were also considered, but were not included for the reasons provided:

- National Pollutant Inventory (NPI) model. The NPI is compiled and maintained by the Australian Government. Manuals are provided on the NPI website[24] to enable emissions from each sector of activity to be calculated. For road vehicles, Environment Australia (2000) provides the emissions estimation techniques for the relevant NPI substances, as well as guidance on the spatial allocation of emissions. The NPI manual for road vehicles is now well out of date, and has not been considered further in this Report. It is worth noting, however, that a new motor vehicle emission inventory for the NPI has been developed using the COPERT Australia software (see below) (Smit, 2014)
- COPERT Australia. This is a commercial model for calculating emissions from traffic on surface roads (Smit and Ntziachristos, 2012; 2013)[25]. The model has been developed to a high standard. It follows a similar structure to that of the COPERT 4 model that is widely used in Europe. COPERT Australia covers all the main vehicle classes and driving conditions in Australia, and is based upon a database of emission tests that is similar to that used in the NSW inventory model. However, the model was not evaluated in detail as part of the M4-M5 Link assessment, because a detailed model was already available from NSW EPA (and reflected the traffic, fuel and fleet conditions in NSW).

[24] http://www.npi.gov.au/reporting/industry-reporting-materials/emission-estimation-technique-manuals

[25] http://www.emisia.com/copertaustralia/General.html

Input data

WestConnex Road Traffic Model

The accurate characterisation of traffic activity (such as number of vehicles, trip distances and modes of operation) and the fleet composition is vital to the estimation of emissions. Although models and emission factors are continually improving, activity data remains one of the main sources of uncertainty in the calculation of emissions.

Data on traffic volume, composition and speed for surface roads in the WestConnex GRAL model domain, which covered an extensive area south of Sydney Harbour, were taken from the WRTM. The WRTM provided outputs on a link-by-link basis for the different scenarios and for all major roads affected by the scheme.

The WRTM was developed to understand changes in future weekday travel patterns under different land use, transport infrastructure and pricing scenarios. Although the WRTM is a network-wide model that encompasses existing and future road networks in the Sydney Metropolitan area, it was principally developed to assess infrastructure improvements associated with the WestConnex component projects individually and in combination. WRTM Version 2.3, which includes induced traffic demand, was used for this EIS.

The WRTM is linked to the Strategic Travel Model (STM), which includes trip generation, trip distribution and mode choice modules, and incorporates demographic data related to land uses including population, employment and education enrolment projections. For WRTM v2.3, these data were supplied by Transport for NSW's Transport Performance and Analytics (TPA) as data extracts from the STM and is based on the DP&E's 2014 population and employment projections.

The WRTM patronage forecasting model process comprises two separate elements, the Base Demand Model and the Toll Choice Assignment Model (to incorporate toll choice behaviour).

The Base Demand Model provides the forecast capability to address changes in land use, trip distribution and mode choice, and produces vehicle traffic demands for peak and off-peak periods for subsequent allocation to routes in the detailed toll choice assignment model.

A separate Toll Choice Assignment Model was developed to test the impacts of toll and infrastructure strategies and provide infrastructure project traffic forecasts. This model is designed to forecast the traffic choosing to use tolled and non-tolled routes for the representative peak and inter-peak periods of the day. It was developed to model the range of driver behaviour, and was adjusted to match the observed patronage on existing tolled roads.

Traffic forecast modelling is highly complex. Reasonable variations in input parameters, data and assumptions result in variations in forecast traffic demand. Forecast traffic from models should be considered as a range as opposed to absolute numbers.

The following sections describe the outputs from the WRTM and how these were adapted for use in GRAL.

Time periods

The WRTM models an average weekday during a school term.

The model included the following time periods:

- The morning ('AM') peak period (07:00-09:00)
- The inter-peak ('IP') period (09:00-15:00)
- The afternoon ('PM') peak period (15:00-18:00)
- The night-time ('EV') period (18:00-07:00).

The WRTM outputs represent an average one-hour peak within each of these periods.

Network description

For surface roads the emission (and dispersion) modelling was undertaken for the main roads in the WestConnex GRAL domain, as defined in the WRTM. The road network in the domain was defined in terms of the start node and end node of each link in the WRTM, with each direction of travel being treated separately. The WRTM output included surface roads, tunnels, and tunnel access ramps.

The road links in the domain are shown in the figures on the following pages. Each figure shows the road links in Do Minimum scenarios, as well as the additional links in the Do Something and Do Something Cumulative scenarios:

- **Figure 8-2** shows the additional links in the 2023-DS and 2033-DS scenarios
- **Figure 8-3** the additional links in the 2023-DSC scenario
- **Figure 8-4** the additional links in the 2033-DSC scenario.

Both surface road links and tunnel links are included. The additional roads in each scenario are predominantly tunnels or tunnel entry/exit ramps.

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
- 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.

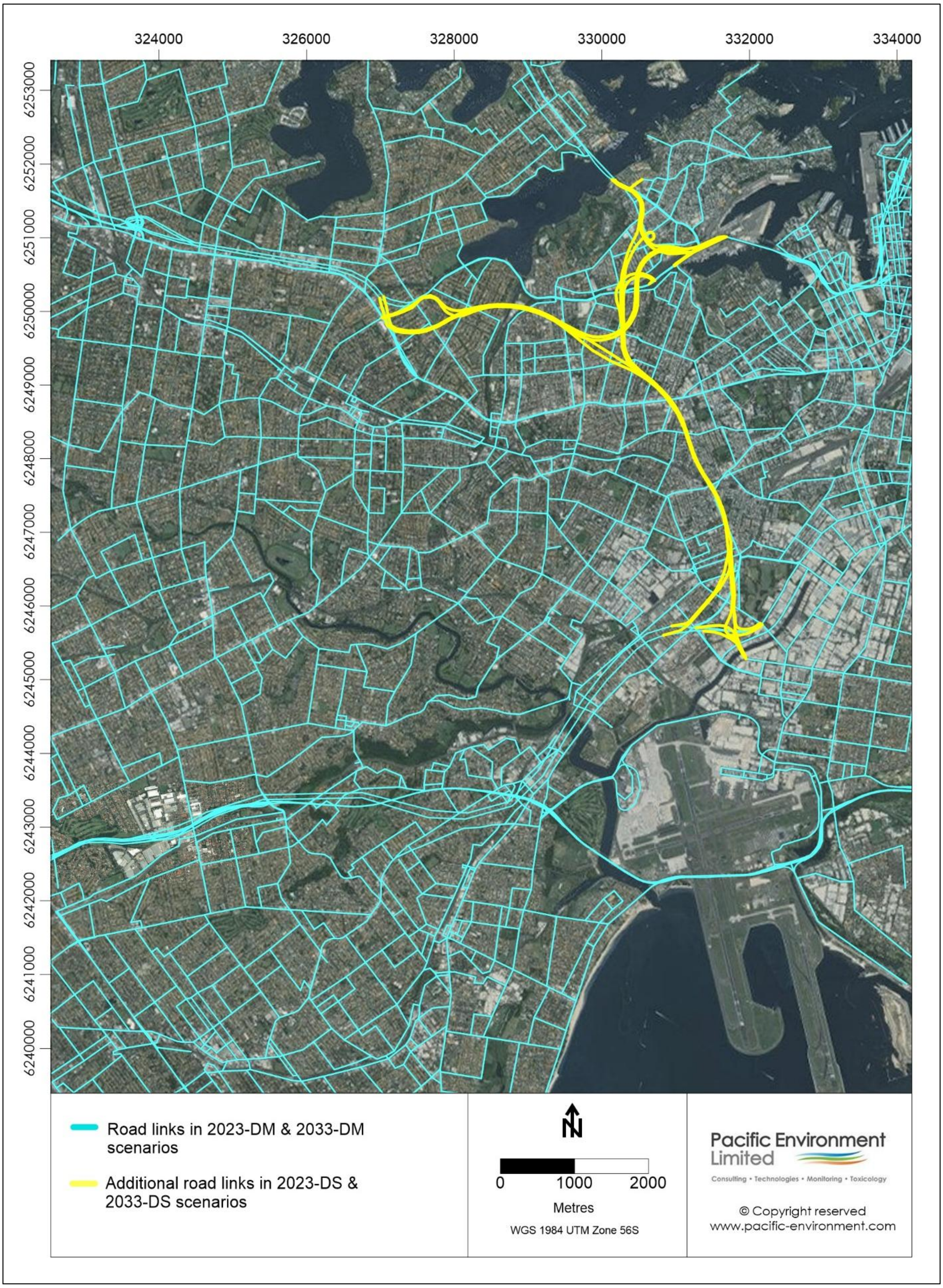

Figure 8-2 Road links in the Do Minimum scenarios, and additional links in the 2023-DS and 2033-DS scenarios (grid system MGA94)

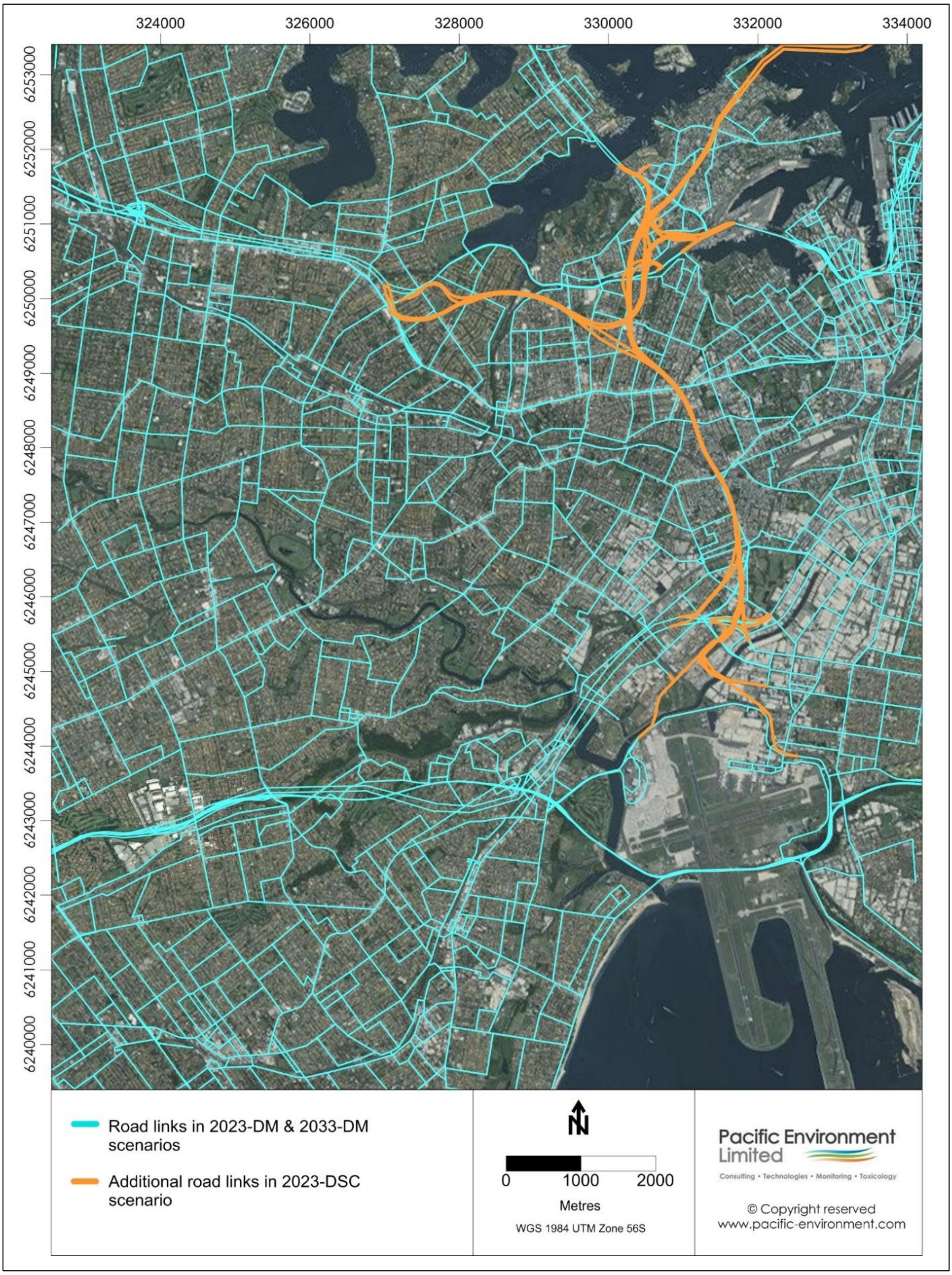

Figure 8-3 Road links in the Do Minimum scenarios, and additional links in the 2023-DSC scenario (grid system MGA94)

Figure 8-4 Road links in the Do Minimum scenarios, and additional links in the 2033-DSC scenario (grid system MGA94)

The road network (including tunnels) had between 5,502 and 5,733 individual links, depending on the scenario (**Table 8-2**). The tunnels were removed from the traffic files before being entered into GRAL. Emissions from these roads were allocated to the tunnel ventilation outlets, as described in **Annexure L**. In some cases, part of a link in WRTM represented a surface road, and part of it represented a tunnel road. Where this was the case, the link was split into two sections based on the tunnel portal location, and the tunnel sections were removed from the traffic model file.

Table 8-2 Number of road links by scenario

Scenario code	Scenario description	Number of road links included (WestConnex GRAL domain)
2015-BY	2015 – Base Year (existing conditions)	5,502
2023-DM	2023 – Do Minimum (no M4-M5 Link)	5,592
2023-DS	2023 – Do Something (with M4-M5 Link)	5,649
2023-DSC	2023 – Do Something Cumulative (with M4-M5 Link and some other projects)	5,699
2033-DM	2033 – Do Minimum (no M4-M5 Link)	5,592
2033-DS	2033 – Do Something (with M4-M5 Link)	5,649
2033-DSC	2033 – Do Something Cumulative (with M4-M5 Link and all other projects)	5,733

Road classification

In the WRTM each road link was defined in terms of its functional class. For the purpose of calculating emissions, the functional class was converted into an NSW EPA road type, as shown in **Table 8-3**. The characteristics of different road types are described in Table E-1 of **Annexure E**. Regional arterial roads in the WRTM were treated as either commercial arterials or commercial highways in the NSW EPA emission model, depending on whether the free-flow traffic speed (taken as the evening period speed) was less than or higher than 70 kilometres per hour.

Table 8-3 Assignment of WRTM road types to NSW EPA road types

Road type in WRTM	Evening period speed (km/h)	EPA road type
Minor	All	Residential
Collector	All	
Sub-arterial	All	Arterial
Arterial	All	
Regional arterial	<=70	Commercial arterial
	>70	Commercial highway
Highway	All	Highway/freeway
Motorway	All	
Motorway ramp	All	

Road width

The width of each road was not required for the emission modelling, but it was required as an input for the GRAL dispersion model to define the initial plume dispersion conditions. It was not feasible to determine the precise width of every road link in modelled road network, and therefore a twofold approach was used:

- For the roads that were considered to be the most important in terms of potential changes air quality, the specific widths were determined
- For all other roads, typical average widths were assumed for each road type.

The road widths were estimated based on samples of roads from Google Earth in December 2016.

In the traffic model, some roads had links separated by direction of travel, whereas other roads had superimposed ('stacked') links. For many major roads, the superimposed links were separated by Pacific Environment to give a better real-world spatial representation, but this was not possible for all roads. Consequently, the widths were determined separately for both roads with separated links and roads with stacked links.

The widths used in GRAL for certain specific roads are given in **Table 8-4**, and the typical road widths are given in **Table 8-5**. The specific road widths were applied to those roads that were materially influenced by the project but had widths that were different from the typical widths. It is worth mentioning that the typical road widths may appear to be unrepresentative of the road types more widely in Australia (eg regional arterial roads being wider than motorways). Again, this is because the values reflect the roads in the GRAL domain, and it happens to be the case that the (few) regional arterial roads in the traffic model are relatively wide. The typical road widths were also applied to any new roads associated with the WestConnex projects.

Table 8-4 Assumed road width by road type – specific roads in the GRAL domain

Road	Estimated road width (m)	
	Separated links (one-way traffic)	Stacked links (two-way traffic)
Parramatta Road	8	17
City West Link (between The Crescent and Victoria Road)	16	32
City West Link (west of The Crescent)	8	16
Western Distributor near Anzac Bridge	12	25
Princes Highway near Sydney Park	8	17
Victoria Road, Rozelle	8.5	18

Table 8-5 Assumed road width by road type – typical roads in the GRAL domain

Road type	Estimated road width (m)	
	Separated links (one-way traffic)	Stacked links (two-way traffic)
Minor	3.7	7.4
Collector	4.4	9.1
Sub-Arterial	4.6	9.5
Arterial	5.8	12.1
Regional arterial	8.6	18.4
Highway	9.9	21.7
Motorway	7.2	17.1
Motorway ramp	5.4	N/A

Road gradient

The average gradient of each road link in the WestConnex GRAL domain was estimated using high-resolution terrain data derived from LIDAR surveys. For each node point in the traffic model output, the elevation above sea level was determined. The average gradient of each link (Δz/Δx) was then estimated based on the difference in the height (Δz) of the start node and the end node and the approximate length of the link (Δx) from the traffic model. The upper and lower limits of the gradient for use in the emissions model were +8 per cent and -8 per cent respectively. The real-world gradients of selection of traffic model links were also estimated using road length and height information from Google Earth, and the results were found to be in good agreement with the gradients determined from the LIDAR data.

Traffic volume, speed and mix (including fuel split)

The traffic volume and speed for each road link and each time period were taken from WRTM.

The WRTM defines vehicles according to the following classes:

- Private vehicles (PVs). These were mainly cars
- Light commercial vehicles (LCVs). These included cars, utility vehicles, vans and light rigid trucks that are registered for business or commercial use
- Heavy commercial vehicles (HCVs). These included all rigid and articulated trucks.

Buses, coaches and motorcycles were not explicitly modelled in WRTM.

The division of these classes into emission-relevant vehicle categories was based on the WRTM output and default traffic mix by year and road type from the EPA emission inventory.

The volumes for cars, LCVs and HCVs from the strategic model were sub-divided into the nine vehicle types that are defined in the EPA model to reflect differences in emissions behaviour. These vehicle types are summarised in **Table 8-6**. The sub-division was based upon a default traffic mix for each road type in the GMR inventory, as shown in **Table 8-7**.

Table 8-6 Vehicle types in the NSW EPA emissions model

Code	Vehicle type	Vehicles included
CP	Petrol car[(a)]	Petrol car, 4WD[(e)], SUV[(f)] and people-mover, LPG[(g)] car/4WD
CD	Diesel car[(a)]	Diesel car, 4WD, SUV and people-mover
LCV-P	Petrol LCV[(b)]	Petrol light commercial vehicle <3.5 tonnes GVM[(h)]
LCV-D	Diesel LCV	Diesel light commercial vehicle <3.5 tonnes GVM
HDV-P	Petrol HDV[(c)]	Petrol heavy commercial vehicle <3.5 tonnes GVM
RT	Diesel rigid HGV[(d)]	Diesel commercial vehicle 3.5 t < GVM <25 t
AT	Diesel articulated HGV	Diesel commercial vehicle >25 tonnes GVM
BusD	Diesel bus	Diesel bus >3.5 tonnes GVM
MC	Motorcycle	Powered two-wheel vehicle

(a) Referred to as ‘passenger vehicle’ in the inventory
(b) LCV = light commercial vehicle
(c) HDV = heavy-duty vehicle
(d) HGV = heavy goods vehicle
(e) 4WD = four-wheel drive
(f) SUV = sports-utility vehicle
(g) LPG = liquefied petroleum gas
(h) GVM = gross vehicle mass

Table 8-7 Default traffic mix by road type

Road type	Year	Proportion of traffic (%)								
		CP	CD	LCV-P	LCV-D	HDV-P	RT	AT	BusD	MC
Residential	2015	70.5	9.6	6.5	8.7	0.1	2.7	0.8	0.6	0.5
	2023	62.5	16.8	3.4	12.1	0.0	3.1	0.9	0.6	0.5
	2033	51.4	27.6	1.0	14.5	0.0	3.4	1.0	0.6	0.5
Arterial	2015	67.7	9.2	7.4	9.8	0.1	3.6	1.1	0.5	0.5
	2023	59.9	16.1	3.8	13.7	0.0	4.2	1.3	0.5	0.5
	2033	49.2	26.4	1.2	16.4	0.0	4.5	1.4	0.5	0.5
Commercial arterial	2015	65.5	8.9	7.9	10.5	0.1	4.7	1.6	0.4	0.5
	2023	57.8	15.6	4.1	14.5	0.0	5.3	1.8	0.4	0.5
	2033	47.3	25.4	1.2	17.5	0.0	5.7	2.0	0.4	0.5
Commercial highway	2015	65.5	8.9	7.9	10.5	0.1	4.7	1.6	0.4	0.5
	2023	57.8	15.6	4.1	14.5	0.0	5.3	1.8	0.4	0.5
	2033	47.3	25.4	1.2	17.5	0.0	5.7	2.0	0.4	0.5
Highway/ freeway	2015	58.4	7.9	7.1	9.5	0.2	10.2	6.0	0.2	0.4
	2023	50.6	13.6	3.7	13.1	0.0	11.7	6.7	0.3	0.4
	2033	40.7	21.9	1.1	15.7	0.0	12.8	7.2	0.3	0.4

The default traffic mix for each road type took into account the projected fuel split (i.e. petrol/diesel). In recent years the refinement of light-duty diesel engines and their superior fuel economy relative to petrol engines has led to increased sales and growth in market share. As a consequence, there are projected increases in the proportions of diesel cars and diesel LCVs in the future. The petrol/diesel splits for cars and LCVs in the inventory are determined based on sales (registration) statistics, 'attrition' functions, and VKT.

There are, almost always, discrepancies between the outputs of traffic models and the input requirements for emission models, and therefore some assumptions were required. In the case of WRTM the most notable of these were as follows:

- The proportions of LCVs in the traffic model outputs were very high compared with typical proportions on the road in relation to how such vehicles are defined in emission models. For example, it is likely that many of the vehicles defined as LCVs in the traffic model were, from an emissions perspective, cars, and some of them would have been more like rigid heavy-duty vehicles. The approach taken was therefore to combine PVs and LCVs from the traffic model, and redistribute these according to the relevant split (road type, year) between CP, CD, LVC-P and LCV-D from **Table 8-7**. This relatively simple approach was adopted because of the large number of surface road links. A more detailed approach was possible for the tunnel links (see **Annexure L**)
- HCVs from the traffic model were redistributed according to the split for HD-P, RT and AT in **Table 8-7**
- Relatively small numbers of buses and motorcycles were added to the traffic model output, again based on the proportions in **Table 8-7**.

An example of the WRTM output for one link is shown in **Figure 8-5**, and the transformation of the data for this link into a suitable format for the NSW EPA emission model is shown in **Figure 8-6**.

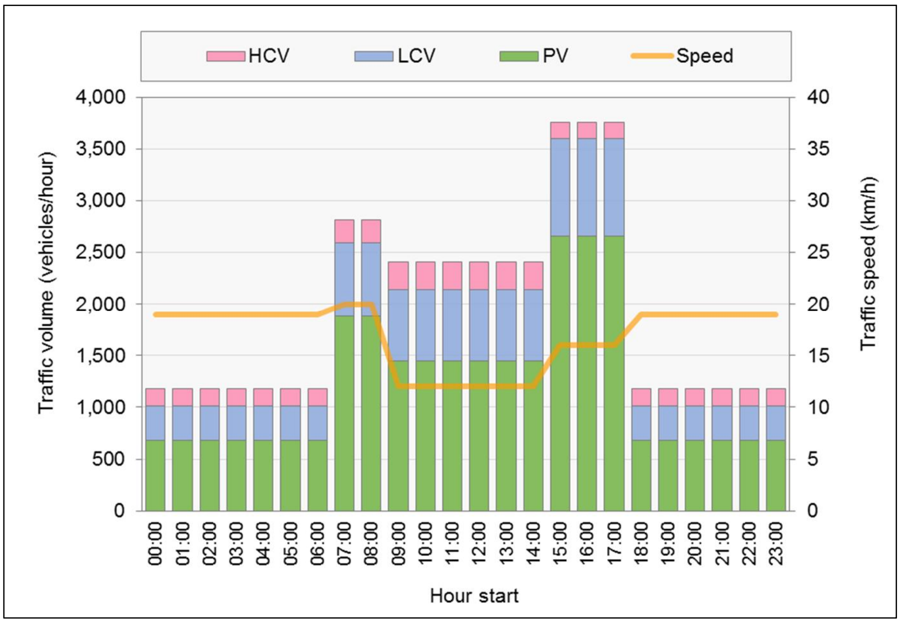

Figure 8-5 Example traffic model output (link 11631-12322, arterial road, 2033-DSC scenario)

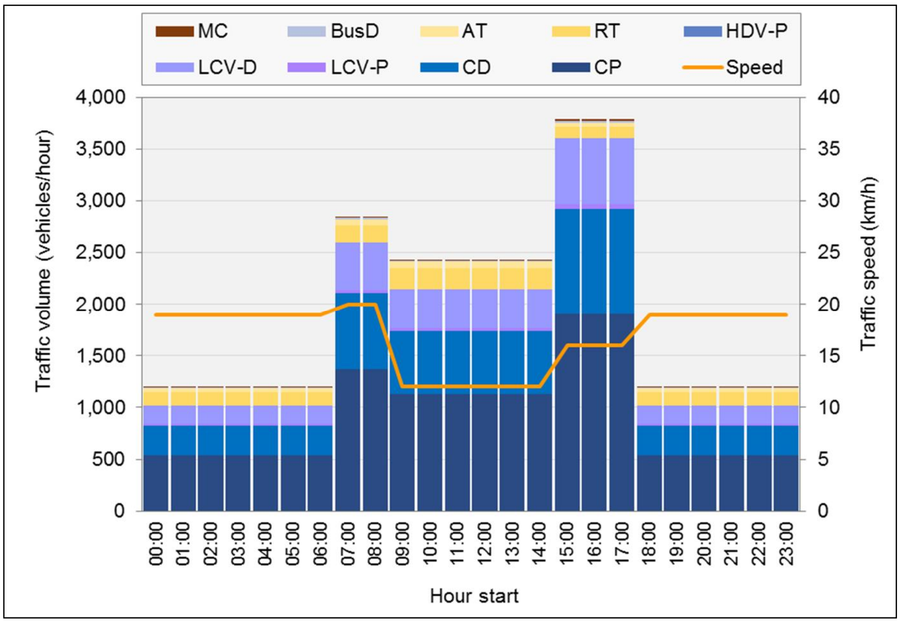

Figure 8-6 Example emission model input (link 11631-12322, arterial road, 2033-DSC scenario)

Results

Expected traffic scenarios

As emissions were determined separately for more than 5,500 road links, multiple pollutants and multiple scenarios, it would not be practical to present all the results in this report. Instead, only the total emissions are for all roads (including tunnels) in the WestConnex GRAL domain are presented.

The total emissions in the WestConnex GRAL domain, in tonnes per year, are given for each scenario in **Table 8-8**, and are also shown graphically in **Figure 8-7**. The absolute and percentage changes in emissions between scenarios are shown in **Table 8-9** and **Table 8-10** respectively. 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 to 2.9 per cent in 2023, and by 2.9 to 3.2 per cent in 2033, depending on the pollutant. For the Do Something Cumulative scenarios, emissions of these pollutants increased by 3.2

to 5.1 per cent in 2023 and by 7.2 to 8.2 per cent in 2033, depending on the pollutant. The changes in 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 8-10** 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 around 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 6 to 9 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 8.5**.

Table 8-8 Total traffic emissions in the WestConnex GRAL domain

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

(a) VKT = vehicle kilometres travelled

Table 8-9 Absolute changes in total traffic emissions in the WestConnex GRAL domain

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

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

Table 8-10 Percentage changes in total traffic emissions in the WestConnex 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%
2033-DSC vs 2033-DM	+7.7%	+7.2%	+8.0%	+8.2%	-0.2%

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

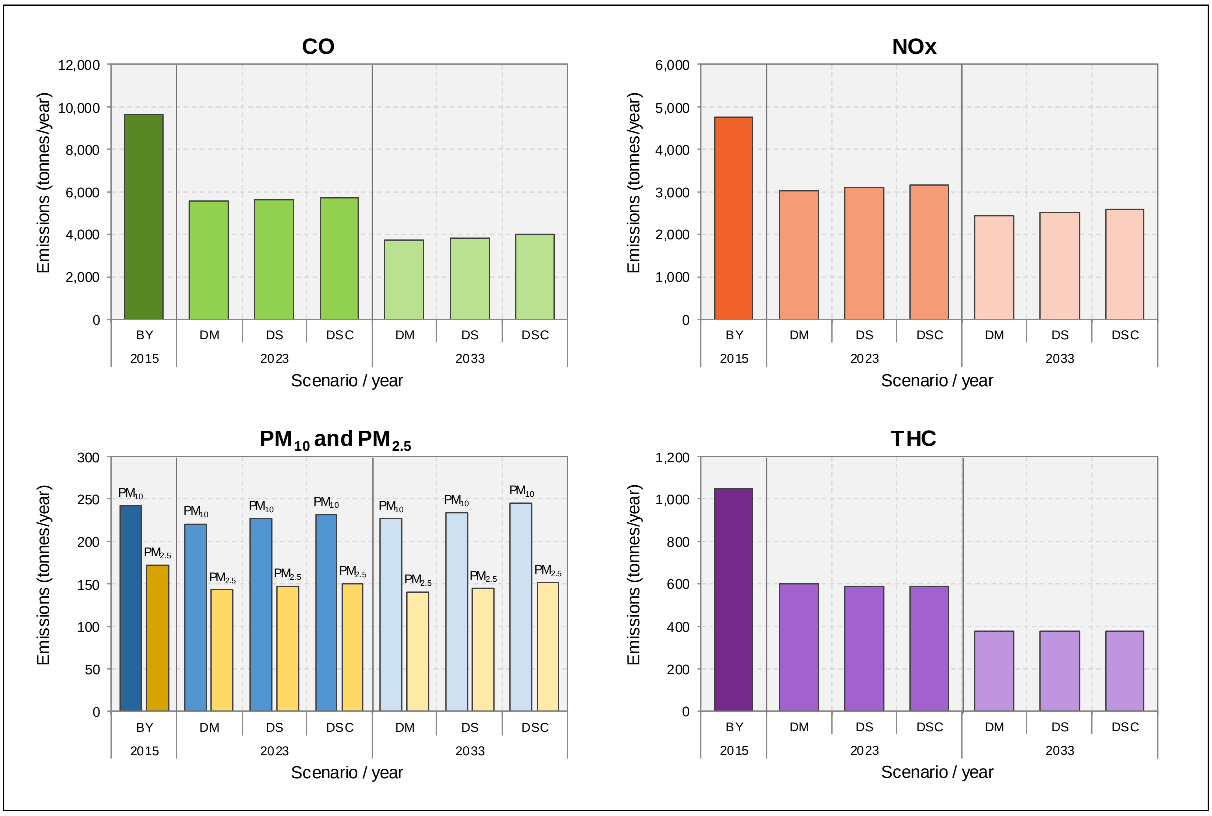

Figure 8-7 Total traffic emissions in the WestConnex GRAL domain

Regulatory worst case scenarios

No additional emission modelling was required for the regulatory worst case scenarios, as the emissions from the ventilation outlets were simply determined by the outlet concentration limits or, in the case of NO_2, the outlet concentration limits in conjunction with the expected traffic results and background concentration.

8.2.4 Evaluation of emission model

The NSW EPA model was evaluated using real-world air pollution measurements in the LCT, bearing in mind that the NSW EPA model is designed for application to surface roads. The findings of the model evaluation are given in **Annexure E**, and are summarised below. Additional analyses of the emission model predictions by vehicle type, and calculations of primary NO_2 emission factors, are provided in the annexure.

- On average, the model overestimated emissions of each pollutant in the tunnel, and by a factor of between 1.7 and 3.3. This overestimation is likely to be due, at least in part, to the following:
  - The overall over-prediction built into the PIARC gradient factors, as well as other conservative assumptions
  - The tunnel environment itself affecting emissions. The piston effect and any forced ventilation in the direction of the traffic flow may combine to produce an effective tail wind that reduces aerodynamic drag on the vehicles in the tunnel (John et al., 1999; Corsmeier et al., 2005)
- There was a strong correlation between the predicted and observed emission rates for CO, NO_x, PM_{10} and $PM_{2.5}$, with an R^2 value of between 0.75 and 0.88
- Different regression slopes were obtained for the eastbound and westbound directions. Gradient effects may not be adequately reflected in the gradient adjustment approach in the model
- For LDVs the predicted emissions were higher than the observed emissions in both the eastbound and westbound tunnels
- For HDVs, emissions of CO, NO_X, PM_{10} and PM2.5 in the eastbound (uphill) tunnel were underestimated by the model, whereas emissions of NO_2 were overestimated. In the westbound tunnel the predicted emissions were considerably higher than the observed emissions, especially for NO_2.

8.3 In-tunnel air quality

The detailed results of the simulation are provided in full in sections 9 and 10 in **Annexure L**. The results demonstrate that the ventilations system would ensure that air in the tunnel would meet the air quality criteria for both the expected traffic cases and the worst case traffic scenarios.

8.4 Local air quality

8.4.1 Overview

The atmosphere is a complex physical system, and the movement of air in a given location is dependent on a number of variables, including temperature, topography and land use, as well as larger-scale synoptic processes. Dispersion modelling is a method of simulating the movement of air pollutants in the atmosphere using mathematical equations. This requires an understanding of the complex interactions and chemical reactions involved, available input data, processing time and data storage limitations. The model configuration particularly affects model predictions during certain meteorological conditions and source emission types. For example, the prediction of pollutant dispersion under low wind speed conditions (typically defined as those less than one metre per second) or for low-level, non-buoyant sources, is problematic for most dispersion models. To accommodate these effects, the model is configured to provide conservative estimates of pollutant concentrations at particular locations. While the models, when used appropriately and with high quality input data, can provide very good indications of the scale of pollutant concentrations and the likely locations of the maximum concentrations occurring, their outputs should not be considered to be representative of exact pollutant concentrations at any given location or point in time (AECOM, 2014b).

8.4.2 Model selection

The GRAMM/GRAL system (version 14.11) was selected for the dispersion modelling for this study for the following reasons:

- It is suitable for regulatory applications and can utilise a full year of meteorological data
- It is a particle model and has the ability to predict concentrations under low-wind-speed conditions (less than one metre per second) better than most Gaussian models (eg CALINE)
- It is specifically designed for the simultaneous modelling of road transport networks, including line sources (surface roads), point sources (tunnel ventilation outlets) and other sources.
- It can take into account vehicle wake effects
- It can characterise pollution dispersion in complex local terrain and topography, including the presence of buildings in urban areas
- It has been validated in numerous studies, as documented by Öttl (2014). These studies have used data sets for:
  - Multiple countries (USA, Norway, Denmark, Germany, Sweden, Austria, Japan, Finland)
  - Multiple source types (power plant stacks, elevated tracers, ground-level tracers, urban roads, street canyons, parking lots and tunnel portals
  - Different terrain types
  - Varying meteorological conditions (high/low wind speeds, stable/unstable atmospheric conditions, etc).

The performance of GRAMM/GRAL has been shown to be at least as good as that of other models.

Although the GRAL system has not been used extensively in Australia, it was used in the assessment of the Waterview Connection tunnels near Auckland, New Zealand (BECA, 2010). The model set up for this project has been tailored to suit the needs of both the study at hand and the regulatory requirements in NSW in relation to air quality.

8.4.3 Model overview

The model system consists of two main modules: a prognostic wind field model (Graz Mesoscale Model – GRAMM) and a dispersion model (GRAL itself). An overview of the GRAMM/GRAL modelling system is presented in **Figure 8-8**. The system has in-built algorithms for calculating emission rates (the grey area of the Figure), but these were replaced by the project-specific emission rates.

GRAMM is the meteorological driver for the GRAL system. Its main features include the use of prognostic wind fields, a terrain-following grid, and the computation of surface energy balance. GRAMM uses roughness lengths, albedo, temperature conductivity, soil moisture content (an average value generated by default), soil heat capacity and emissivity in its calculations. The prognostic wind field model provides a good representation of dynamic effects due to obstacle-influenced air flows, and is capable of accommodating complex topography with high horizontal resolution (Öttl et al., 2003). A grid resolution of less than 10 metres is possible in GRAMM, although larger grid cells tend to be required for larger areas to maintain acceptable processing times.

GRAL is a Lagrangian model, whereby ground-level pollutant concentrations are predicted by simulating the movement of individual 'particles' of a pollutant emitted from an emission source in a three-dimensional wind field. The trajectory of each of the particles is determined by a mean velocity component and a fluctuating (random) velocity component.

GRAL stores concentration fields for user-defined source groups. Up to 99 source groups can be defined (eg traffic, domestic heating, industry), and each source group can have specific monthly and hourly emission variations. In this way annual mean, maximum daily mean, or maximum concentrations for defined periods can be computed. Usually, about 500–600 different meteorological situations are sufficient to characterise the dispersion conditions in an area during all 8,760 hours of the year.

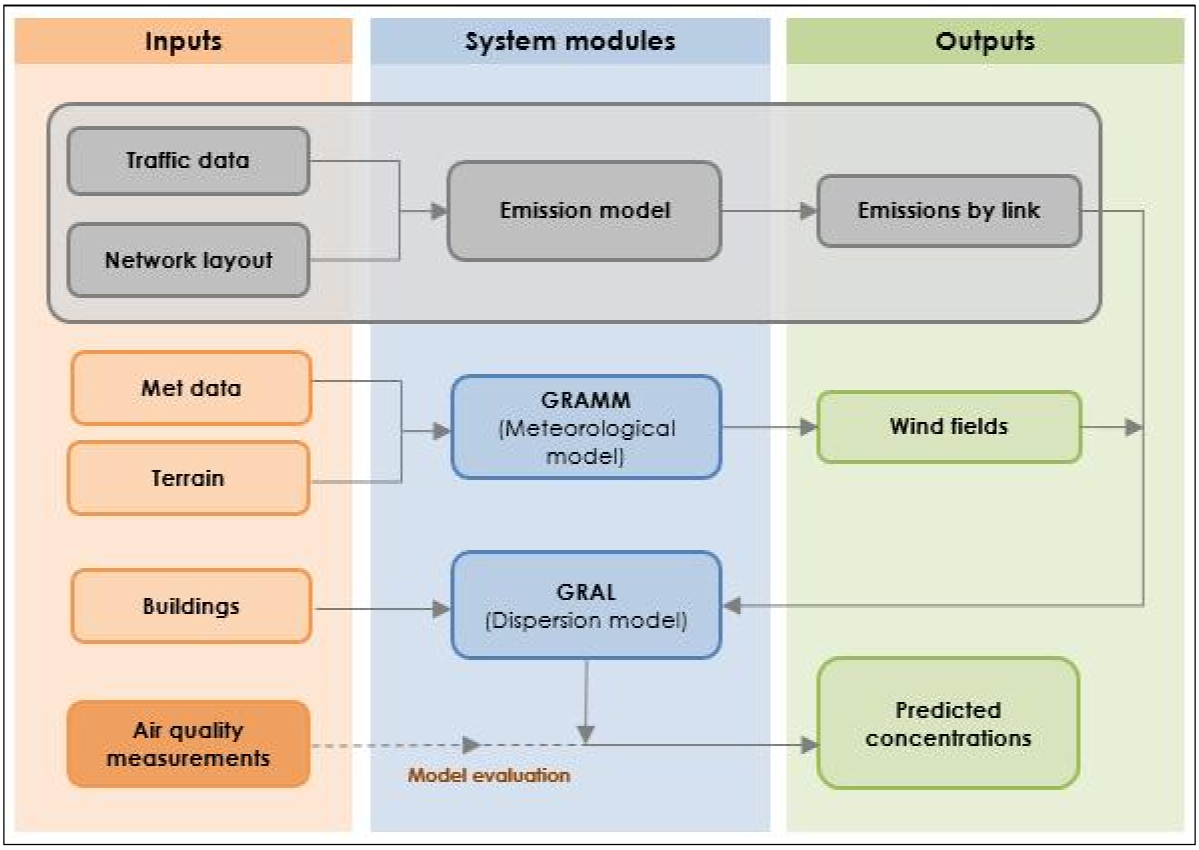

Figure 8-8 Overview of the GRAMM/GRAL modelling system

Other general parameters required by the program include surface roughness length, dispersion time, the number of traced particles (influences the statistical accuracy of results), counting grids (variable in all three directions), as well as the size of the model domain.

Because the simulation of an hourly time series of a whole year would be very time consuming, GRAL computes steady-state concentration fields for classified meteorological conditions (using 3-7 stability classes, 36 wind direction classes, and several wind speed classes). The steady-state concentration field for each classified meteorological situation is stored as a separate file. Based on these results, the concentration fields for the annual mean value, maximum daily mean value and maximum value are calculated using a post-processing routine. Diurnal and seasonal variations for each source group can be defined in GRAL using 'emission modulation factors'. The final result is a time series of concentration that is dependent on the classified meteorological situations and the seasonal and diurnal emission modulation factors.

8.4.4 GRAMM configuration

GRAMM domain and set-up

The GRAMM domain (see **Figure 5-1**) was defined so that it covered most of the WestConnex project with a sufficient buffer zone to minimise boundary effects in GRAL. The domain was 23 kilometres along the east-west axis and 23 kilometres along the north-south axis.

Table 8-11 presents the meteorological and topographical parameters that were selected in GRAMM.

Table 8-11 GRAMM set-up parameters

Parameter	Input/value
Meteorology	
Meteorological station	BoM Canterbury Racecourse AWS (Station 066194)
Period of meteorology	1 January 2015 – 31 December 2015
Meteorological parameters	Wind speed (m/s), Wind direction (^{o}), stability class (1-7)
Number of wind speed classes	10
Wind speed classes (m/s)	0-0.5, 0.5-1.5, 1.5-2.5, 2.5-3.5, 3.5-4.5, 4.5-5.5, 5.5-6.5, 6.5-7.5, 7.5-9 >9
Number of wind speed sectors	36
Sector size (degrees)	10
Anemometer height above ground (m)	10
Concentration grids and general GRAMM input	
GRAMM domain in UTM (m)	N = 6259000, S = 6236000, E = 315000, W = 338000
Horizontal grid resolution (m)[(a)]	200
Vertical thickness of the first layer (m)[(b)]	10
Number of vertical layers	15
Vertical stretching factor[(c)]	1.2
Relative top level height (m)[(d)]	730
Maximum time step (s)[(e)]	10
Modelling time (s)	3,600
Relaxation velocity[(f)]	0.1
Relaxation scalars[(f)]	0.1

(a) Defines the horizontal grid size of the flow field.
(b) Defines the cell height of the lowest layer of the flow field. Typical values are 1–2 metres.
(c) Defines how quickly cell heights increase with height above ground. For example, a factor of 1.1 means a cell is 10 per cent higher than the one below it.
(d) Defined as the relative height from the lowest level in the domain.
(e) Defines the amount of time taken to ensure that calculations are done efficiently but stably.
(f) These are chosen to ensure the numerical stability of GRAMM simulations.

Terrain

Terrain data were processed within the GEOM (Geographical/Geometrical grid processor) component of GRAMM. As described in **section 6.2**, the terrain data for the GRAMM domain were obtained from the ASTER website, and converted into a text file for use in GRAMM. The terrain data used in GRAMM had a resolution of 30 metres. The terrain within the study area 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. Although the terrain is not especially complex, a spatially-varying terrain file was used to provide an accurate reflection of the situation.

NB: All heights for buildings, ventilation outlets and dispersion modelling results are relative to the heights in the terrain file. At the node points in the terrain file the heights are equivalent to AHD heights. However, at all other locations the heights in the terrain file are interpolated. This means that there would tend to be small differences between the heights in the model and AHD heights across the domain.

Land use

A spatially-varying land use file was developed for use in the assessment. Various land use types can be specified in GRAMM, and CORINE (Coordination of Information on the Environment) land cover parameters can be imported. The land use file was based on a visual classification using aerial imagery base maps in ArcGIS. Firstly, a polygon shapefile was digitised using eight CORINE land cover classes (Continuous Urban Fabric, Discontinuous Urban Fabric, Industrial or Commercial Units, Road and Rail Networks, Airports, Green Urban Areas/Sports and Leisure Facilities, Forests and Water Bodies), which are also used in GRAMM. Within the GRAMM domain, the visually distinguishable areas were then classified according to these eight classes. The resulting file was converted to a 50 metre resolution ASCII raster for use within GRAMM. As discussed in **section 6.2**, the land use in the study area primarily consists of urban areas with pockets of small recreational reserves and waterbodies.

Reference meteorological data

GRAMM features a method for computing wind fields in complex terrain. The flow field computations are based on classified 'meteorological situations' (wind direction, wind speed, dispersion classes and frequency) that are derived from local wind observations and stability classes. The meteorological requirements for the model are comparatively low, involving an assessment of atmospheric stability status (classified as stable, neutral, or unstable), wind speed, and wind direction. As GRAMM uses input data from a single meteorological station, it is important to select a site that is both reliable and representative of meteorology within the domain. As discussed in **Annexure H**, meteorological data from the BoM Canterbury Racecourse AWS site for 2015 were selected for use in GRAMM to determine three-dimensional wind fields across the modelling domain.

Cloud cover is not recorded at the BoM Canterbury Racecourse site. The stability classes (classes 1–7) required for GRAMM were therefore calculated using the temperature at 10 metres above ground level and cloud content data from the BoM Sydney Airport AMO meteorological station.

Figure 8-9 provides an example of a wind field situation across the GRAMM domain. In total, 1,040 different wind fields were produced to represent the different conditions in each hour of the meteorological file. The wind fields are based upon the wind speeds and wind directions at the BoM Canterbury Racecourse AWS site. In this particular example, winds are from a northwest direction, with higher wind speeds over elevated terrain to the northeast. The terrain of the study area was not especially complex (i.e. relatively flat), and this is reflected in the broadly similar wind conditions across the area. The wind field shows how the dispersion of a pollutant that is emitted from any point in the domain would be affected.

GRAMM Re-Order function

The GRAMM 'Re-Order' function was used to refine the order of the predicted wind fields to provide a better match to the observations the BoM Canterbury Racecourse site. GRAMM simulates flow fields based on a time series of wind speed, direction and stability class at a specific point usually located within the GRAMM domain (in this case, the BoM Canterbury Racecourse site). GRAMM then breaks up the time series into many frequency bins of different 'dispersion situations' based on the measured meteorological data. At the end of the GRAMM simulation, a wind field is stored corresponding to each dispersion situation (in this case, 1,040 situations), which by default are ordered by frequency of occurrence.

The Re-Order function searches within these generated flow fields and fits ('re-orders') these to better match the observed data at the location of the meteorological measurement. For example, flow field number 500 may best fit dispersion situation number one and so on. In this example, flow field number 500 is renamed to be wind field number one which corresponds to the highest frequency situation. This procedure is then repeated for all dispersion situations.

The Re-Order function is applied as it is understood that in meteorological modelling, the initial model results may not be realised in full detail, especially in complex terrain. Therefore, the Re-Order function is applied as a type of 'nudging' mechanism to ensure that predicted meteorological conditions are representative of the observed meteorology. It is noted that the Re-Order function only re-orders those wind fields with similar stability classes (eg a flow field with stable conditions is only matched to other flow fields with stable conditions).

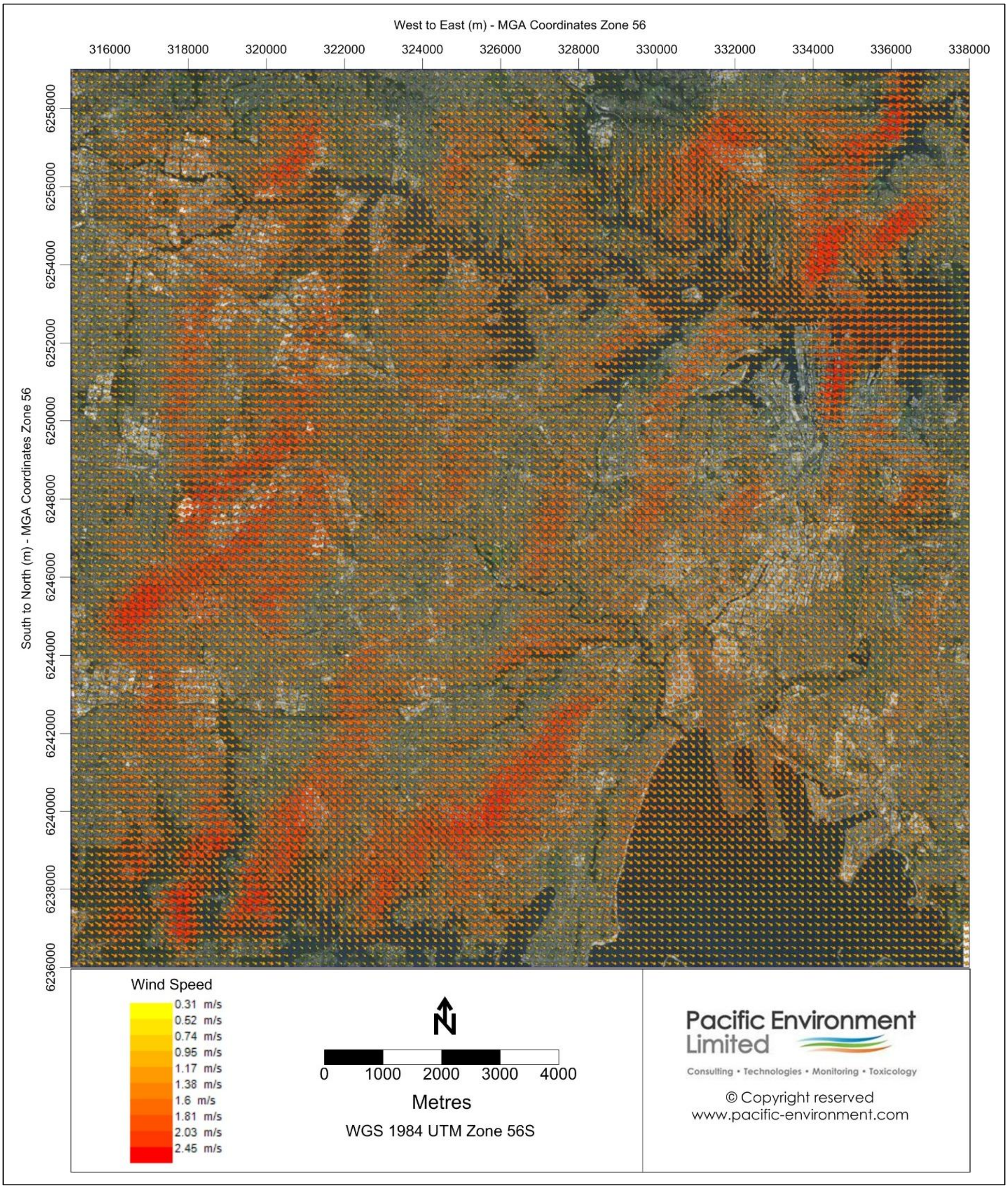

Figure 8-9 Example of a wind field across the GRAMM domain (grid system MGA94)

8.4.5 Evaluation of meteorological model

Wind speed and wind direction values were extracted for each of the meteorological stations shown in **Figure 6-3**, and a statistical analysis was carried out to compare these extracted (predicted) data with the observations at each of those sites. This work is described in **Annexure H**.

The analysis showed a very good agreement between the predicted and observed wind speeds at the Canterbury Racecourse station, which was the site used for modelling. There was a fair agreement at Sydney Olympic Park (Archery Centre) and Sydney Airport, but a poorer agreement at the OEH sites. These results are not unusual, as GRAMM (like other models such as CAL3CHQR) uses meteorological data from one location to represent the domain. On balance, the level of agreement for the sites other than Canterbury Racecourse is considered to be acceptable given that these data were not included in the GRAMM modelling.

8.4.6 GRAL configuration – expected traffic scenarios

The following sections describe the configuration of GRAL for the expected traffic scenarios, and cover all parameters except emissions (described earlier).

GRAL domains and main parameters

The GRAL domain was shown in **Figure 5-1**. **Table 8-12** presents the main parameters selected in GRAL for the model runs.

GRAL was configured to provide predictions for a Cartesian grid of points with an equal spacing of 10 metres in both the x and y directions. For the GRAL domain, the total number of points in the grid was around 1.8 million. Typically, GRAMM simulations are performed with a coarse resolution relative to that of the GRAL resolution (in this case a GRAMM resolution of 200 metres compared with the GRAL resolution of 10 metres) to capture meteorological conditions over a larger study area. For the project, the terrain was resolved even further by selecting the original terrain file (with a much higher resolution of 30 metres) to be included in the GRAL model.

Table 8-12 GRAL configuration

Parameter	Value(s)
General	
Domain in UTM (WestConnex GRAL)	N = 6254000, S = 6239000, E = 322500, W = 334500
Dispersion time (s)	3600
Number of particles per second[(a)]	400 for roads and outlets
Surface roughness[(b)]	0.5
Latitude (˚)[(c)]	-33
Buildings	None
Concentration grid	
Vertical thickness of concentration layers (m)	1
Horizontal grid resolution (m)	10
Number of horizontal slices	1
Height above ground level (m)[(d)]	3 (effectively ground level)

(a) Defines the total number of particles released in each dispersion situation.

(b) Defines the roughness length in the whole model domain. The roughness length alters the shape of the velocity profile near the surface.

(c) Average latitude of the model domain.

(d) Defines the height above ground for each concentration grid. In specific reference to the GRAL model, a height of 3m represents concentrations effectively at ‘ground level’. In the GRAL model, 0m is the direct boundary layer which contains boundary conditions not appropriate for accurate concentration predictions.

Representation of buildings

The size of the GRAL domain and the fine grid resolution meant that building data could not be practically included in the modelling. Due to the complex nature of GRAL's prognostic building calculations, the ideal model set-up to account for the effects of buildings would be a maximum domain size of around two kilometres by two kilometres, with a maximum horizontal grid resolution of five metres. To include buildings in the project set-up, and utilising GRAL's prognostic building calculation approach, would have resulted in extremely long model run times (in the order of weeks per scenario). Moreover, the post-processing of the results at a five-metre resolution across a modelling domain of 12 kilometres by 15 kilometres would have been impractical.

It is worth noting however, that there are only a small number of tall buildings in proximity to the proposed ventilation outlets, and therefore the effects of building downwash (refer to **Annexure B**) would probably have been rather limited.

Contour plots

The Air Quality Assessment Report presents contour plots showing concentrations, and changes in concentration, across the entire M4-M5 Link GRAL domain. The concentrations were based on a Cartesian grid of points with an equal spacing of 10 metres in the x and y directions. This resulted in 1.8 million grid locations across the M4-M5 Link GRAL domain.

Discrete receptors

Receptors are defined by NSW EPA as anywhere someone works or resides, or may work or reside, including residential areas, hospitals, hotels, shopping centres, playgrounds, recreational centres, etc. 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.

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

- 'Community receptors'. These were taken to be representative of particularly sensitive locations such as schools, child care centres and hospitals within a zone around 500 to 600 metres either side of the project corridor, and generally near significantly affected roadways. This zone was sufficiently large to capture the largest impacts of the project. For these receptors, a detailed approach was used to calculate the total concentration of each pollutant. This involved the combination of the contemporaneous road/outlet time series of concentrations from GRAL and the background time series of concentrations, stated as a one hour mean for each hour of the year in each case. In total, 40 community receptors were included in the assessment
- 'Residential, workplace and recreational (RWR) receptors'. These were all discrete receptor locations along the project corridor, and mainly covered residential and commercial land uses. For these receptors, a simpler[26] 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 in space - 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 therefore not designed for the assessment of changes in total population exposure. **Appendix K** (Technical working paper: Human health risk assessment) of the EIS 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.

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

The main reason for the distinction was to permit a more detailed analysis of short-term metrics for community receptors. The number of such receptors that could be included was dictated by the limit on the number of time series for individual receptors that could be extracted from GRAL. Due to the computational requirements of GRAL, it was not possible to include a large number of time series for community receptors. **Figure 8-10** shows the locations of the various discrete receptors.

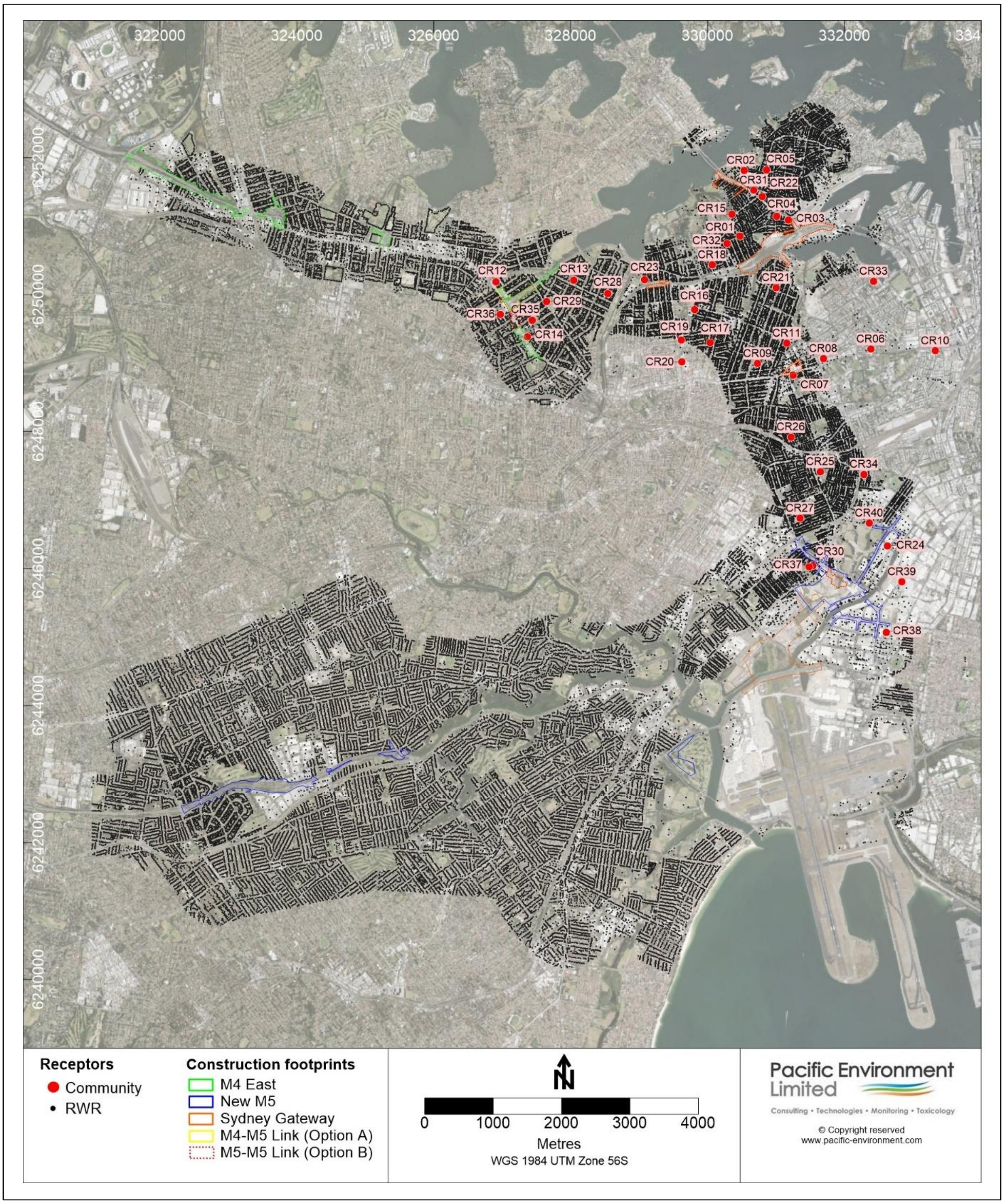


Figure 8-10 Modelled discrete receptor locations and project footprints

A full list of community receptors is given in **Table 8-13**, and the numbers of RWR receptors are listed by category in **Table 8-14**. It is worth pointing out that although not all particularly sensitive receptors along the project corridor were included in the first type, they were included in the second type. This included, for example, aged care facilities and some additional schools. This approach was considered to be appropriate, in that it allowed all relevant receptors to be included in the assessment while recognising model limitations.

The list of RWR receptors was based on the receptors defined for the three separate WestConnex project corridors (M4 East, New M5 and M4-M5 Link). The following were excluded:

- Any receptors outside the GRAL domain for the M4-M5 Link
- Any receptors within the project footprint for M4-M5 Link (and other projects). This included a provisional footprint for the Sydney Gateway project. All the project footprints are shown in **Figure 8-10**, including Options A and B for the M4-M5 Link
- Any receptors that were duplicated across projects.

Table 8-13 Full list of community receptors (grid system MGA94)

Receptor code	Receptor name	Address	Suburb	Receptor location	
				x	y
CR01	The Jimmy Little Community Centre	19 Cecily Street	Lilyfield	330469.0	6250853.6
CR02	Balmain Cove Early Learning Centre	35 Terry Street	Rozelle	330533.2	6251815.0
CR03	Rosebud Cottage Child Care Centre	5 Quirk Street	Rozelle	331181.8	6251090.1
CR04	Sydney Community College	2A Gordon Street	Rozelle	331009.0	6251145.1
CR05	Rozelle Total Health	579 Darling Street	Rozelle	330859.1	6251819.4
CR06	Laurel Tree House Child Care Centre	61 Arundel Street	Glebe	332384.3	6249205.6
CR07	Bridge Road School	127 Parramatta Road	Camperdown	331254.2	6248824.9
CR08	NHMRC Clinical Trials Centre	92-94 Parramatta Road	Camperdown	331691.0	6249068.3
CR09	Annandale Public School	25 Johnston Street	Annandale	330729.7	6248994.2
CR10	The University of Notre Dame Australia	Broadway	Chippendale	333325.6	6249180.8
CR11	Laverty Pathology	34C Taylor Street	Annandale	331156.8	6249291.8
CR12	Little VIPs Child Care Centre	113 Dobroyd Parade	Haberfield	326909.7	6250187.6
CR13	Dobroyd Point Public School	89 Waratah Street	Haberfield	328042.6	6250207.3
CR14	Peek A Boo Early Learning Centre	183 Parramatta Road	Haberfield	327368.5	6249387.7
CR15	Rozelle Child Care Centre	450 Balmain Road	Lilyfield	330358.2	6251178.8
CR16	Sydney Secondary College Leichhardt Campus	210 Balmain Road	Leichhardt	329811.3	6249783.5
CR17	Rose Cottage Child Care Centre	1 Coleridge Street	Leichhardt	330035.5	6249303.4
CR18	Inner Sydney Montessori	10 Trevor Street	Lilyfield	330064.6	6250434.1
CR19	Leichhardt Little Stars Nursery & Early Learning Centre	10 Wetherill Street	Leichhardt	329616.7	6249336.0
CR20	Leichhardt Montessori Academy	67 Norton Street	Leichhardt	329627.1	6249017.5
CR21	St Basil's Sister Dorothea Village	252 Johnston Street	Annandale	330999.9	6250102.6
CR22	St Thomas Child Care Centre	668 Darling Street	Rozelle	330802.2	6251428.8
CR23	Billy Kids Lilyfield Early Learning Centre	64 Charles Street	Lilyfield	329081.0	6250219.6
CR24	Little Learning School	95 Burrows Road	Alexandria	332629.9	6246331.2
CR25	Newtown Public School Combined Out of School Hours Care	Norfolk Street	Newtown	331647.3	6247409.4
CR26	The Athena School	28 Oxford Street	Newtown	331217.0	6247918.8
CR27	Camdenville Public School	Laura Street	Newtown	331350.5	6246731.0
CR28	St Joan of Arc Home for the Aged	7 Tillock Street	Haberfield	328541.1	6250016.5

Receptor code	Receptor name	Address	Suburb	Receptor location	
				x	y
CR29	Inner West Education Centre	207 Ramsay Street	Haberfield	327649.7	6249901.6
CR30	St Peters Community Pre-school	Church Street	St Peters	331538.0	6246040.3
CR31	Rozelle Public School	663 Darling Street	Rozelle	330675.7	6251523.6
CR32	Lilyfield Early Learning Centre	2/6 Justin Street	Lilyfield	330282.0	6250748.6
CR33	Sydney Secondary College Blackwattle Bay	Taylor Street	Glebe	332427.1	6250195.9
CR34	Erskineville Public School	13 Swanson Street	Erskineville	332284.6	6247373.8
CR35	Haberfield Public School	Bland Street	Haberfield	327441.0	6249631.0
CR36	The Infants Home	17 Henry Street	Ashfield	326972.5	6249711.5
CR37	St Peters Public School	Church Street	St Peters	331483.9	6246029.1
CR38	Active Kids Mascot	18 Church Avenue	Mascot	332608.9	6245071.2
CR39	Alexandria Early Learning Centre	3/100 Collins Street	Alexandria	332838.5	6245806.1
CR40	Sydney Park Childcare Centre	177 Mitchell Road	Alexandria	332360.0	6246661.5

Table 8-14 Summary of RWR receptor types

Receptor type	Number	% of total
Aged care	20	0.02%
Child care/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)]

(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.

NB: At Haberfield, Option B for the M4-M5 Link had a larger footprint than Option A. The additional area contained 25 RWR receptors that had to be removed from the list in **Table 8-14** for the assessment of Option B, and the receptors listed in the Table effectively relate to Option A. However, rather than duplicating the entire assessment for Options A and B, a brief commentary is provided on the results. Because Option B involved removing receptors rather than adding them, and because all 25 receptors were commercial premises, only the changes in $PM_{2.5}$ have been reported.

Mesh Block centroids

Appendix K (Human health risk assessment) of the EIS includes a population exposure assessment based on annual mean $PM_{2.5}$. A population-weighted average $PM_{2.5}$ concentration has been calculated on the basis of the smallest statistical division provided by the Australian Bureau of Statistics, termed 'Mesh Blocks'. These are small blocks that cover an area of around 30 urban residences.

For each scenario, the annual mean $PM_{2.5}$ concentration was determined for the centroid of the Mesh Blocks in the GRAL domain, and these are shown **Figure 8-11**. It should be noted that this information was not used in the air quality assessment, and therefore the results are not presented in this report.

Figure 8-11 Mesh Block centroids in the GRAL domain

Elevated receptors

The main emphasis in the assessment was on ground-level concentrations (as specified in the 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 have been different to the impacts at ground level, and therefore these were evaluated separately. In addition, it was considered important to understand, provisionally, how future building developments (eg apartment blocks) in the domain might be restricted from an air pollution perspective.

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 8-12**, and the overall frequency distribution is shown in **Figure 8-13**.

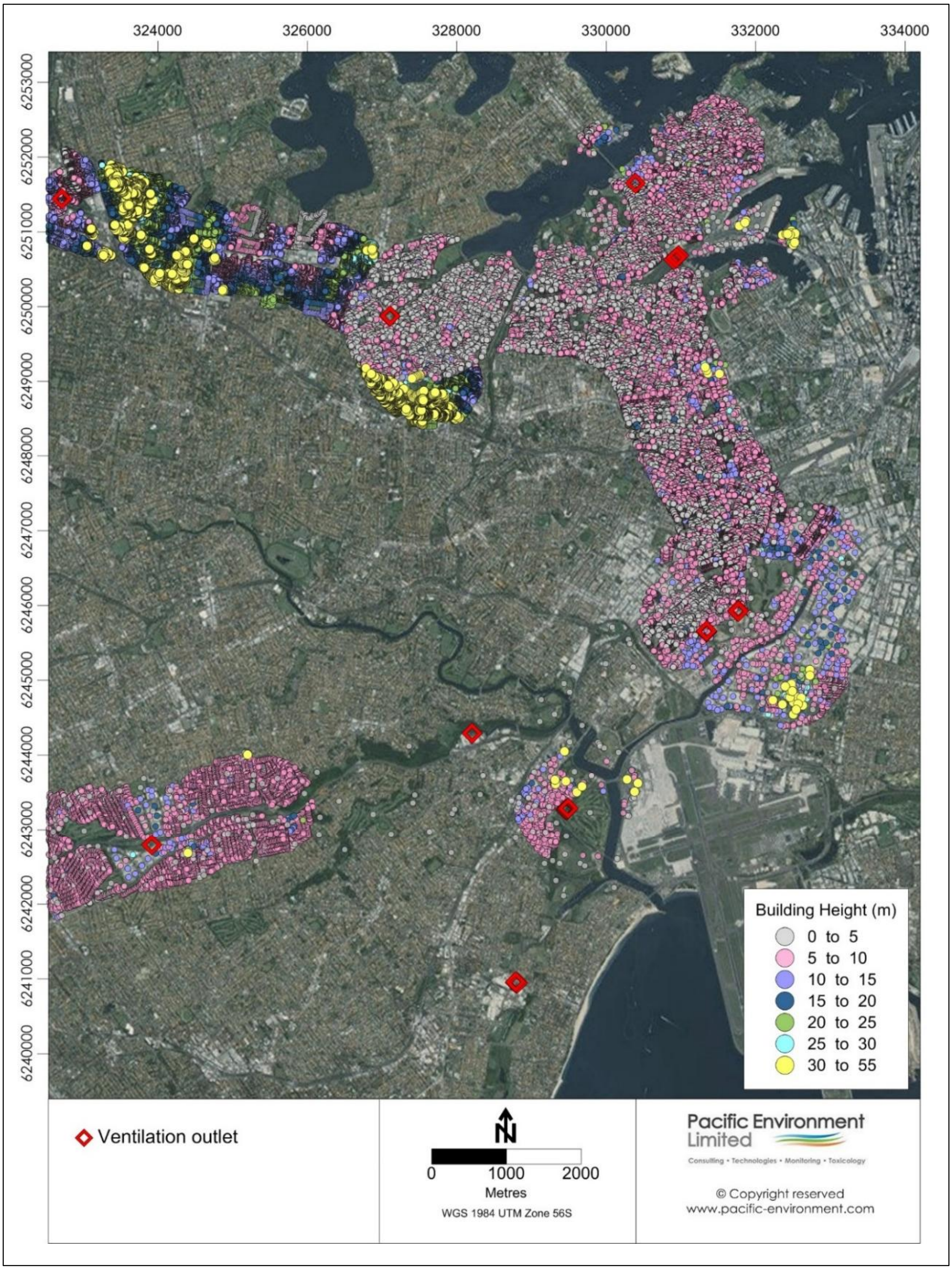


Figure 8-12 Sample of building heights in the GRAL domain (grid system MGA94)

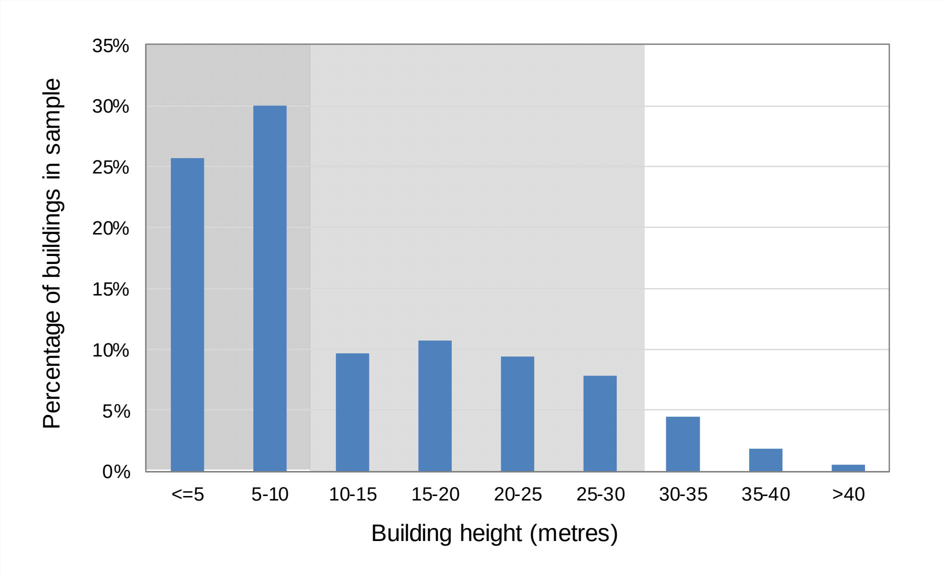


Figure 8-13 Frequency distribution of building heights

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. Only 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 WestConnex domain was conducted across the GRAL domain.

Given the provisional nature of this part of the assessment, it 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. Only the changes in the $PM_{2.5}$ concentration are therefore presented in the report.

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 the height of 10 metres
- 2033-DM at the height of 30 metres
- 2033-DSC at the height of 10 metres
- 2033-DSC at the height of 30 metres
- Change in annual PM2.5 (2033-DSC minus 2033-DM) at the height of 10 metres
- Change in annual $PM_{2.5}$ (2033-DSC minus 2033-DM) at the height of 30 metres.

Ventilation outlets

Locations and height

The locations and heights (above ground level) of the ventilation outlets included in the assessment are given in **Table 8-15**. The outlet diameters used in the assessment were either fixed or variable, depending on the assumed operational configuration. This is explained later in this section of the report. The ventilation outlets for the 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.

Table 8-15 Ventilation outlets: locations and heights

Ventilation outlet	Tunnel project	Location	Traffic direction	Ventilation outlet(s)	Outlet location (MGA94)		Ground elevation (m)	Outlet height above 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	EB	PAR-1	327100	6249870	12.4	25.0
C	M4 East	Underwood Road	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	WB	PAR-2	327108	6249875	12.1	25.0
H	WHT	Rozelle (west)	SB	ROZ-1	330906	6250633	4.2	35.0
I	M4-M5 Link/Iron Cove Link	Rozelle (east)	Various	ROZ-2	330972	6250679	5.0	35.0
J	M4-M5 Link/Iron Cove Link	Rozelle (mid)	Various	ROZ-3	330939	6250656	4.5	35.0
K	M4-M5 Link	St Peters interchange	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	Iron Cove Link	Rozelle near Iron Cove	NB	ICL-1	330391	6251650	23.2	20.0
M	F6 Extension	Arncliffe	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	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

(a) Taken from GRAMM terrain file.

Volumetric flow rate

The project would be serviced by ventilation systems, the operating parameters of which would vary depending on traffic volume and emissions. The volume of air to be extracted from the tunnels, and hence the number and output of the fans in use, would therefore vary by time of day. This would result, in turn, in hourly-varying outlet exit velocities, effective outlet diameters (in some cases), and emission rates. A number of assumptions were required to accommodate these factors in GRAL.

The calculation of the volumetric air flow (in m^3/s) for each of the proposed tunnel ventilation outlets is described in **Annexure L**. The required air flow was provided for each hour of the day based on the projected traffic data for expected operation and a traffic speed of 80 kilometres per hour. An example of the diurnal air flow profile is shown as the blue line in **Figure 8-14**.

It was necessary to simplify the ventilation profile for use in GRAL, given the large number of sources being modelled. Each ventilation profile was simplified to three phases (nominally 'high', 'medium' and 'low'), or in some cases two phases. To maintain a degree of conservatism in the dispersion modelling, the simplified air flows were, as far as possible, set to values that were within or close to the envelope of the profile. The simplified profile is shown as the blue columns in the Figure. The air flows that were applied in GRAL for each scenario and each ventilation outlet are given in **Annexure I**.

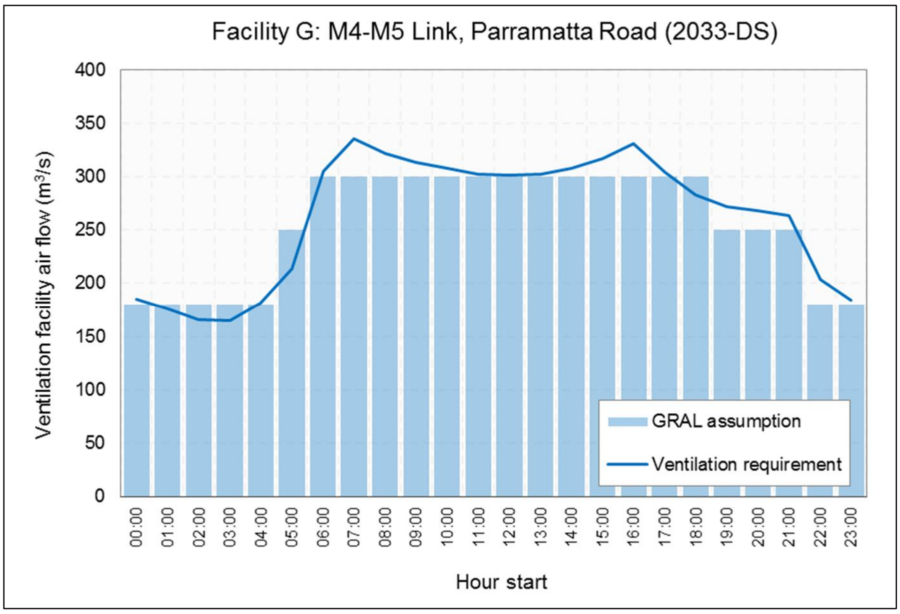


Figure 8-14 Example of ventilation air flow profile used in GRAL

The volumetric air flows for the existing M5 East outlet were determined from measurements during 2014, and a simplified diurnal profile was developed for GRAL following the approach described above for the proposed ventilation outlets. The air flows were converted to exit velocities using a cross-sectional area for the outlet of 42.3 square metres (effective circular diameter of 7.3 metres).

Effective outlet diameter and exit velocity

The fan configurations of the different ventilation outlets were slightly different. Each ventilation outlet was modelled as one of the following three types:

- Ventilation outlets with a single, fixed-diameter physical outlet for air. The outlet had a varying exit velocity, depending on the air flow
- Ventilation outlets with a single physical outlet for air, but with multiple variable-speed fans, with the number in use at any given time being determined by the in-tunnel ventilation requirement.

Ventilation outlets C and F had this configuration. The effective outlet diameter and exit velocity was based on the volumetric air flow. It was assumed that:

- Each fan would have a rating of 200 m^3/s, but would never be used at its maximum capacity
- At least two fans would be in use at all times
- So, for example, an air flow of less than 200 m^3/s would require two fans, an air flow of 400 m^3/s would require three fans, and an air flow of 750 m^3/s would require four fans

· Ventilation outlets with multiple, fixed-diameter sub-outlets. The sub-outlets had a varying exit velocity, depending on the air flow and the number of sub-outlets operating.

The time-varying outlet diameters, and outlets in use, were represented in GRAL using different source groups in combination with modulation factors to switch source groups on and off by time period, as required.

The resulting effective outlet diameters and exit velocities are given in **Annexure I**.

Outlet temperature

Diurnal temperature profiles are provided for each proposed ventilation outlet in **Annexure L**. Separate profiles were determined for summer and winter, and as minimum, average and maximum values. However, the temperature profiles were only produced for the 2023-DSC and 2033-DSC scenarios. For simplicity and practicality in GRAL, and given the uncertainty in the tunnel temperature model, a single exhaust temperature for the whole year was defined for each ventilation outlet, and the following approach was used in any given year (ie 2023 or 2033):

· For the cumulative scenario, the corresponding annual average temperature from the ventilation study was used in GRAL. This was taken as the average of the summer and winter hourly average temperatures in the ventilation report

· For the Do Minimum and Do Something scenarios, the annual average minimum temperature was used in GRAL. Again, this was based on the data in the ventilation report (ie the average of the summer and winter hourly minimum temperature profiles). For these scenarios the minimum temperature was selected as a precautionary assumption in the absence of specific information for the scenarios. That is, it would be likely to result in poorer dispersion – and hence higher model impact predictions - than the average temperature, all else being equal.

This approach is illustrated in **Figure 8-15**.

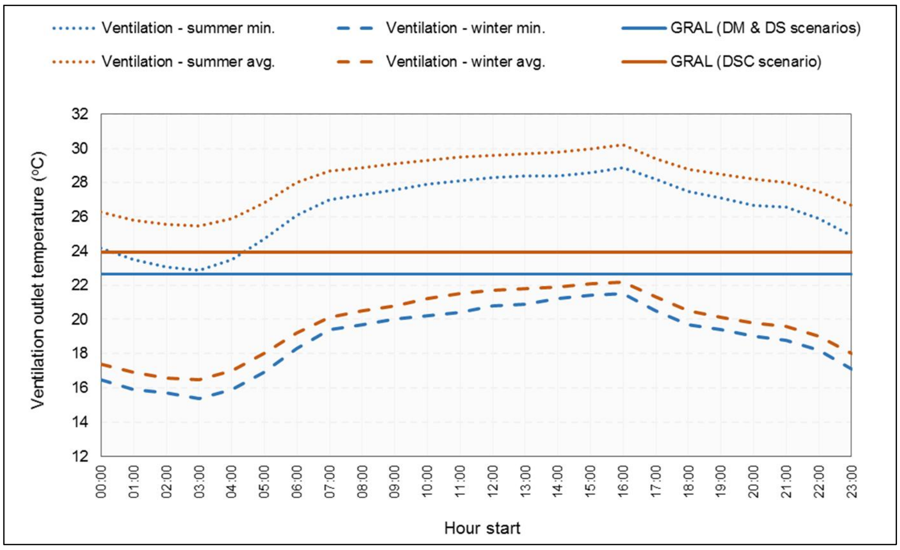


Figure 8-15 Example of outlet temperature used in GRAL (ventilation outlet F)

The temperature of the air in the existing M5 East outlet did not vary greatly during the day or from month to month. A constant temperature of 30°C, reflecting the annual average, was therefore used.

The temperatures used for each scenario and outlet are given in **Annexure I**.

The uncertainty in the outlet temperature was addressed through sensitivity testing. For the sensitivity testing (applicable to all outlets), upper and lower bound temperatures that were 10°C higher and lower than an average of 25°C were applied.

8.4.7 GRAL configuration – regulatory worst case scenarios

Overview

As noted earlier, the objective of the regulatory worst case scenarios was to demonstrate that compliance with the concentration limits for the tunnel ventilation outlets would guarantee acceptable ambient air quality.

The regulatory worst case assessment involved a separate modelling exercise for the tunnel ventilation outlets only, although for NO_2 the process was more involved and required the consideration of contributions from other sources. In the case of maximum one hour NO_2, a second modelling step and contemporaneous assessment were required.

The concentration limits for the tunnel ventilation outlets – taken from the NorthConnex, M4 East and New M5 conditions of approval – are shown in **Table 8-16**. These were converted to mass emission rates (in kg/h) based on assumed ventilation settings, as described below.

Table 8-16 Concentration limits for ventilation outlets

Pollutant	Limit concentration (mg/m^3)
PM_{10}	1.1[(a)]
$PM_{2.5}$	1.1
NO_X	20.0
NO_2	2.0
CO	40.0
VOC/THC	4.0

(a) Stated as 'solid particles' in the conditions of approval.

The assumptions for the ventilation outlets are summarised in **Annexure I**.

Work undertaken for the M4 East air quality assessment showed that the predicted concentrations were not sensitive to the air flow assumption (WDA, 2015). To err on the side of caution in the M4-M5 Link regulatory worst case, a relatively low exit velocity was used for each ventilation outlet. For each ventilation outlet, the lowest exit velocity of the different source groups in GRAL from the corresponding expected traffic scenario was determined. The corresponding air flows and emissions for the regulatory worse case scenarios were calculated.

The temperature of the air from the outlets in the regulatory worst scenarios was not known, as these scenarios do not represent any real-world conditions. A 'typical' outlet temperature of 25°C was therefore assumed for these scenarios.

For the different pollutants and metrics, the next steps are described below.

Approach for CO, PM_{10}, $PM_{2.5}$ and THC

For these pollutants the next steps were as follows:

1. The worst case scenario for the tunnel ventilation outlets only was identified by modelling the outlet contribution to annual mean $PM_{2.5}$ in all four scenarios (i.e. RWC-2023-DS, RWC-2023-DSC, RWC-2033-DS, RWC-2033-DSC). The worst case scenario was determined to be RWC-2033-DSC[27]

2. The RWC-2033-DSC scenario was used to model the outlet contributions to CO (maximum one hour), PM_{10} (annual and maximum 24 hour), $PM_{2.5}$ (annual and maximum 24 hour) and THC (maximum one hour)

3. The maximum contribution of tunnel ventilation outlets at any of the 86,375 RWR receptors in the GRAL domain and in the RWC-2033-DSC scenario was determined.

Approach for annual mean NO_2

For annual mean NO_2 the next steps were:

1. The outlet contributions to annual mean NOx at all RWR receptors in the GRAL domain were determined in all four RWC scenarios

2. The outlet NOx for each RWC scenario was added to the corresponding surface road NOx and mapped background NOx, and the outlet contribution to NO_2 at each RWR receptor was calculated in the same way as in the expected traffic cases

3. The maximum contribution of tunnel ventilation outlets to NO_2 at any of the RWR receptors in each scenario was determined.

Approach for maximum one hour NO_2

For maximum one hour NO_2 the next steps were:

1. The outlet contributions to maximum one hour NOx at all RWR receptors in the GRAL domain were determined in all four RWC scenarios

2. A small domain (two kilometres by two kilometres) was defined around each ventilation facility area for the M4-M5 Link. These domains are shown in **Figure 8-16**. The small domain for Rozelle/Iron Cove Link included the Iron Cove Link northbound facility, and small domain for St Peters interchange included the facility for New M5

3. The RWR receptors in the each small domain were ranked in terms of the largest ventilation outlet contributions to one hour NO_X, and the 'top 10' receptors were identified. These receptors are shown in **Figure 8-17**, **Figure 8-18** and **Figure 8-19**

4. The GRAL model was re-run for the top 10 receptors to obtain a time series for NO_X

5. A contemporaneous assessment was conducted for the top 10 receptors to combine the background contributions, GRAL surface road predictions (expected traffic) and GRAL outlet prediction (RWC) for NO_X

6. The NO_X concentration in each hour was converted to a maximum NO_2 concentration, and the background, road and outlet contributions were calculated. The overall maximum outlet contribution to NO_2 was then determined. The outlet contribution to total NO_2 was also determined for the hour with the maximum total NO_2 concentration.

[27] Although it was anticipated that the 2033-DSC scenario would tend to give the highest concentrations as it has the most ventilation outlets, this could not be stated definitively beforehand because of the assumption relating to exit velocities (i.e. using the lowest exit velocities from expected traffic case scenarios).

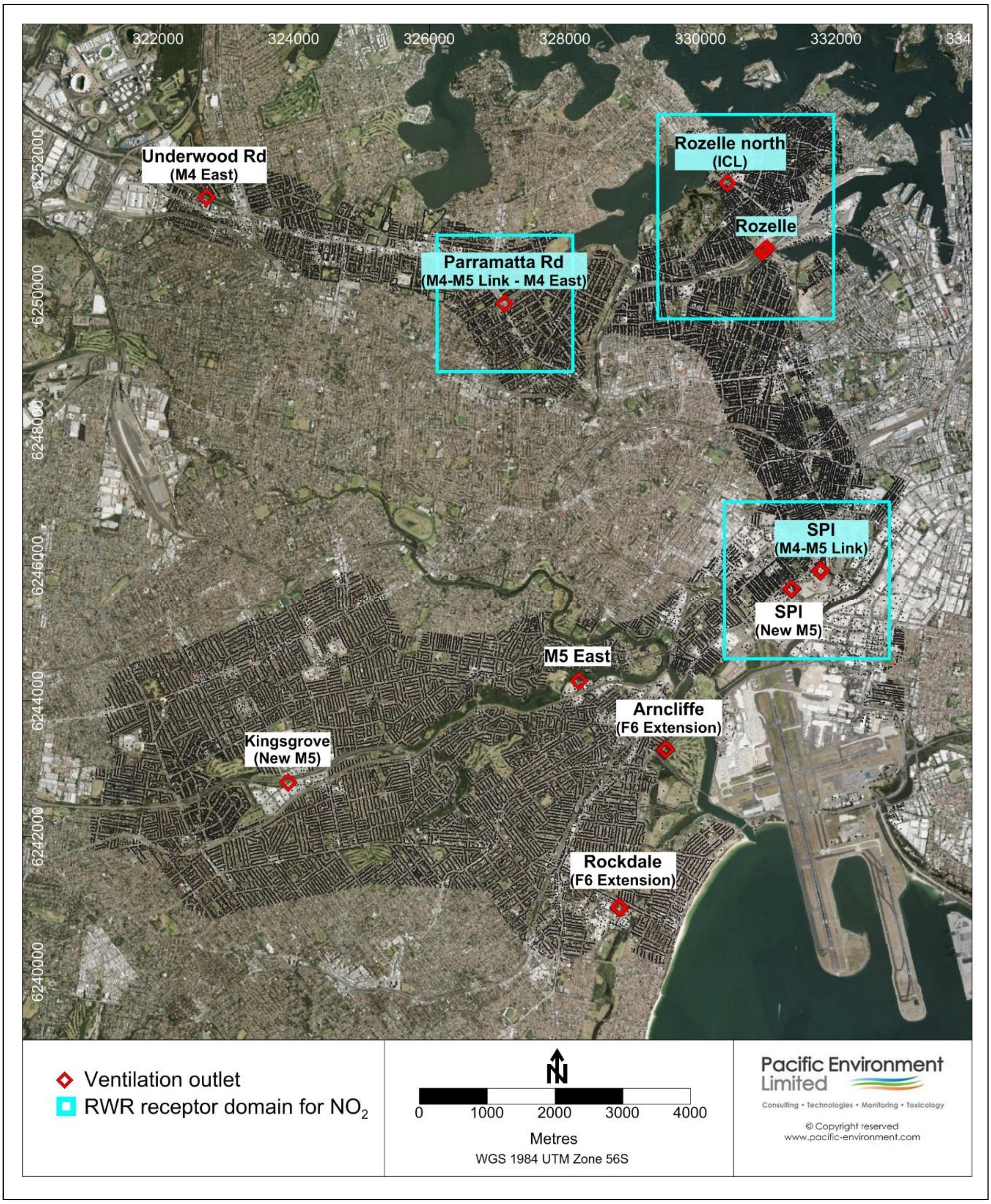


Figure 8-16 Domains around ventilation outlets for one hour NO_2 RWC assessment

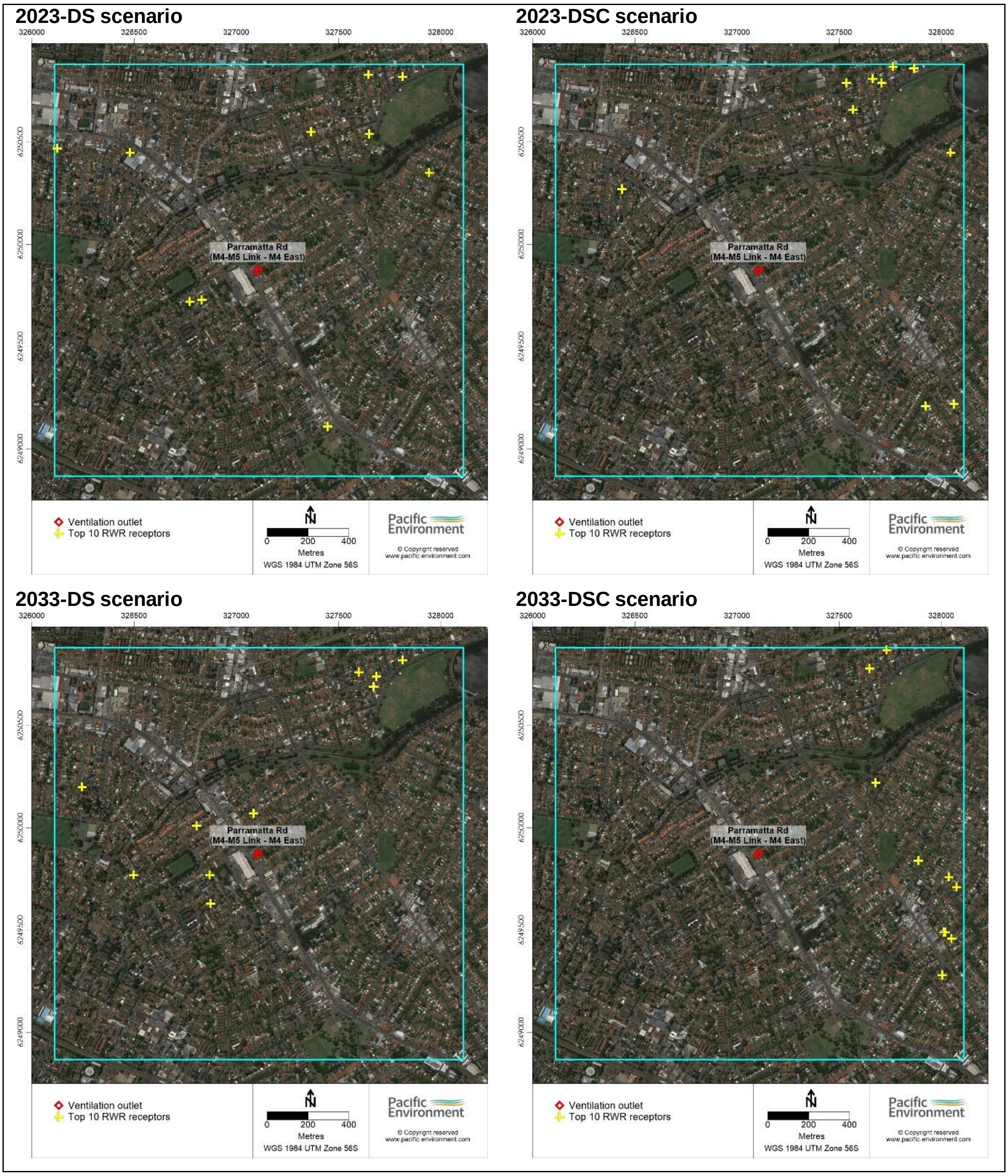


Figure 8-17 Top 10 receptors for one hour NO_X (Parramatta Road ventilation outlet)

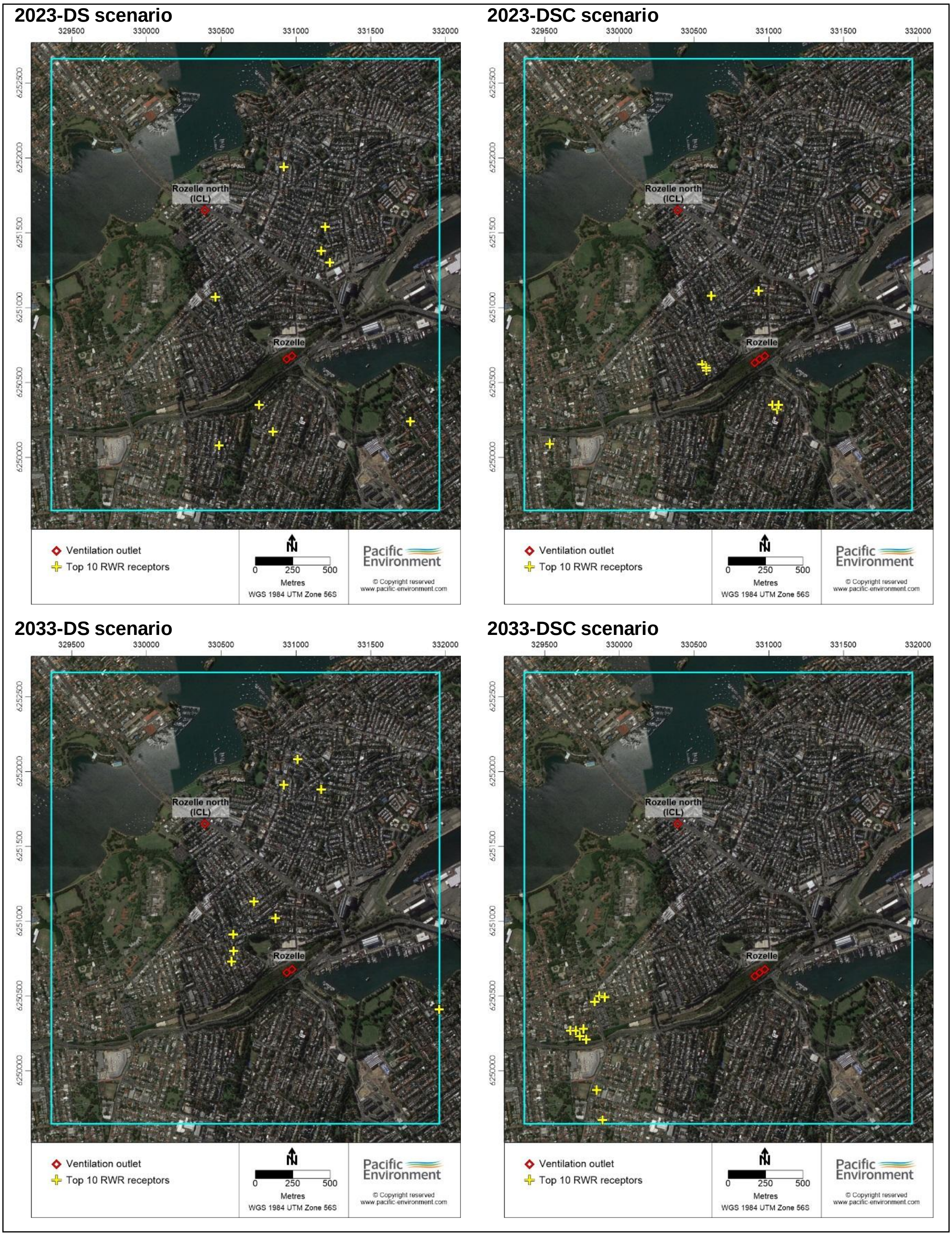


Figure 8-18 Top 10 receptors for one hour NO_X (Rozelle/Iron Cove Link ventilation outlets)

Figure 8-19 Top 10 receptors for one hour NO_X (SPI ventilation outlets)

8.4.8 Calculation of total concentrations

Total pollutant concentrations were required for comparison with the applicable air quality criteria. This required a variety of different methods because of the range of metrics in the criteria, as well as the nature of the information that could be extracted from GRAL for the two types of receptor. For the 40 community receptors a contemporaneous method was used to incorporate background concentrations, but this was not possible for the very large number of RWR receptors included in the assessment, and simpler approaches were required.

Carbon monoxide (maximum one hour mean)

For the community receptors, a contemporaneous approach was used, with the one hour mean CO concentration from GRAL being added to the corresponding one hour background CO concentration for every hour of the year. The maximum total one hour concentration during the year was then determined.

For the RWR receptors, the maximum one hour CO concentration from GRAL was added to the maximum one hour background concentration. Although the two maxima would be unlikely to coincide in reality (and therefore the approach was conservative), the total CO concentrations were still low relative to the air quality criterion.

Carbon monoxide (maximum rolling 8 hour mean)

For the community receptors, a contemporaneous approach was used, with the rolling 8 hour mean CO concentration from GRAL being added to the corresponding rolling eight hour background CO concentration for every hour of the year. The maximum total rolling eight hour concentration for the year was then determined.

For the RWR receptors, the maximum one hour CO concentration in a given year from GRAL was added to maximum one hour background concentration. The result was then converted to a maximum rolling eight hour CO concentration using a relationship based on the data from the air quality monitoring stations in Sydney (see **Figure 8-20**).

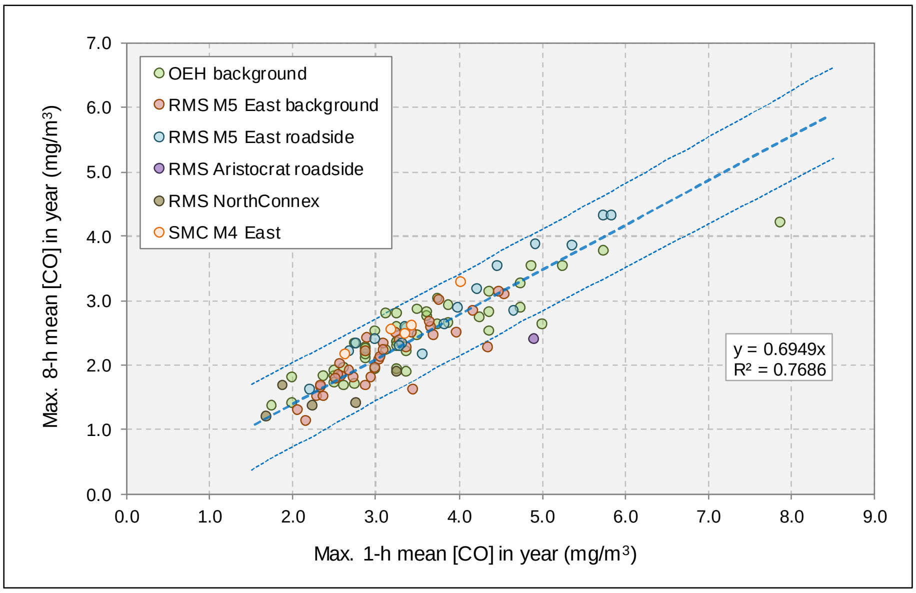


Figure 8-20 Relationship between maximum rolling eight hour mean CO and maximum one hour mean CO (dotted blue lines show 95 per cent prediction intervals)

Nitrogen dioxide (annual mean)

The estimation of NO_2 concentrations near roads is not straightforward. In order to ensure that an appropriate and pragmatic method was selected for the M4-M5 Link assessment, a review of the literature and data was undertaken, and an analysis of local monitoring data was conducted. Various air quality guidance documents recommend the use of local monitoring data to estimate NO_2 concentrations, where such data are available. Empirical methods for converting NO_X to NO_2 were developed specifically for the M4-M5 Link assessment, and these are documented in **Annexure G**.

For both the community and RWR receptors, the annual mean NO_X concentration from GRAL was added to a mapped background NO_X concentration. The total annual mean NO_X concentration was then converted to an annual NO_2 concentration using an empirical function (section G.4.2.1 of **Annexure G**).

Nitrogen dioxide (maximum one hour mean)

For the community receptors, a contemporaneous approach was used. The one hour mean NO_X concentration from GRAL was added to the corresponding one hour mean background NO_X concentration for every hour of the year. Each total one hour mean NO_X concentration was then converted to a maximum one hour mean NO_2 concentration using an empirical function (refer to section G.4.2.2 of **Annexure G**). The overall maximum one hour NO_2 concentration for the year was then determined.

For RWR receptors, in the EISs for the M4 East and New M5 projects the maximum predicted one hour mean NO_X contribution from surface roads and ventilation outlets was added to the 98th percentile background NO_X concentration from the synthetic profile (Boulter et al., 2015; Manansala et al., 2015). The total NO_X concentration was then converted to a maximum one hour NO_2 concentration using the appropriate empirical function. The implications of using this 'statistical' method were investigated by comparing the results with those from the contemporaneous method at the community receptors, on the assumption that the latter provided a more accurate estimate of NO_2. The results showed that there was a reasonably good agreement between the two approaches, with the statistical method tending to give slightly lower maximum NO_2 concentrations than the contemporaneous method.

However, this approach did not work as well for M4-M5 Link. When the 98th percentile NO_X background (301 µg/m^3) was used (**Figure 8-21**), the results matched those from the contemporaneous assessment, except for a group of receptors which had an under-prediction (actually, most of the receptors were in this group). There was therefore a tendency for the 98th percentile approach to underestimate concentrations, which would have been undesirable. As an alternative, the use of the maximum background NO_X concentration (797 µg/m^3) was tested (**Figure 8-22**). When the maximum background NO_X was used, most of the results fell on the 1:1 line, but a proportion of the data points (around 10 per cent) now had an overestimated NO_2 concentration relative to the contemporaneous assessment. The extent of the overestimate was proportional to the modelled NO_X contribution.

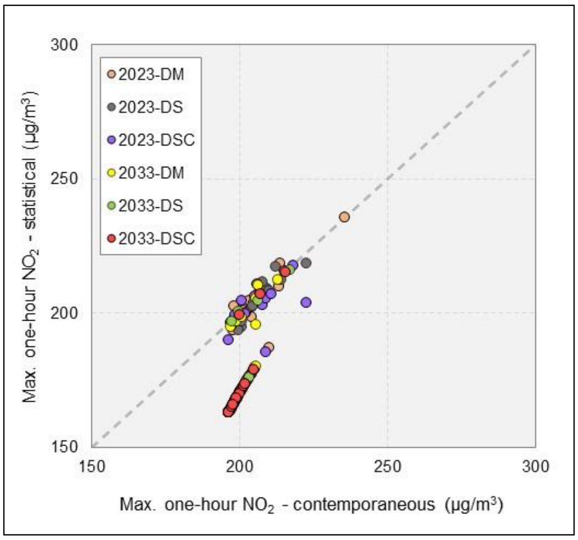


Figure 8-21 Comparison between statistical and contemporaneous approaches for one hour NO_2 at community receptors (98th percentile background NO_X)

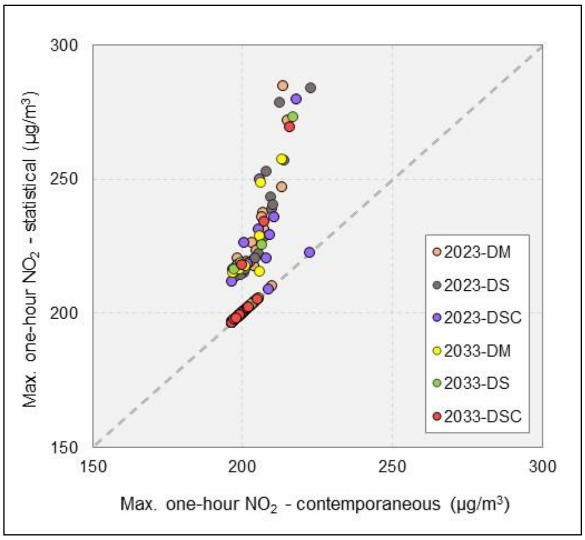


Figure 8-22 Comparison between statistical and contemporaneous approaches for calculating maximum one hour NO_2 at community receptors (maximum background NO_X

Consequently, for the M4-M5 Link assessment, it was considered that the use of the maximum one hour background NO_X concentration from the synthetic profile would be more appropriate than the 98th percentile, and this was implemented. Otherwise, it is possible that the maximum total NO_2 concentrations at most RWR receptors would have been underestimated. Maximum NO_2 concentrations were therefore likely to be significantly overestimated where there was a large road contribution to NO_X. Clearly, there was considerable uncertainty in the predictions of maximum one hour NO_2 at RWR receptors.

PM_{10} (annual mean)

For both the community and RWR receptors, the annual mean PM_{10} concentration from GRAL was added to a mapped background PM_{10} concentration to give the total annual mean concentration.

PM_{10} (maximum 24 hour mean)

For the community receptors, a contemporaneous approach was used. The 24 hour mean PM_{10} concentration from GRAL was added to the corresponding 24 hour mean background PM_{10} concentration for every day of the year. The maximum 24 hour PM_{10} concentration for the year was then determined.

For the RWR receptors, the use of the 98th percentile background concentrations again underestimated PM_{10} concentrations relative to the contemporaneous assessment (**Figure 8-23**). It should be noted that, unlike for NO_2, the approach for PM_{10} (and $PM_{2.5}$) is simply additive; increasing or decreasing the assumed background value simply shifts the whole dataset up or down the y axis. The same solution as that used for NO_2 – based on the maximum background concentration - was therefore implemented to avoid a gross underestimation of maximum 24 hour PM_{10} concentrations. This resulted in an almost exact match between the statistical and contemporaneous methods (**Figure 8-24**). There was a clear reason for this: the total concentration at (almost) all community receptors was dominated by the maximum value for 24h PM_{10} in the synthetic background profile (46.2 µg/m^3 on 1 July). In other words, whatever the modelled contributions were on other days, the highest PM_{10} concentration (almost) always occurred at the community receptors on 1 July.

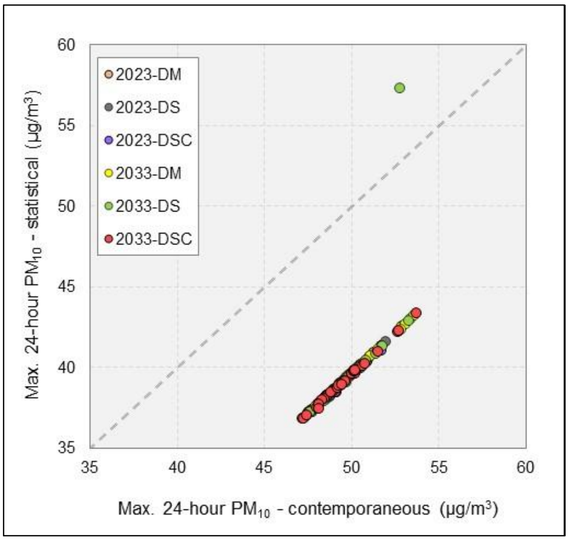


Figure 8-23 Comparison between statistical and contemporaneous approaches for 24 hour PM_{10} at community receptors (98th percentile background)

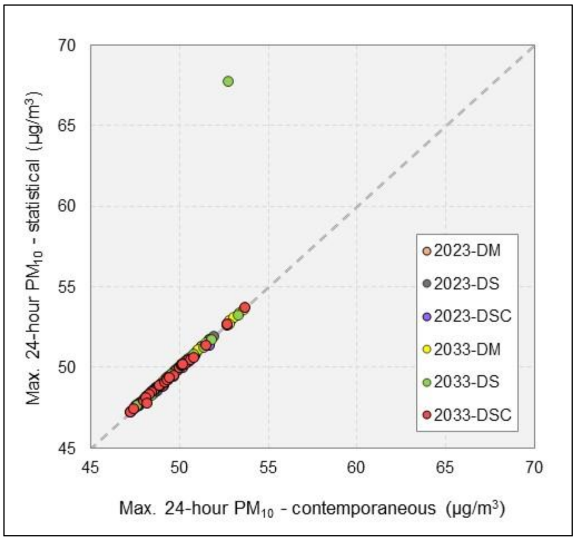


Figure 8-24 Comparison between statistical and contemporaneous approaches for calculating maximum 24 hour PM_{10} at community receptors (maximum background)

One obvious feature of the comparison for PM_{10} is that there is a very prominent outlier. One community receptor (CR10, University of Notre Dame, Broadway) in the 2023-DS and 2033-DS scenarios (and no others) did not behave at all like the rest of the receptors/scenarios. For all other community receptors in all scenarios, the maximum 24 hour PM_{10} concentration was determined by the maximum concentration in the background profile (the 46.2 µg/m^3 on 1 July). However, for CR10, on 25 May there was a large road traffic contribution (21.5 µg/m^3) and a much lower background concentration (31.3 µg/m^3) than the maximum in the synthetic profile. This meant that when the statistical method was applied to this one receptor an (incorrectly) large background was combined with a large road component, and the concentration was significantly overestimated (again, relative to the contemporaneous approach).

There is therefore a kind of 'switch' which dictates the level of overestimation. Some receptors would have a total concentration that is composed of the maximum background value and a small model component, whereas other receptors have a total that is composed of a lower background value and a large model component. For most receptors in the M4-M5 link analysis, the statistical method would work quite well, as the model component would be quite small; the total concentration would tend to be dictated by the maximum background 46.2 µg/m^3. The second highest PM_{10} concentration in the synthetic background profile was 46.0 µg/m^3 (i.e. only 0.2 µg/m^3 lower than the highest value). However, the third highest PM_{10} concentration in the synthetic background profile was quite a bit lower (38.3 µg/m^3). This is almost exactly 8 µg/m^3 lower than the highest background value. Therefore, the statistical method should still work reasonably well unless the road/stack component is greater than this 8 µg/m^3.

To illustrate the implications of this, the distribution of the model components in the 2033-DS scenario is summarised in **Table 8-17**. For the 10 per cent of RWR receptors that had a modelled component of more than 8 µg/m^3, the extent of the overestimation would depend on both the value of the maximum road/stack component, and when it happens. The latter was not known for the RWR receptors.

Table 8-17 Distribution of modelled 24 hour PM_{10} components in 2033-DS scenario

Max 24h PM_{10} (model component)	Number of receptors	% of receptors
>5 µg/m^3	44,724	52%
>8 µg/m^3	**8,706**	**10.1%**
>10 µg/m^3	2,965	3.4%
>15 µg/m^3	328	0.38%
>20 µg/m^3	75	0.09%

To summarise the above, the results of the statistical method were clearly very dependent on the assumption concerning the background concentration, and this highlights the difficulties with the assessment of short-term particulate matter impacts for road transport projects. A significant overestimation of concentrations can occur using the statistical approach where there is a relatively large modelled 24 hour PM_{10} component (greater than around 8 µg/m^3). This would affect, to a varying degree, around 10 per cent of the RWR receptors. For a very small proportion of receptors (less than one tenth of one percent), the overestimation could be as high as 20 µg/m^3. It should be noted that this only affected the total PM_{10} concentrations; the changes in concentration were not affected.

$PM_{2.5}$ (annual mean)

For both the community and RWR receptors, the annual mean $PM_{2.5}$ concentration from GRAL was added to a fixed background $PM_{2.5}$ concentration (8 µg/m^3) to give the total annual mean concentration. The rationale for the selection of this values is given in **Annexure F**.

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

The approaches used for $PM_{2.5}$ were essentially the same as those used for PM_{10}.

For the RWR receptors, the 98th percentile background method from the previous EISs was replaced with the maximum background method. **Figure 8-25** shows the results using the former, and **Figure**

8-26 shows the results using the latter. There appear to be two 'levels' of data, as in the contemporaneous assessment the background at a given community receptor is one of two values. In this case, there were no obvious outliers. This was because, in the contemporaneous assessment, the road component was too small to result in a switch to a much lower background value.

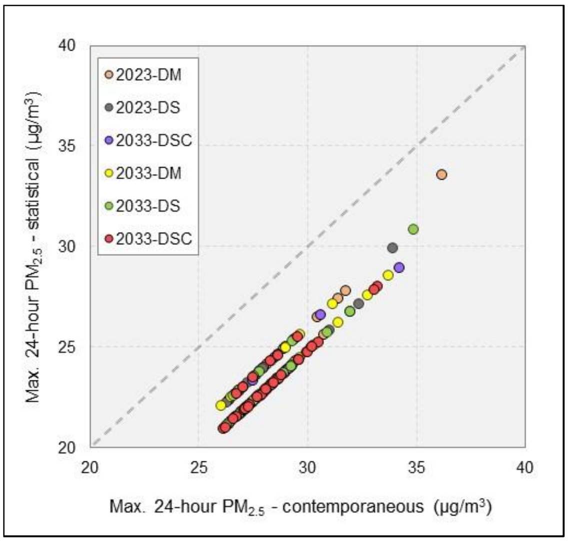


Figure 8-25 Comparison between statistical and contemporaneous approaches for 24 hour $PM_{2.5}$ at community receptors (98th percentile background)

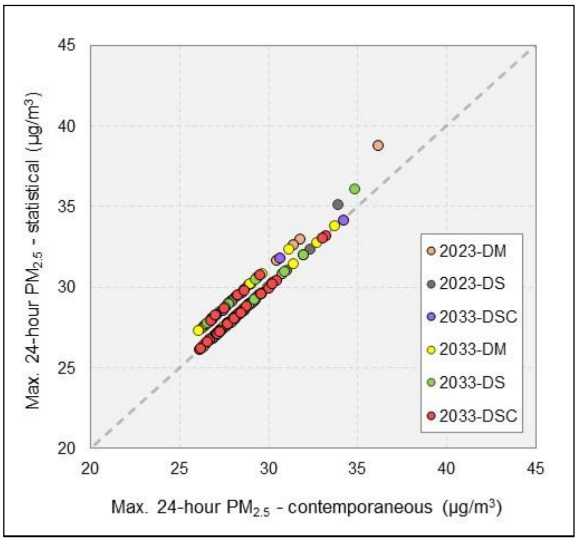


Figure 8-26 Comparison between statistical and contemporaneous approaches for calculating maximum 24 hour $PM_{2.5}$ at community receptors (maximum background)

Air toxics

For both the community and RWR receptors, the THC concentrations from GRAL were converted to concentrations for specific air toxics using vehicle exhaust emission speciation profiles. The speciation profiles for the compounds of interest were taken from the GMR emission inventory methodology (NSW EPA, 2012b), and are given in **Table 8-18**. NSW EPA provides profiles for petrol light-duty vehicles (cars and LCVs) running on petrol with no ethanol (E0) and petrol with 10 per cent ethanol (E10), as well as diesel vehicles (the profiles are the same for light-duty and heavy-duty diesel vehicles).

Table 8-18 THC speciation profiles by fuel type (NSW EPA, 2012b; Environment Australia, 2003)

Pollutant/metric	% of THC (where THC=VOC)			
	Petrol light duty		Diesel light duty	Diesel heavy duty
	Petrol (E0)	Petrol (E10)		
Benzene	4.95	4.54	1.07	1.07
PAHs (as b(a)p) (a)	0.03	0.03	0.08	0.08
Formaldehyde	1.46	1.82	9.85	9.85
1,3-butadiene	1.27	1.20	0.40	0.40

(a) NSW EPA assumes that THC and VOC are equivalent

(b) Based on a combination of PAH fraction of THC from NSW EPA (2012b) and the b(a)p fraction of PAH of 4.6 per cent from Environment Australia (2003)

The NSW EPA speciation profiles were combined with additional information to determine profiles that were applicable to the GRAL THC predictions. Firstly, for petrol vehicles it was assumed that 60 per cent of the fuel used would be E10; this percentage represents the target for petrol sold in New South Wales under the Biofuels Act 2007. Secondly, the percentages in **Table 8-18** were weighted according to THC emissions from the different vehicle categories. In practice, THC emissions for each vehicle type vary according to the year, the road type (fleet mix) and the traffic speed. Given the uncertainties associated with the speciation profiles, for this assessment a single combination of road type and speed was used to represent a 'central estimate' of THC emissions (commercial highway road type, with a speed of 50 kilometres per hour), although emissions for three years were estimated (2015, 2023 and 2033). The weighted profiles are given in **Table 8-19**.

Table 8-19 Weighted THC speciation profiles for 2015, 2023 and 2033

Pollutant/metric	Weighted % of THC for traffic		
	2015	2023	2033
Benzene	4.3	4.2	3.6
PAHs (as b(a)p)	0.03	0.03	0.04
Formaldehyde	2.6	2.9	4.2
1,3-butadiene	1.1	1.1	1.0

Where a refined dispersion modelling technique has been used (as in this case), the criteria in the Approved Methods for individual air toxics relate to incremental impacts (i.e. project only) for an averaging period of one hour and as the 99.9th percentile of model predictions. However, the approach and assessment criteria in the Approved Methods cannot be readily applied to complex road projects in urban areas, as they are based on the assumption that a project represents a new source, and not a modification to an existing source. In the case of the current project the 'impacts' are dependent in part on the emissions from the tunnel ventilation outlets but, more importantly, on how the traffic on the existing road network is affected and, at many receptors, the concentrations of air toxics actually decreased as a result of the project. A modified version of the usual approach was therefore used, whereby only the change in the maximum one hour concentration of each compound as a result of the project was compared with the corresponding impact assessment criterion in the Approved Methods.

Summary

The approaches used for determining the total concentration of each pollutant for the community and RWR receptors are summarised in **Table 8-20**.

Table 8-20 Methods for combining modelled (GRAL) contribution and background contribution

Pollutant/ metric	Averaging period	Method	
		Community receptors	RWR receptors
CO	1 hour	1 hour GRAL CO added to contemporaneous 1 hour background CO	Maximum 1 hour GRAL CO added to maximum 1 hour background CO
	8 hours (rolling)	Rolling 8 hour GRAL CO added to contemporaneous rolling 8 hour background CO	Maximum 1 hour GRAL CO added to maximum 1 hour background CO, and converted to maximum rolling 8 hour CO
NO_2	1 hour	1 hour GRAL NO_X added to contemporaneous 1 hour background NO_X, and 1 hour total NO_X converted to maximum total 1 hour NO_2	Maximum 1 hour GRAL NO_X added to 98th percentile 1 hour background NO_X from synthetic profile, then converted to maximum 1 hour NO_2
	1 year	GRAL NO_X added to mapped background NO_X, then converted to NO_2	GRAL NO_X added to mapped background NO_X, then converted to NO_2
PM_{10}	24 hours	24 hour GRAL PM_{10} added to contemporaneous 24 hour background PM_{10}	Maximum 24 hour GRAL PM_{10} added to maximum 24 hour background PM_{10} from synthetic profile

	1 year	GRAL PM_{10} added to mapped background PM_{10}	GRAL PM_{10} added to mapped background PM_{10}
$PM_{2.5}$	24 hours	24 hour GRAL $PM_{2.5}$ added to contemporaneous 24 hour background $PM_{2.5}$	Maximum 24 hour GRAL $PM_{2.5}$ added to maximum 24 hour background $PM_{2.5}$ from synthetic profile
	1 year	GRAL $PM_{2.5}$ added to fixed background $PM_{2.5}$	GRAL $PM_{2.5}$ added to fixed background $PM_{2.5}$ of 8 µg/m^3

8.4.9 Evaluation of dispersion model

The overall performance of the GRAMM-GRAL system was evaluated by comparing the predicted and measured concentrations at multiple OEH, Roads and Maritime, and SMC air quality monitoring stations in 2015. The model predictions were based on the WRTM data for the 2015 Base Year scenario. The method, results and limitations of the evaluation are given in **Annexure J**.

The monitoring stations considered in the evaluation were those located within the GRAL domain, and included a mixture of background and near-road sites. The characteristics of the stations are summarised in **Annexure J**. Of the 20 stations identified in the annexure, thirteen (M01 to M13) had data for the whole of 2015, whereas the remaining seven (M14 to M20) had data for part of 2015. To simplify the presentation, only the results for stations M01 to M13 are shown in this report. However, the findings for these stations were also broadly representative of stations M14 to M20. The performance of GRAL was not investigated at the project-specific (ie M4-M5 Link) monitoring stations as no data from these were available for 2015.

GRAL was configured to predict hourly concentrations of NO_X, NO_2, CO and PM_{10} at the various stations. For PM_{10}, daily average concentrations were also calculated. The emphasis was on NO_X and NO_2, as the road traffic increment for CO and PM_{10} tends to be small relative to the background. $PM_{2.5}$ was not assessed as there were insufficient measurements to provide a detailed characterisation of background concentrations.

The GRAL predictions were for the combined surface road network and the existing M5 East tunnel ventilation outlet. A number of different approaches were to account for the background contribution to the predicted concentrations, and to compare the effects of different assumptions. This is because the approaches for calculating short-term concentrations in the M4-M5 Link were quite conservative, and therefore unlikely to give an accurate impression of model accuracy.

In order to cover different characteristics of the data, three statistical metrics were used: the annual mean concentration, the maximum short-term concentration (one hour or 24 hour, depending on the pollutant), and the 98th percentile short-term concentration.

The results can be summarised as follows:

- For annual mean concentrations of all pollutants, there was, broadly speaking, a reasonably good agreement between the measured concentrations and those predicted by GRAL. An example of the results is shown in **Figure 8-27**. However, there was a general overestimation of concentrations, and this could be attributed to GRAL itself
- As expected, the results for the maximum and 98th percentile concentrations were more variable than the annual means. Maximum pollutant concentrations are inherently very difficult to predict, and the comparisons here reflect this. Nevertheless, there was a clear tendency towards the overestimation of maximum and (to a lesser degree) 98th percentile concentrations
- The temporal assessment of NO_X revealed the following:
  - At all stations, there was a pronounced overestimation of concentrations at night-time and during peak traffic periods. At most stations, the inter-peak concentrations were reasonably well reproduced, although there was still a marked overestimation at some stations and underestimation at others
  - The seasonal variation in concentrations was, on average, well reproduced, with the under-

and overestimation during the day being cancelled out at some stations. There was generally a consistent overestimation of the monthly average concentration

- The overestimation was larger at the weekend than on weekdays, due in large part to the assumption of weekday traffic volumes on every day of the year in the modelling

· For annual mean and maximum one hour NO_2 the model with the empirical NO_X-to-NO_2 conversion methods gave more realistic predictions than the model with ozone limiting method. The empirical NO_X-to-NO_2 method for determining the maximum one hour concentration is not well suited to the estimation of other NO_2 statistics such as means and percentiles.

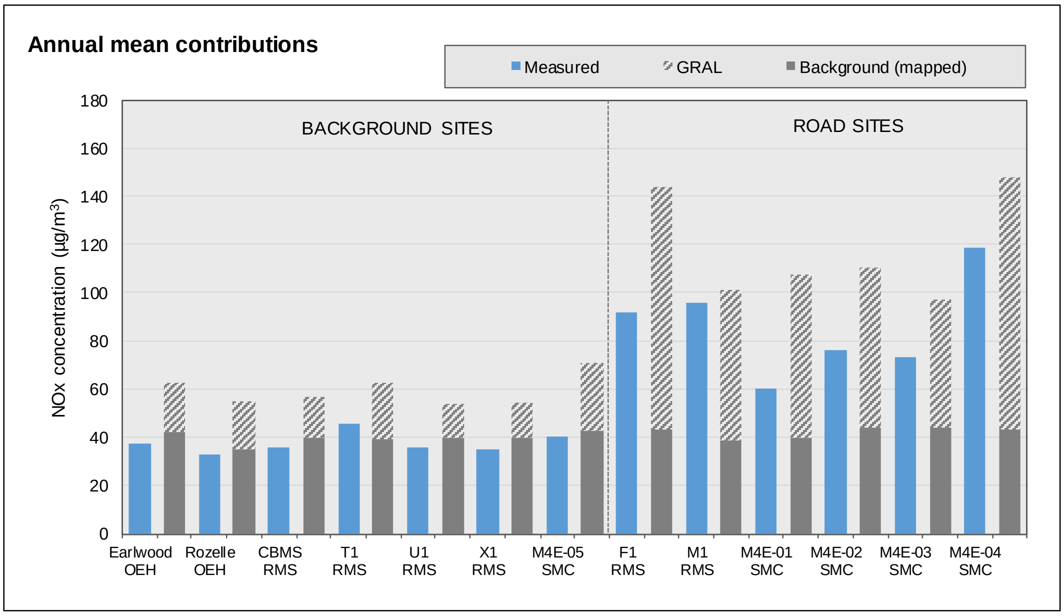


Figure 8-27 Comparison between measured and predicted annual mean NO_X concentrations

Overall, the results supported the application of GRAL in the assessment, along with the empirical conversion methods for NO_2, noting that the results tend to be quite conservative. The results suggest that the estimated concentrations ought to be conservative for most of the modelling domain.

8.4.10 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**.

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

· 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 total concentration, and changes in concentration, at the community receptors
- Ranked bar charts for total concentration, and changes in concentration, at the RWR receptors

· As spatially mapped pollutant concentrations (ie contour plots) across the GRAL 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 $PM_{2.5}$.

Some important points to consider when viewing these results are identified below.

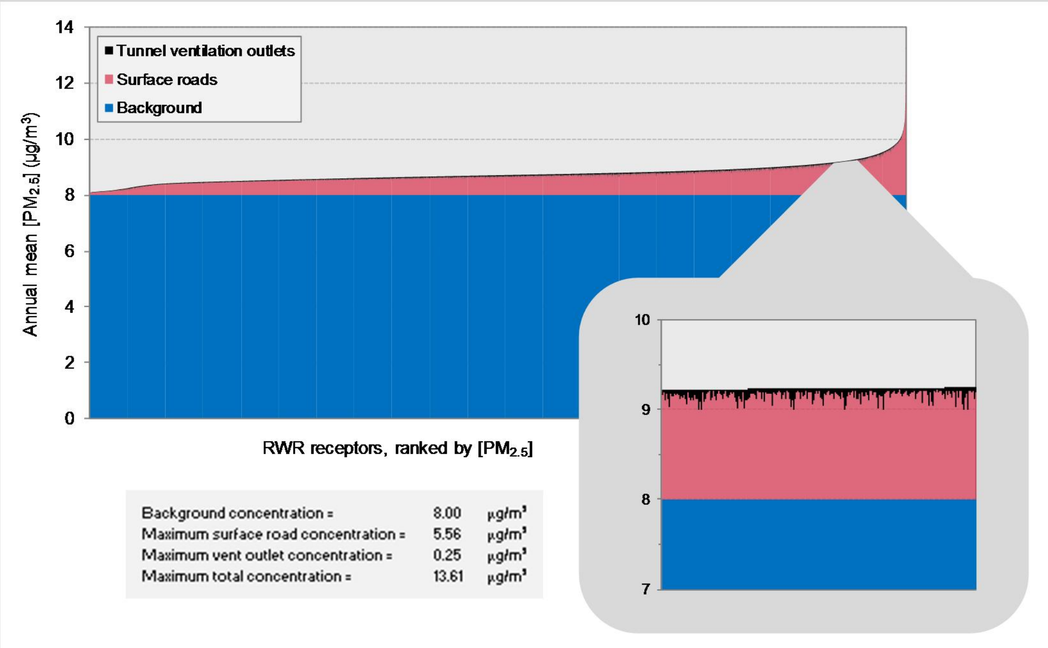
NB 1: To avoid a large amount of duplication, the main report only includes the contour plots for the most complex scenario in terms of changes in traffic, 2033-DSC, and the corresponding Do Minimum scenario, 2033-DM, where applicable. For all other scenarios, the contour plots are given in **Annexure K**.

NB 2: It is well known that the accuracy of dispersion model predictions decreases as the averaging period of the predictions decreases. In addition, the reliability of predictions based on a detailed contemporaneous approach for incorporating background should be greater than that of predictions based on a simpler statistical approach. Consequently, not all the model predictions in this assessment should be viewed with the same level of confidence, but rather according to the following hierarchy:

- Annual mean predictions for community and RWR receptors
- Short-term (1h and 24h) predictions for community receptors
- Short-term (24h) predictions for RWR receptors
- Short-term (1h) predictions for RWR receptors

Confidence in predictions

NB 3: The ranked RWR plots are highly compressed along the x-axis, given that almost 90,000 receptors are included. Given that the tunnel ventilation outlet contributions are generally small compared with the background and surface road contributions, they are quite difficult to see on this scale. Therefore, in each plot the maximum contributions from each source, and the maximum total concentration, are also given. An example of this compression is shown in the figure below. The inset shows the results for a sub-set of 500 RWR receptors, with the ventilation outlet contribution being more clearly depicted.



Carbon monoxide (maximum one hour mean)

Results for community receptors

The maximum one hour mean CO concentrations at the 40 community receptors in the with-project and cumulative scenarios (2023-DS, 2023-DSC, 2033-DS and 2033-DSC) are shown in **Figure 8-28**. At all these receptor locations the CO concentration was well below the NSW impact assessment criterion of 30 mg/m^3. The concentrations were also well below the lowest international air quality standard identified in the literature (California, 22 mg/m^3).

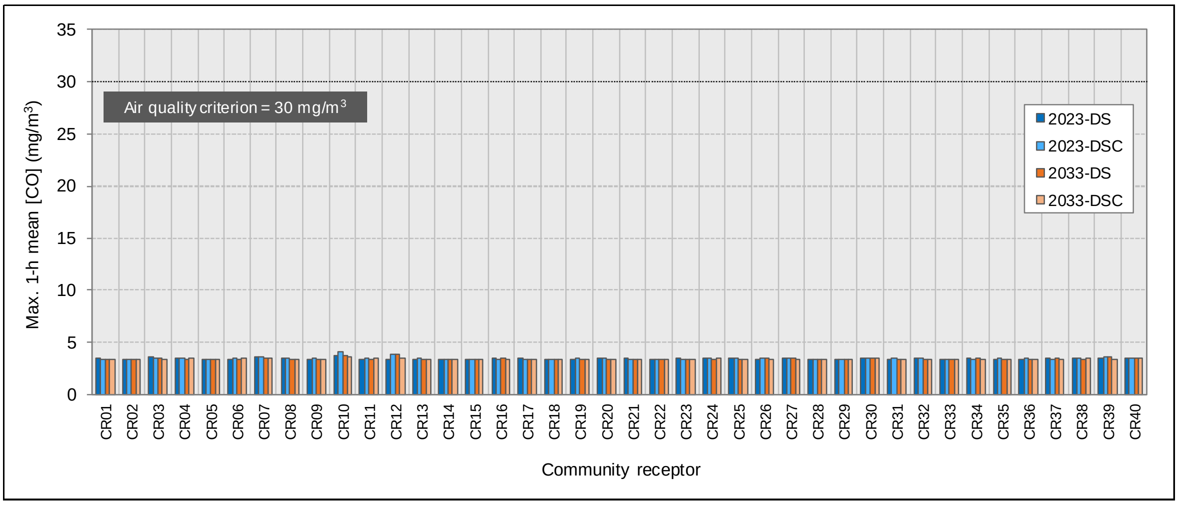


Figure 8-28 Maximum one hour mean CO concentration at community receptors (with-project and cumulative scenarios)

Figure 8-29 demonstrates the changes in the maximum one hour CO concentration in the Do Something scenarios relative to the Do Minimum scenarios at the community receptors. There was a mixture of increases and decreases in concentration at the receptors. The largest increase at any receptor was around 0.4 mg/m^3, which equated to just 1.5 per cent of the impact assessment criterion of 30 mg/m^3.

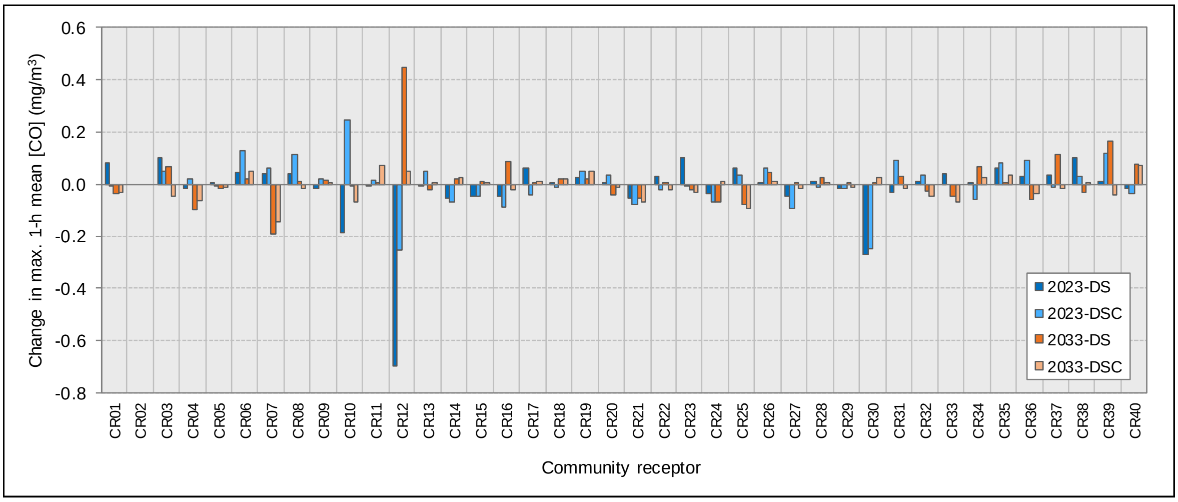


Figure 8-29 Change in maximum one hour mean CO concentration at community receptors (with-project and cumulative scenarios, relative to corresponding Do Minimum scenarios)

Figure 8-30 presents the separate contributions of the background, surface roads and ventilation outlets to the maximum one hour mean CO concentrations in the with-project and cumulative scenarios. At most of the receptors, the maximum concentration was dominated by the background. The hour of the year is not the same for all receptors, which explains why the background concentration varies. At some locations, there was a marked surface road contribution (up to 68 per cent of the total), such as at receptors CR-10 and CR-12 in some scenarios. These highest model values generally (but not in all cases) coincided with the morning peak traffic period, when traffic emissions would be relatively high and dispersion quite poor. In contrast, the contribution of tunnel ventilation outlets to the maximum CO concentration was zero for all receptors. In other words, at all receptors, the concentration due to emissions from the ventilation outlets was zero during the hour of the year when the maximum total concentration occurred. For any given receptor, it is possible that larger one hour contributions from roads and ventilation outlets could have occurred during other hours of the year. However, these contributions would have been added to a lower background, and the overall total would have been lower than that given in the Figure.

Results for RWR receptors

The ranked one hour CO concentrations at the RWR receptors are shown for the with-project and cumulative scenarios in **Figure 8-31**, ranked by total CO concentration. The contributions from surface roads and ventilation outlets are not shown separately, as for any short-term metric such as this the hours when the maxima for the different sources occurred were not known.

A typical feature of these ranked plots, which also extends to other pollutants, is that most of the receptors in the domain tend to have a fairly low concentration, but a very small proportion of receptors have unrealistically high concentrations. An explanation for this is provided in **section 8.4.14**.

The one hour CO criterion for NSW was not exceeded at any of the RWR receptors in any scenario. The highest one hour concentrations in any with-project or cumulative scenario was predicted to be 7.7 mg/m^3. The largest contribution from ventilation outlets at any receptor was less than 0.1 mg/m^3.

The changes in the maximum one hour CO concentration at the RWR receptors in the with-project and cumulative scenarios are shown in **Annexure K** (Figure K-5). There was an increase in concentration of between 32 per cent and 38 per cent of receptors with the project. However, even the largest increase in any scenario, which was 1.6 mg/m^3, was small compared with the criterion.

Figure 8-30 Source contributions to maximum one hour mean CO concentration at community receptors (with-project and cumulative scenarios)

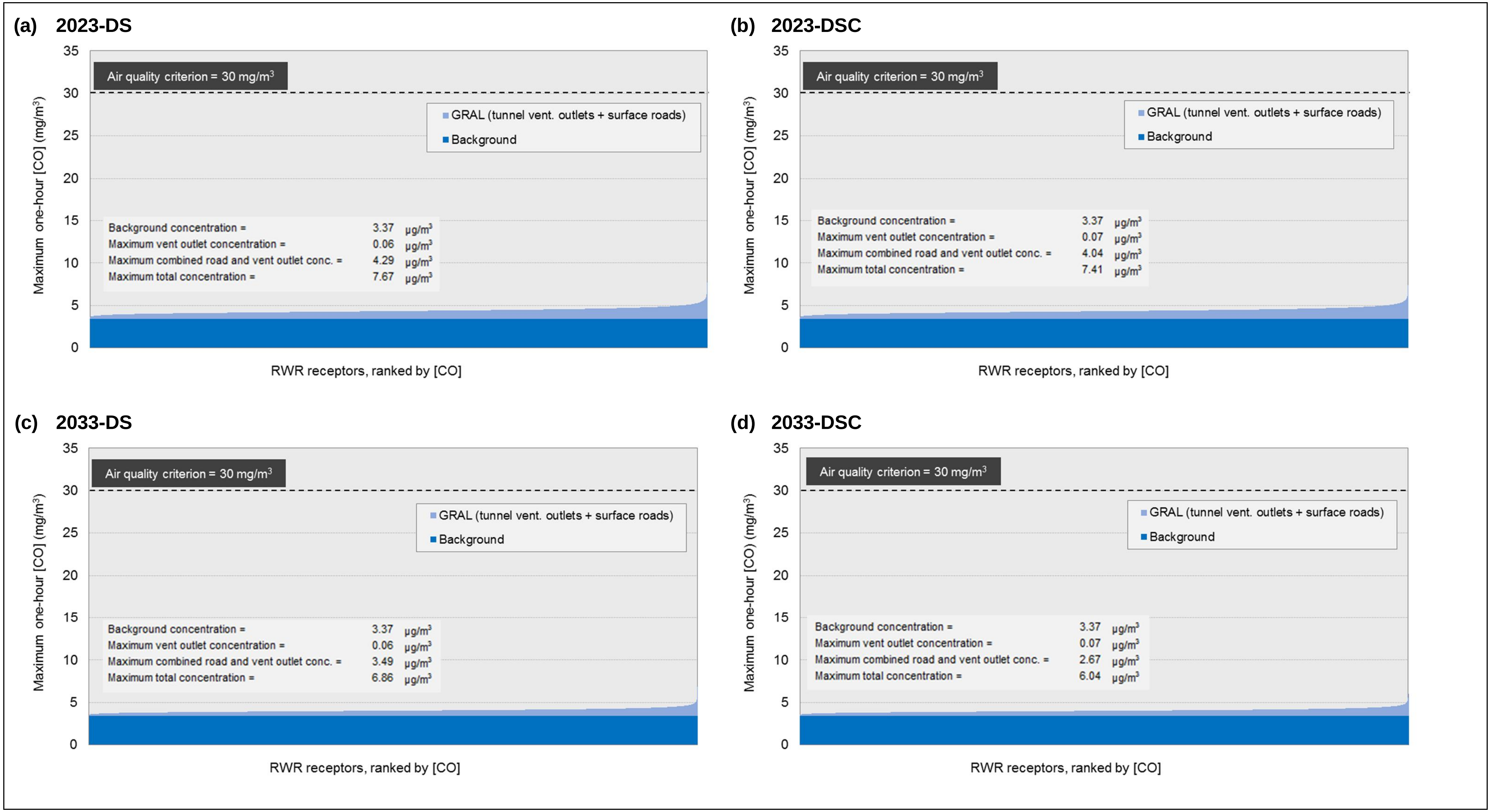


Figure 8-31 Source contributions to maximum one hour CO concentration at RWR receptors (with-project and cumulative scenarios)

Carbon monoxide (maximum rolling 8 hour mean)

Results for community receptors

Figure 8-32 shows the maximum rolling 8 hour mean CO concentrations at the community receptors with the project and in the cumulative scenarios. Because no model predictions were available for the period with the highest background concentration, the maximum background value was combined with the maximum model prediction. The background was therefore 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.

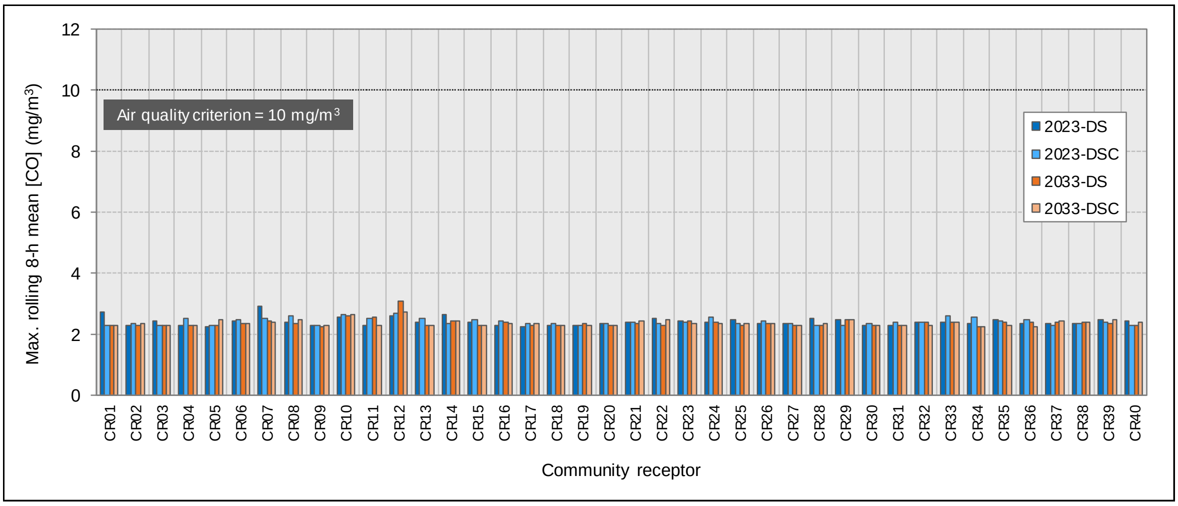


Figure 8-32 Maximum rolling 8 hour mean CO concentration at community receptors (with-project and cumulative scenarios)

It can be seen in **Figure 8-33** that the changes in the maximum rolling 8 hour CO concentration at all the community receptors were mostly less than 0.4 mg/m^3. The largest increase with the project and in the cumulative scenarios was around 0.6 mg/m^3 (equating to six per cent of the criterion).

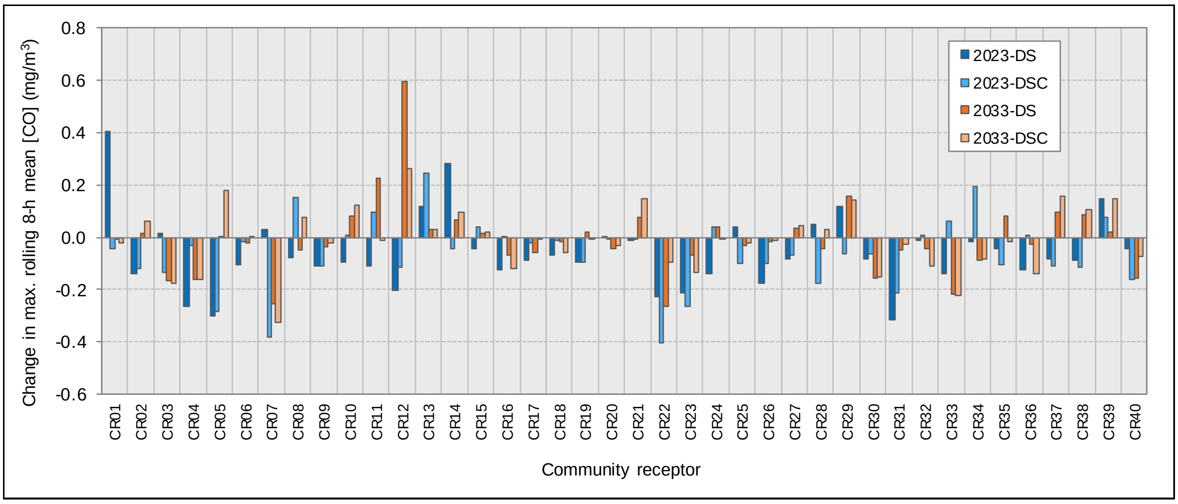


Figure 8-33 Change in maximum rolling 8 hour mean CO concentration at community receptors (with-project and cumulative scenarios, relative to Do Minimum scenarios)

The main contributor at these receptors was the background concentration (**Figure 8-34**). The maximum surface road contribution in any with-project or cumulative scenario was 28 per cent, whereas the tunnel ventilation outlet contribution was zero or negligible in all cases.

Figure 8-34 Source contributions to maximum rolling 8 hour mean CO at community receptors (with project and cumulative scenarios)

Results for RWR receptors

Rolling 8 hour mean CO concentrations were not extracted from GRAL. However, these would be broadly similar to those obtained for maximum one hour concentrations.

Nitrogen dioxide (annual mean)

Results for community receptors

Figure 8-35 shows the annual mean NO_2 concentrations for the with-project and cumulative 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 have been adopted elsewhere (e.g. 40 µg/m^3 in the EU).

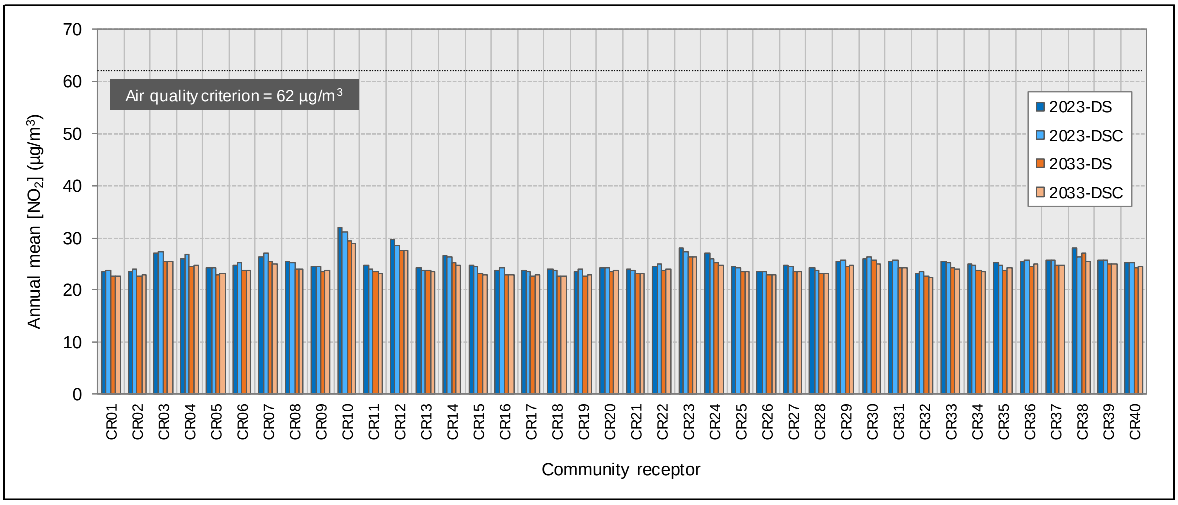


Figure 8-35 Annual mean NO_2 concentration at community receptors (with-project and cumulative scenarios)

Figure 8-36 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 2 and 4 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).

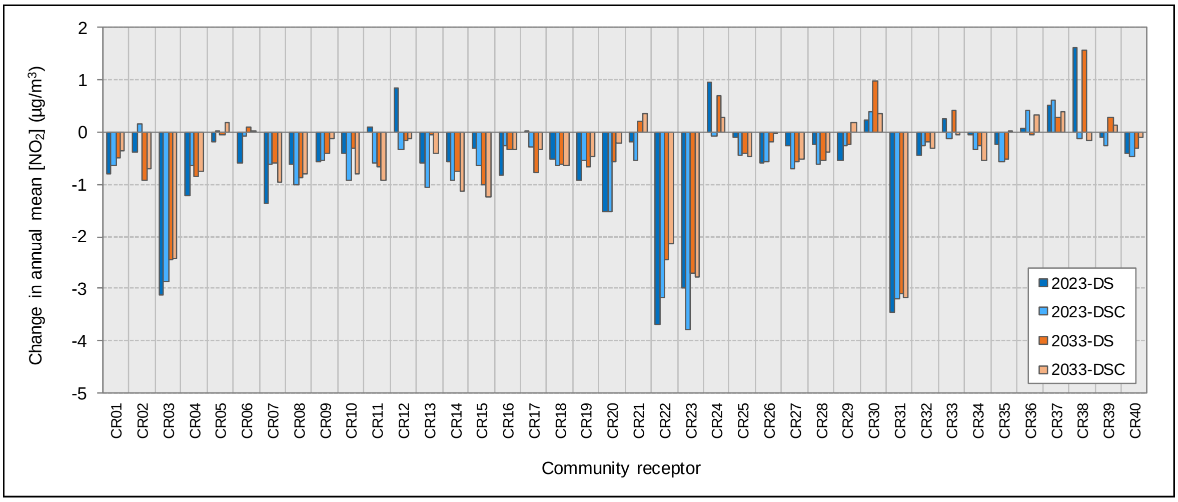


Figure 8-36 Change in annual mean NO_2 concentration at community receptors (with-project and cumulative scenarios, relative to Do Minimum scenarios)

Figure 8-37 gives the source contributions to total annual mean NO_2 concentrations in the with-project and cumulative scenarios.

These source contributions were estimated using a 'cumulative' approach involving the following steps:

Step A: The background NO_X concentration alone was converted to NO_2

Step B: The sum of the background and road NO_X concentrations was converted to NO_2

Step C: The sum of the background, road and outlet NO_X concentrations was converted to NO_2.

The road and outlet contributions were then obtained as the differences in NO_2, where road NO_2 was determined as NO_2 from Step B minus NO_2 from Step A, and outlet NO_2 was determined from Step C minus Step B. This allowed for the reduced oxidising capacity of the near-road atmosphere at higher total NO_X concentrations.

The results indicate that the background component at these receptors is likely to 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 and cumulative scenarios, surface roads were responsible for between around 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.

Results for RWR receptors

The annual mean NO_2 concentrations at the RWR receptors in the with-project and cumulative scenarios are shown, with a ranking by total concentration, in **Figure 8-38**. 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 2023, NO_2 concentrations were also below the EU limit value of 40 µg/m^3. However, the 11 receptors with an exceedance in 2023 was lower than the 17 receptors with an exceedance in the 2023-DM scenario. The highest concentrations with the project and in the cumulative scenarios in 2023 were predicted to be around 43 µg/m^3.

In 2033 no receptors had a concentration above the EU limit value. The highest concentrations with the project in 2033 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.

The changes in the annual mean NO_2 concentration at the RWR receptors in the with-project and cumulative scenarios (relative to the Do Minimum scenarios) are shown, ranked by the change in concentration, in **Figure 8-39**. 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. Conversely, there was a reduction in annual mean NO_2 at between around 80 per cent and 85 per cent of receptors.

Whilst the largest increases in NO_2 were substantial (up to 8.8 µg/m^3), the increase in was greater than 2 µg/m^3 for only around 0.1 per cent of receptors. As with CO, an explanation for the high concentrations at a small proportion of receptors is provided in **section 8.4.14**.

Figure 8-37 Source contributions to annual mean NO_2 concentration at community receptors (with-project and cumulative scenarios)

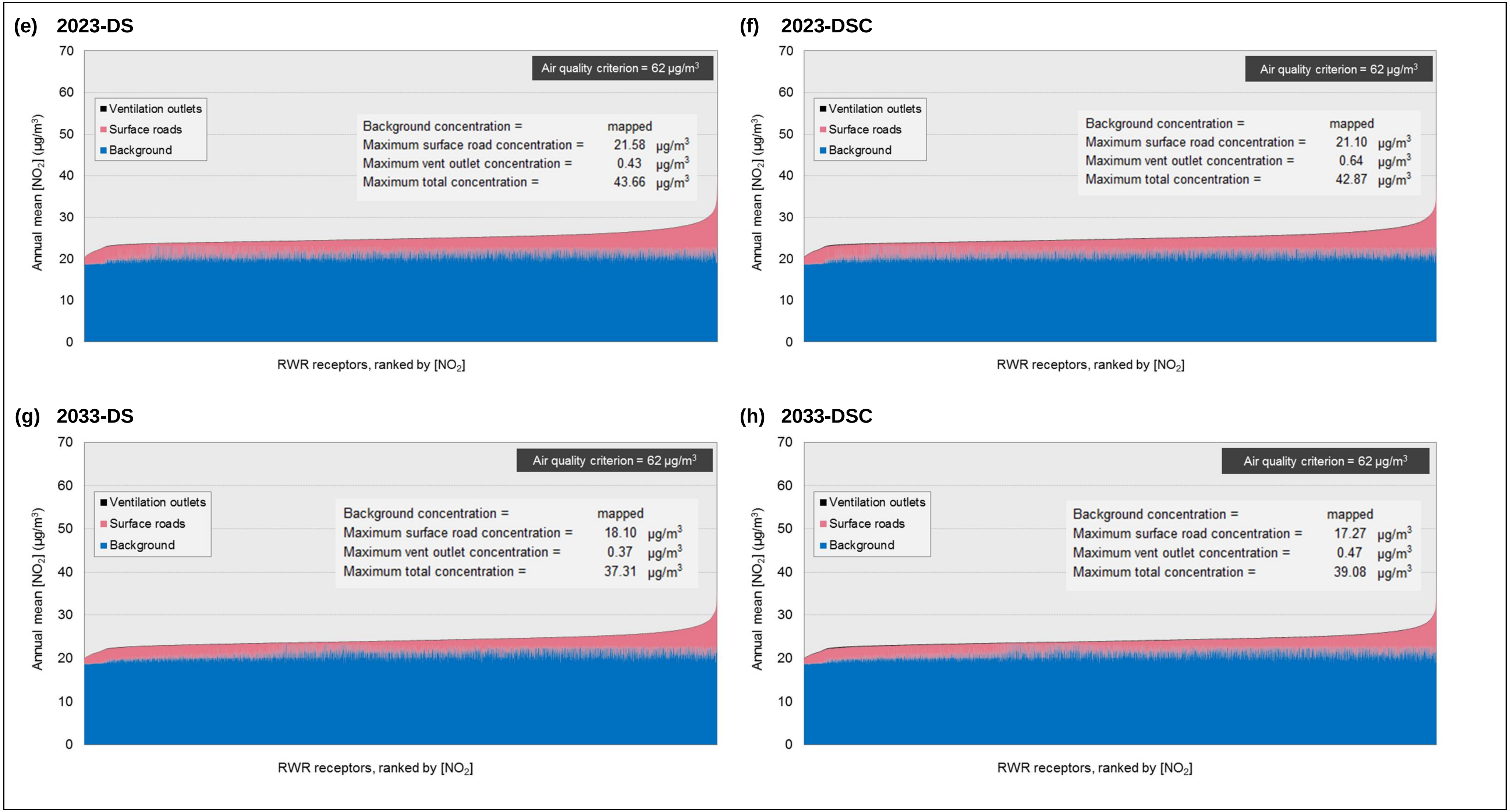


Figure 8-38 Source contributions to annual mean NO_2 concentration at RWR receptors (with-project and cumulative scenarios)

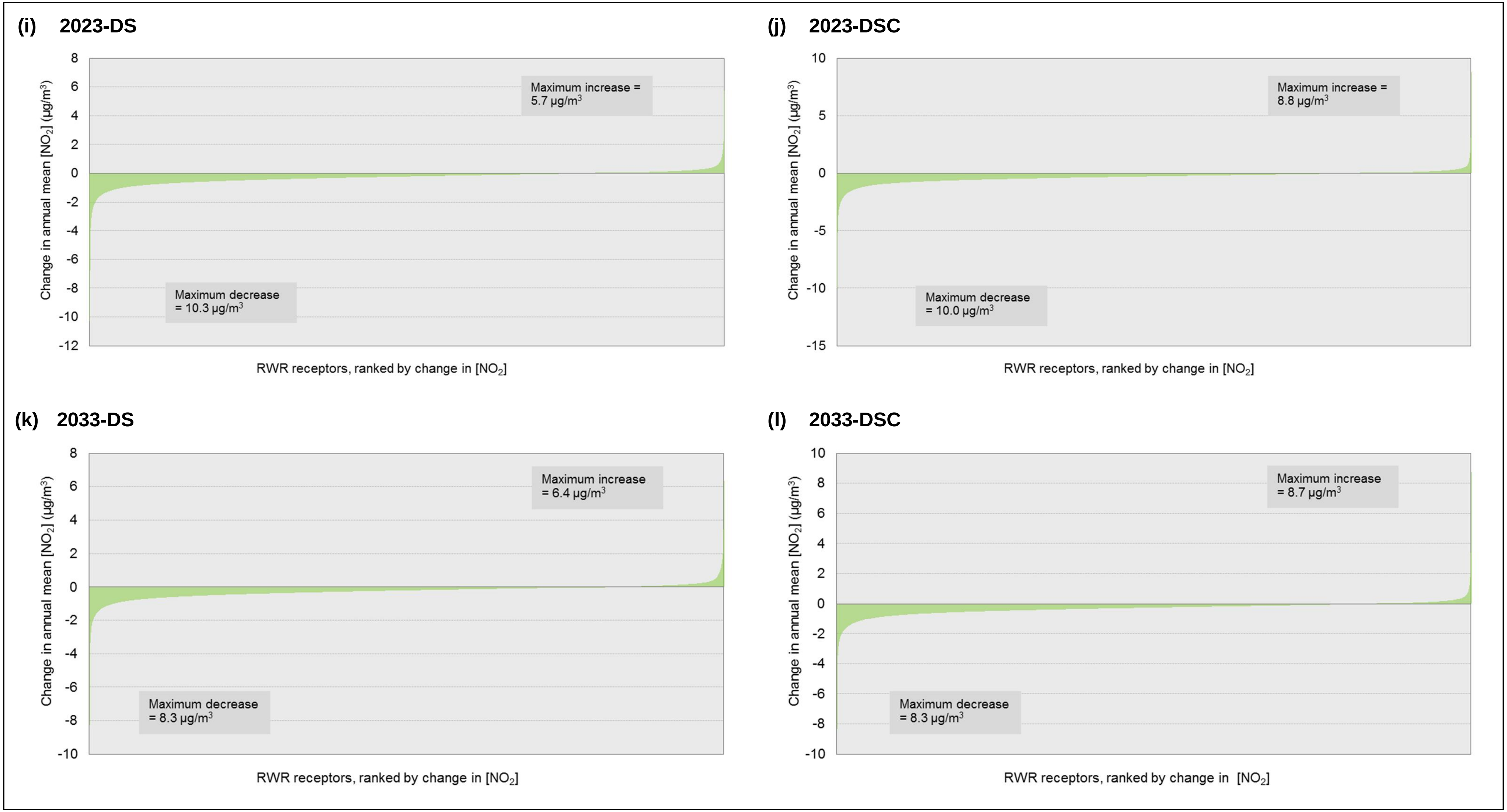


Figure 8-39 Change in annual mean NO_2 concentration at RWR receptors (with-project and cumulative scenarios, relative to corresponding Do Minimum scenarios)

Contour plots – all sources

Contour plots were developed to illustrate the spatial distribution of pollutant concentrations (from all sources) across the GRAL domain. As noted earlier, to avoid a large amount of duplication the main report only includes the contour plots for the most complex scenario, 2033-DSC, and the corresponding Do Minimum case, 2033-DM, where applicable. For all other scenarios the contour plots are given in **Annexure K**.

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 contour plot of annual mean total NO_2 concentrations across the GRAL domain in the 2033-DM scenario (ie all sources without the project) is provided in **Figure 8-40**, and an equivalent plot for the 2033-DSC scenario (i.e. all sources in the cumulative scenario) is shown in **Figure 8-41**. 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 total 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 is relieved by the M4 East project.

It is noticeable that the tunnel ventilation outlets have little impact on total annual mean NO_2 concentrations.

The contour plot in **Figure 8-42** shows the changes in annual mean NO_2 concentration in the 2033-DSC scenario. The green shading represents a decrease in concentration with the projects included in the cumulative scenario, and the purple shading an increase in concentration. Any changes in NO_2 of less than 2 $\mu g/m^3$ are not shown.

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 8-21** summarises the average weekday two-way traffic on some affected roads in all scenarios from WRTM, and **Table 8-22** gives the changes between scenarios.

In **Figure 8-42** there are noticeable decreases in NO_2 along Dobroyd Parade/City West Link and Parramatta Road to the south-east 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.

There is predicted to be a substantial reduction in surface traffic – and hence NO_2 concentration – along the Victoria Road corridor south of Iron Cove at Rozelle. This is due to traffic being diverted through the Iron Cove Link tunnel. For example, the average traffic volume on Victoria Road decreases from around 76,000 vehicles per day without the project (2033-DM) to around 29,000 vehicles per day in the cumulative scenario (2033-DSC), a reduction of around 60 per cent. On the other hand, there would be additional traffic to the north of Iron Cove Link and near Anzac Bridge as a result of the general increase in traffic due to the project.

There would also be reductions in concentrations along General Holmes Drive, Princes Highway and the M5 East Freeway.

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 Sydney Gateway project.

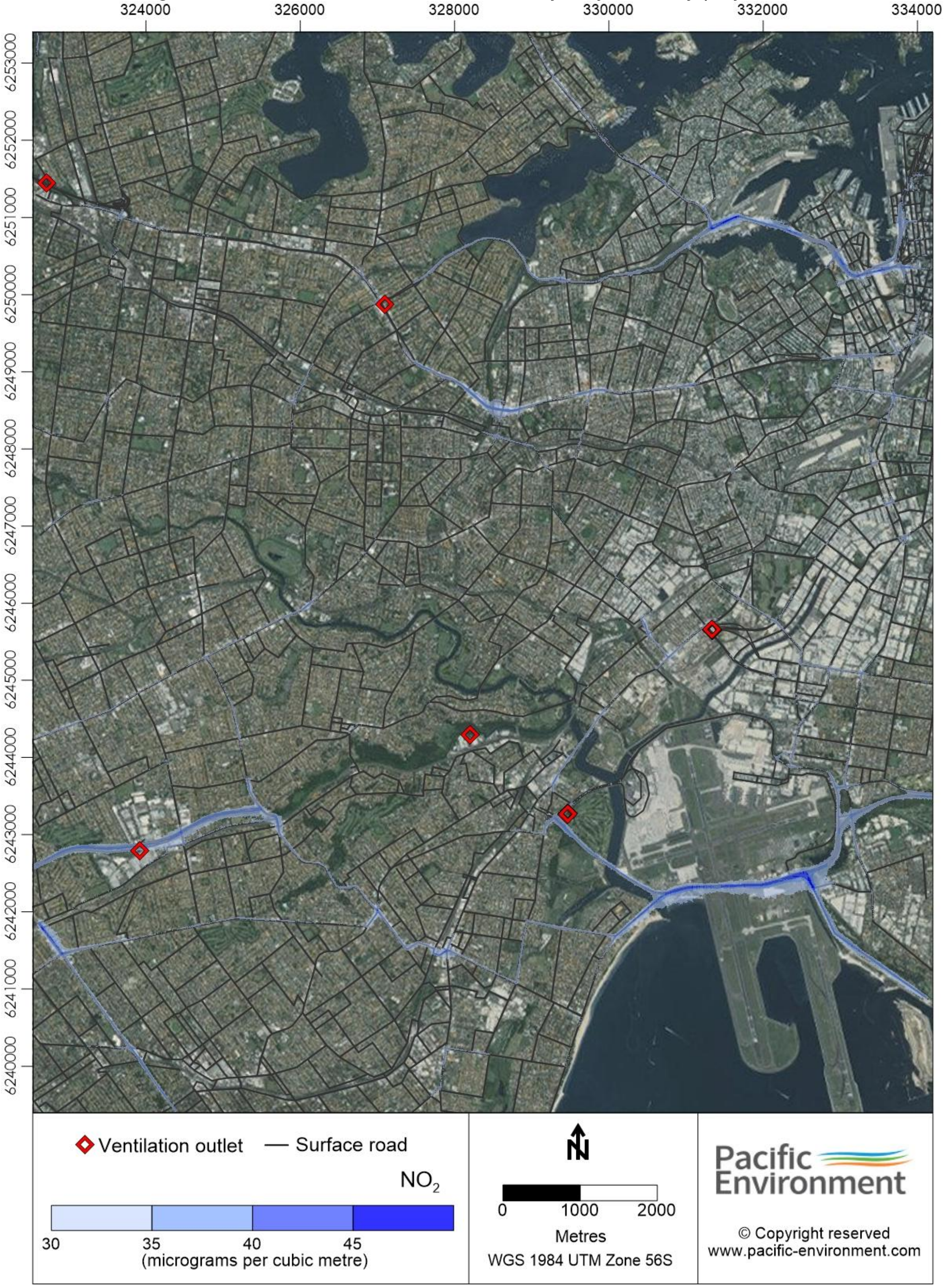


Figure 8-40 Contour plot of annual mean NO_2 concentration in the 2033 Do Minimum scenario (2033-DM)

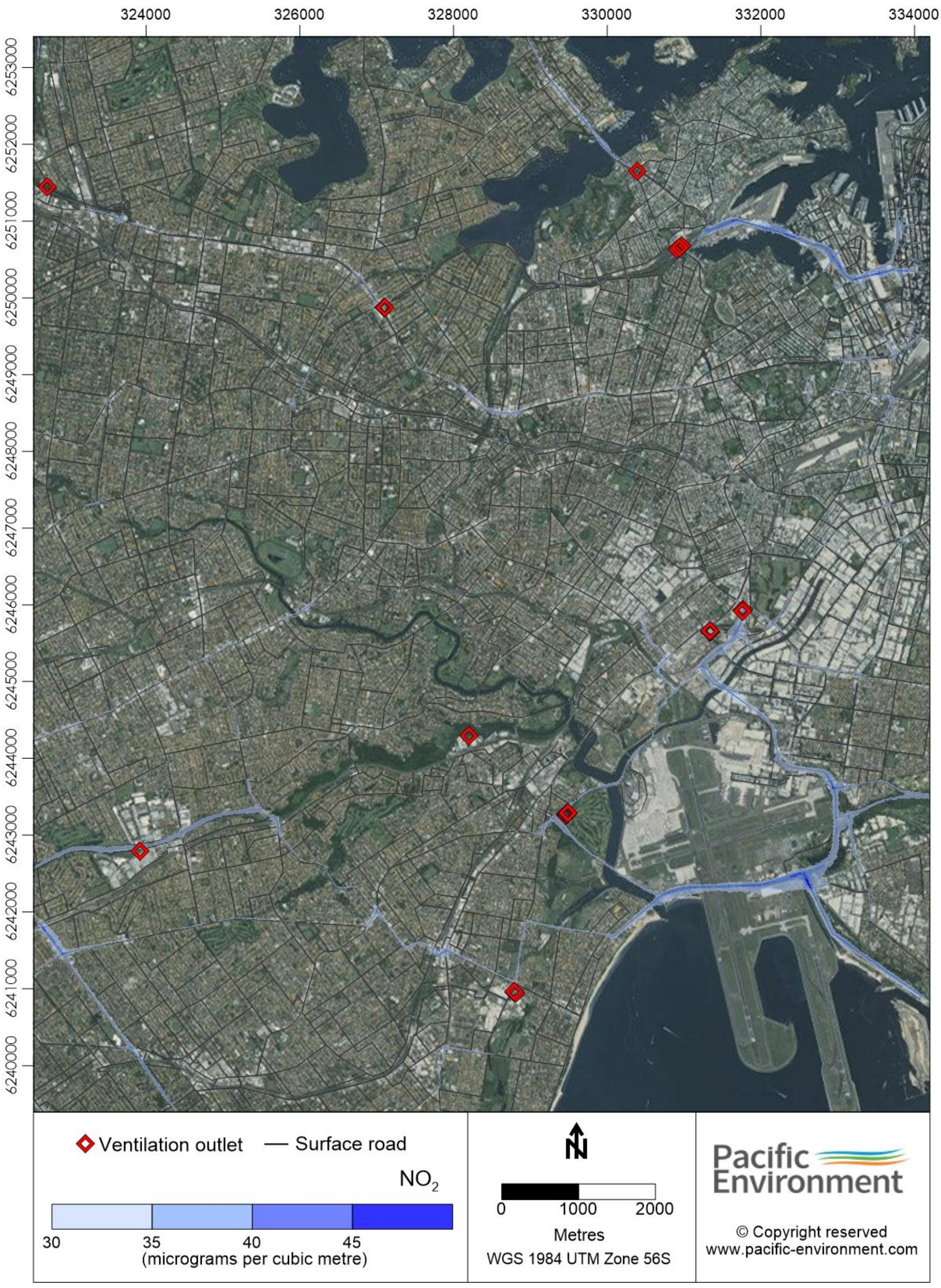


Figure 8-41 Contour plot of annual mean NO_2 concentration in the 2033 cumulative scenario (2033-DSC)

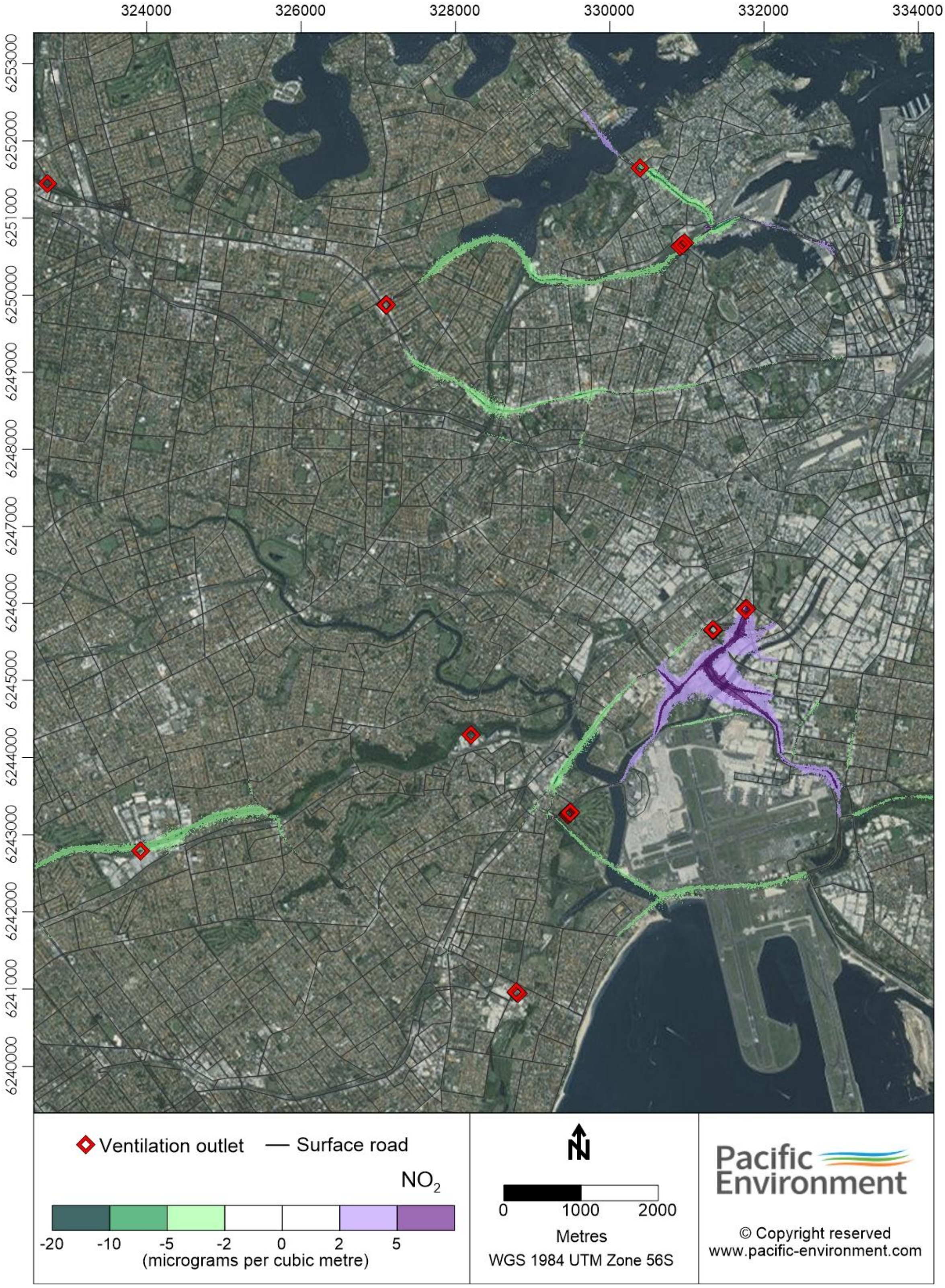


Figure 8-42 Contour plot of change in annual mean NO_2 concentration in the 2033 cumulative scenario (2033-DSC minus 2033-DM)

Table 8-21 Average weekday two-way traffic volume on selected roads

Road	Average weekday 2-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, SE 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 8-22 Changes in average weekday two-way traffic volume on selected roads

Road	Change in average weekday 2-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, SE 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. These included all the ventilation outlets that were relevant to a given scenario, and the plot for the 2033-DSC scenario is shown in **Figure 8-43**. The contributions from the surface road network and the background are not included in these plots. As noted earlier, the contour plots for all other scenarios are given in **Annexure K**.

The impacts at the three main areas with M4-M5 Link ventilation facilities – Haberfield, Rozelle and St Peters interchange can clearly be seen, but again in absolute terms, the NO_X concentrations are low. There is also a spatial separation between the NO_X contributions from the outlets in three areas; in other words, the emissions from the separate outlets do not combine to produce high cumulative concentrations.

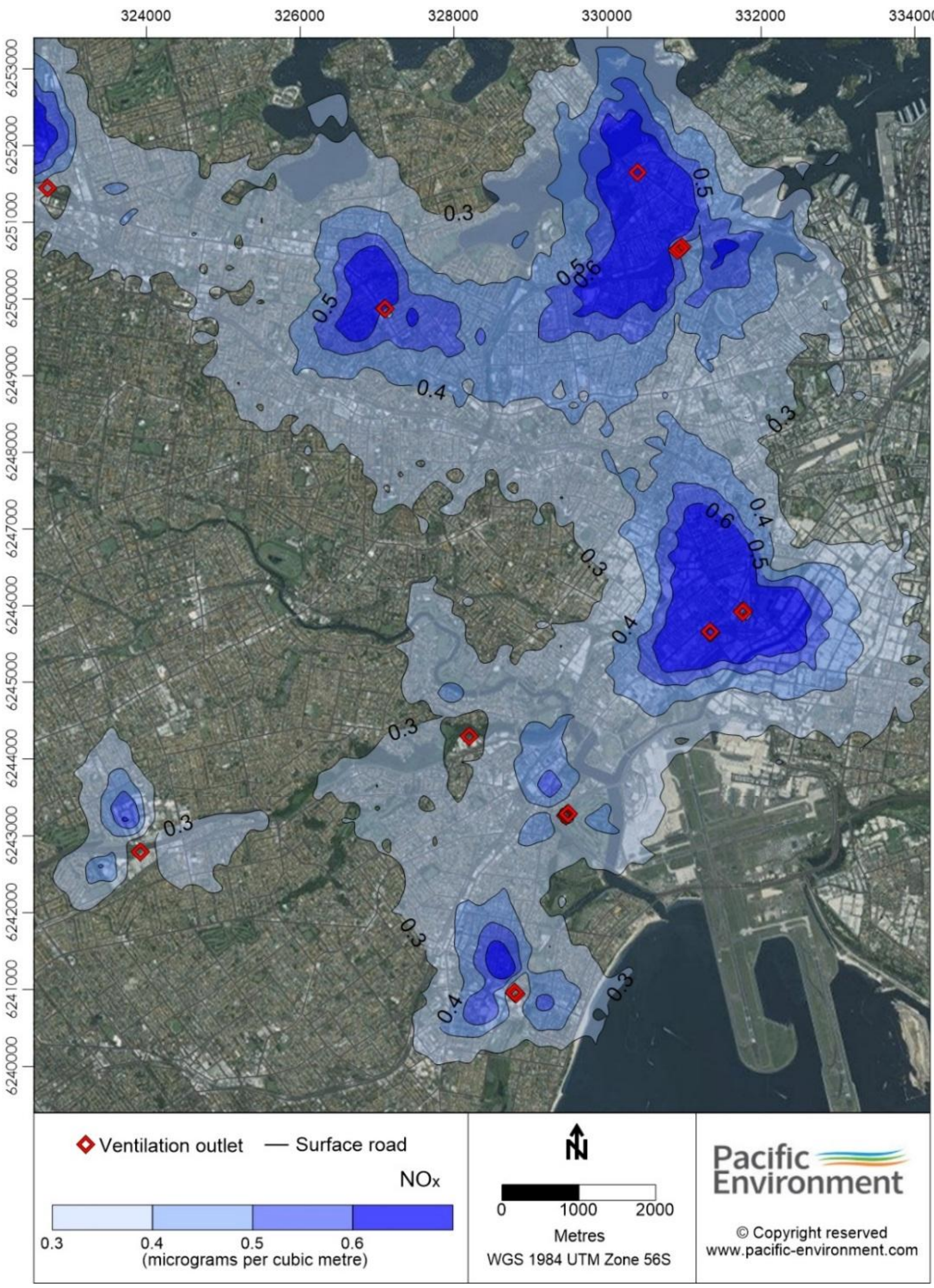


Figure 8-43 Contour plot of annual mean NO_X concentrations for ventilation outlets (2033-DSC)

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 and cumulative scenarios are shown in **Figure 8-44**. 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.

Lower air quality standards are in force in other countries. For example, New Zealand has a limit value of 200 µg/m^3 but with nine allowed exceedances per year. There were more than nine exceedances of the New Zealand standard at three community receptors (CR03, CR07 and CR10) in at least one scenario. For receptor CR03 there were 15 exceedances in 2023-DM, but this reduced to 10 in 2023-DS, and below nine in the other scenarios. Receptor CR07 had more than nine exceedances in 2023-DM. Receptor CR10 had the most exceedances, but the number decreased with the project; for example, this receptor had 29 exceedances in 2023-DM, 26 in 2023-DS and 18 in

2023-DSC. In general, the number of exceedances decreased in the with-project and cumulative scenarios compared with the corresponding Do Minimum scenarios.

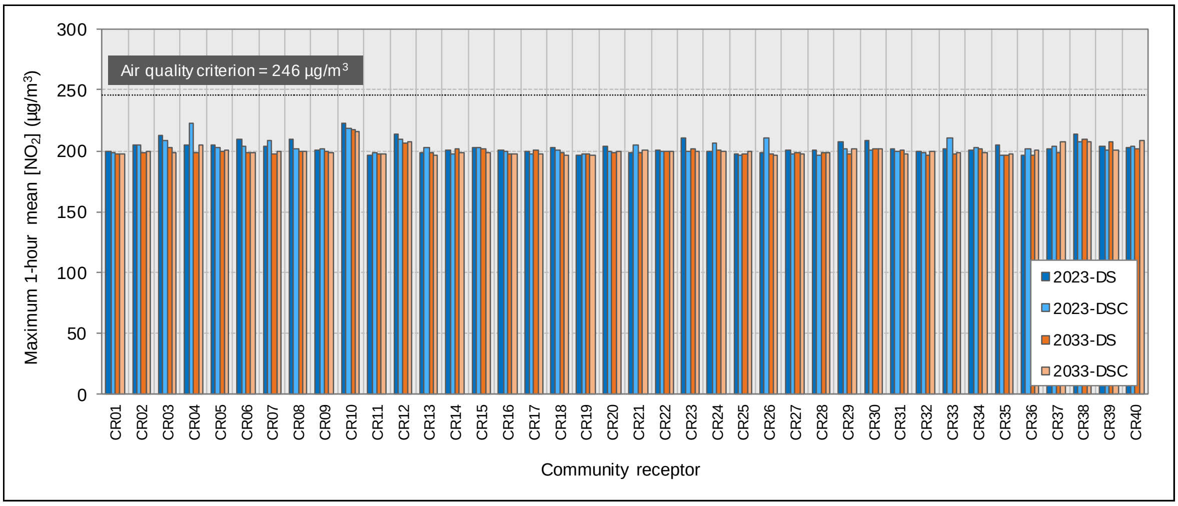


Figure 8-44 Maximum one hour mean NO_2 concentration at community receptors (with-project and cumulative scenarios)

The changes in the maximum one hour NO_2 concentration relative to the Do Minimum scenarios are shown in **Figure 8-45**. 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.

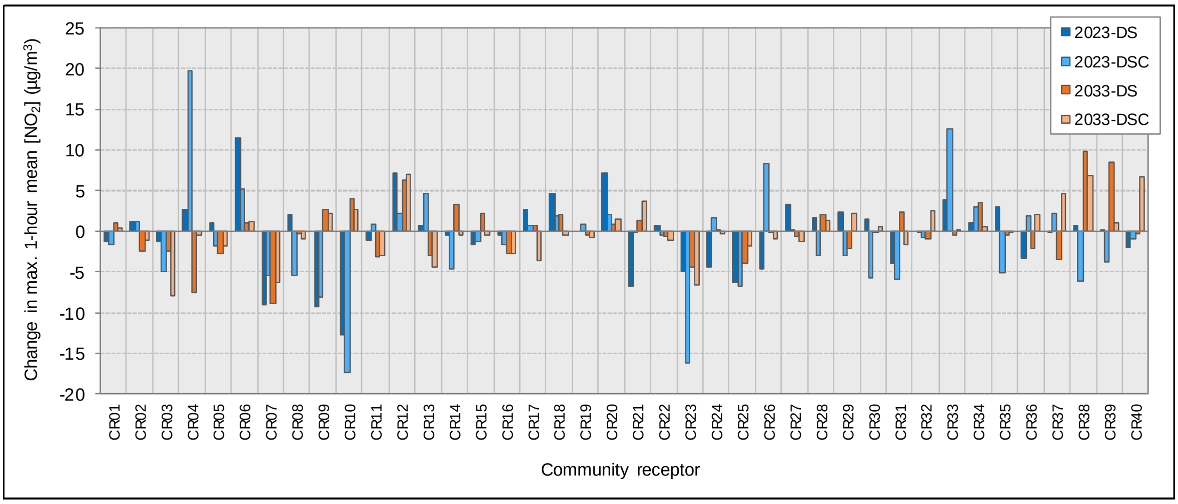


Figure 8-45 Change in maximum one hour mean NO_2 concentration at community receptors (with-project and cumulative scenarios, relative to Do Minimum scenarios)

To calculate the contributions of different sources to maximum one hour NO_2, it was firstly necessary to identify the hour in which the maximum NO_X value occurred, and then determine the modelled surface road and outlet contributions during that hour. Once the relevant hours had been identified, the source contributions to maximum one hour NO_2 were estimated using the method described earlier for the annual mean. The results are shown in **Figure 8-46**. 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 negligible. As with one hour mean CO, larger one hour contributions from roads and outlets could have occurred during other hours of the year, but the total concentration would have been lower.

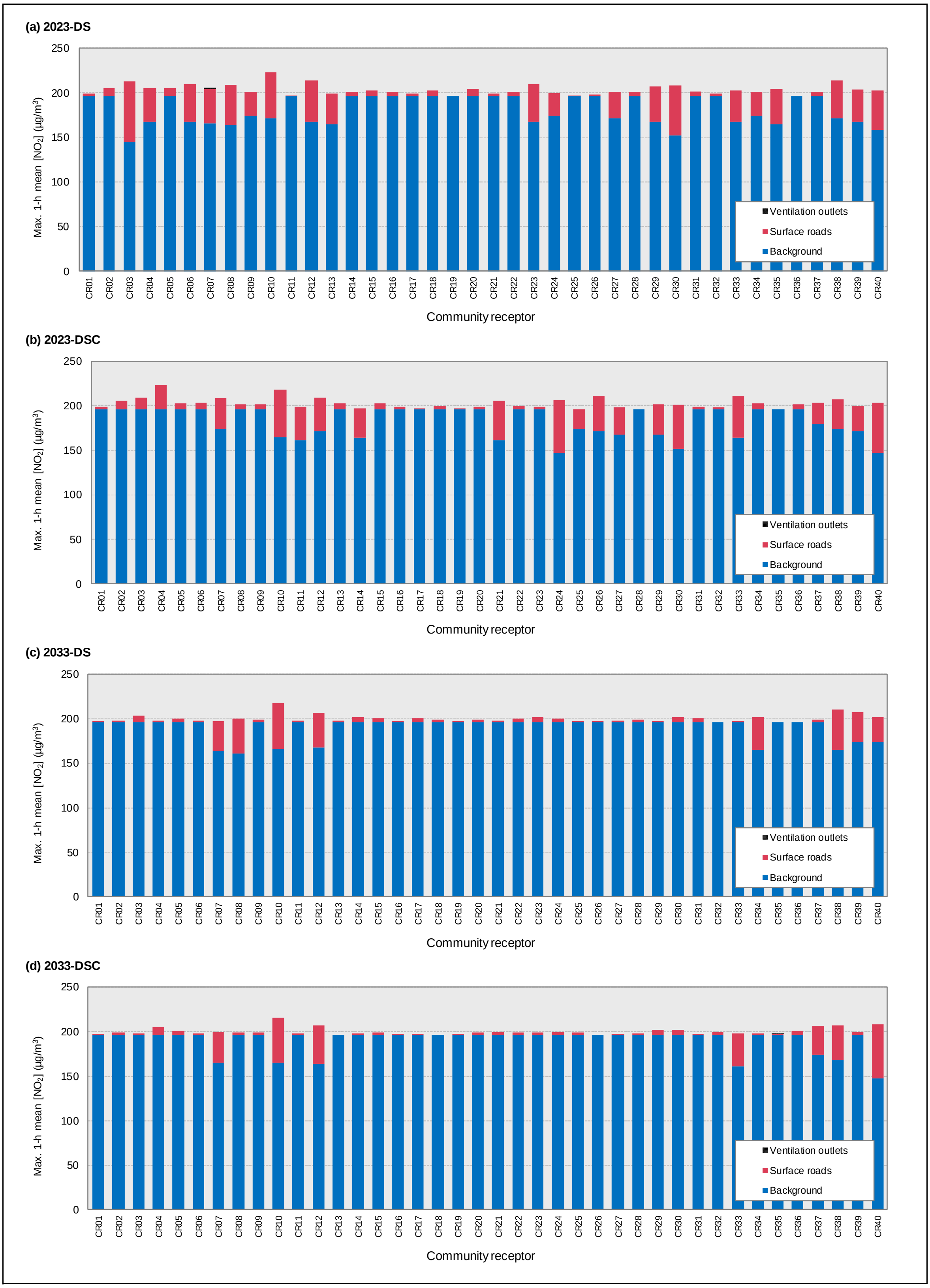


Figure 8-46 Source contributions to maximum one hour mean NO_2 concentration at community receptors (with-project and cumulative scenarios)

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 8-47**. The contribution of surface roads and ventilation outlets are not shown separately in **Figure 8-47**; as in the case of one hour CO and other short-term metrics, the hours when the maxima for the different sources occurred were not known.

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 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 (1.0 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 calculated, the maximum contribution of tunnel outlets to NO_X at any receptor in the with-project and cumulative 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.

Compliance with the New Zealand limit value of 200 µg/m^3 with nine allowed exceedances per year could not be determined for the RWR receptors, as time series were not available.

The changes in the maximum one hour mean NO_2 concentration at the RWR receptors in the with-project and cumulative scenarios are shown, ranked by change in concentration as a result of the project, in **Figure 8-48**. There was predicted to be an increase in the maximum one hour NO_2 concentration at between 26 per cent and 33 per cent of receptors, depending on the scenario. Conversely, there was a reduction in the maximum concentration at 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 (up to 234 µg/m^3), and again this is discussed **section 8.4.14**.

Contour plots – all sources

Contour plots of maximum one hour NO_2 concentrations in the 2033-DM and 2033-DSC scenarios are provided in **Figure 8-49** and **Figure 8-50** respectively. 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 contour plot for the change in the maximum one hour NO_2 concentration with in the 2023 cumulative scenario is given in **Figure 8-51**. The locations with the highest concentrations and largest changes in concentration are similar to this for annual mean NO_2.

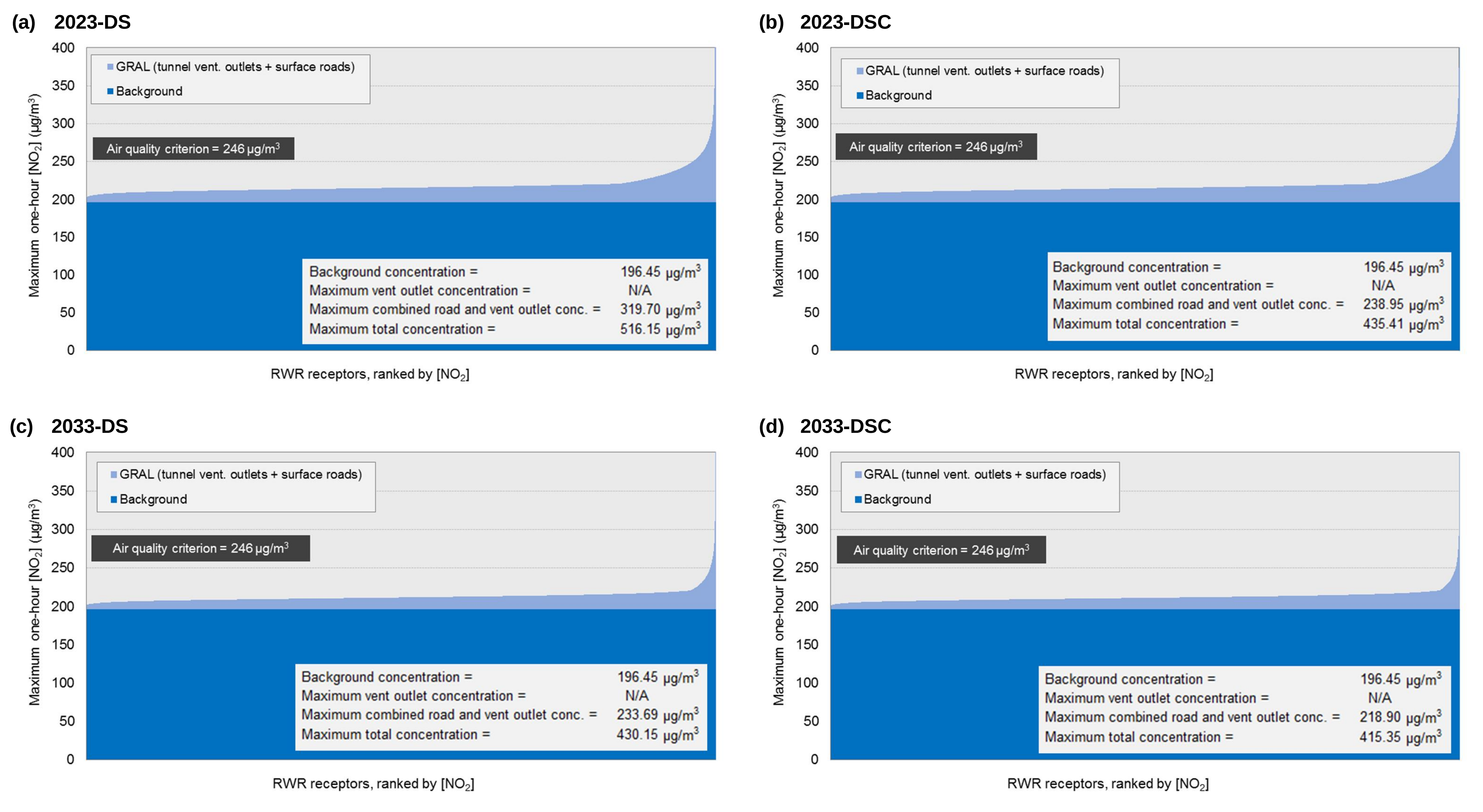


Figure 8-47 Source contributions to maximum one hour mean NO_2 concentration at RWR receptors (with-project and cumulative scenarios)

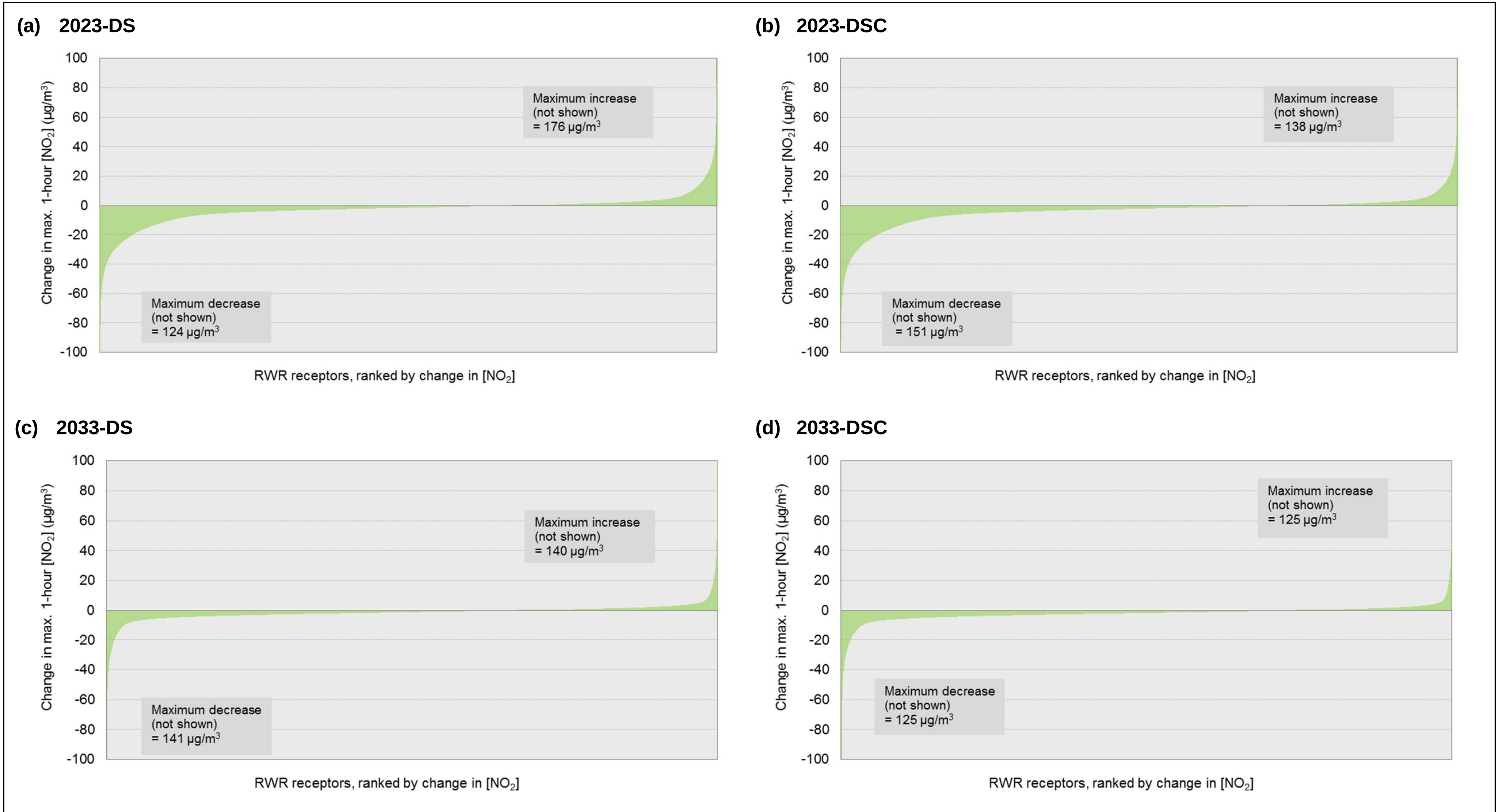


Figure 8-48 Change in maximum one hour mean NO_2 concentration at RWR receptors (with-project and cumulative scenarios, relative to Do Minimum scenarios)

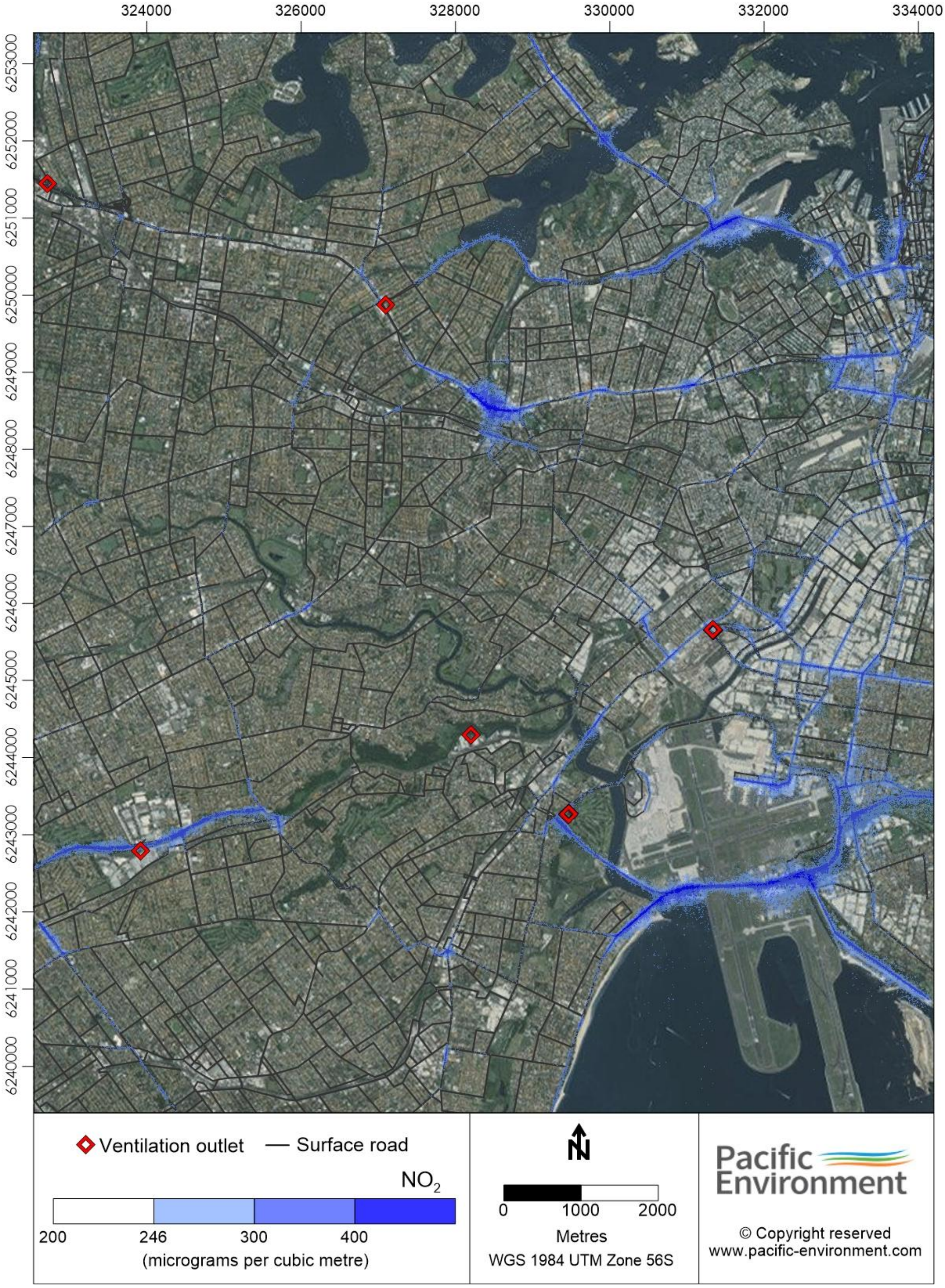


Figure 8-49 Contour plot of maximum one hour NO_2 concentration in the 2033 Do Minimum scenario (2033-DM)

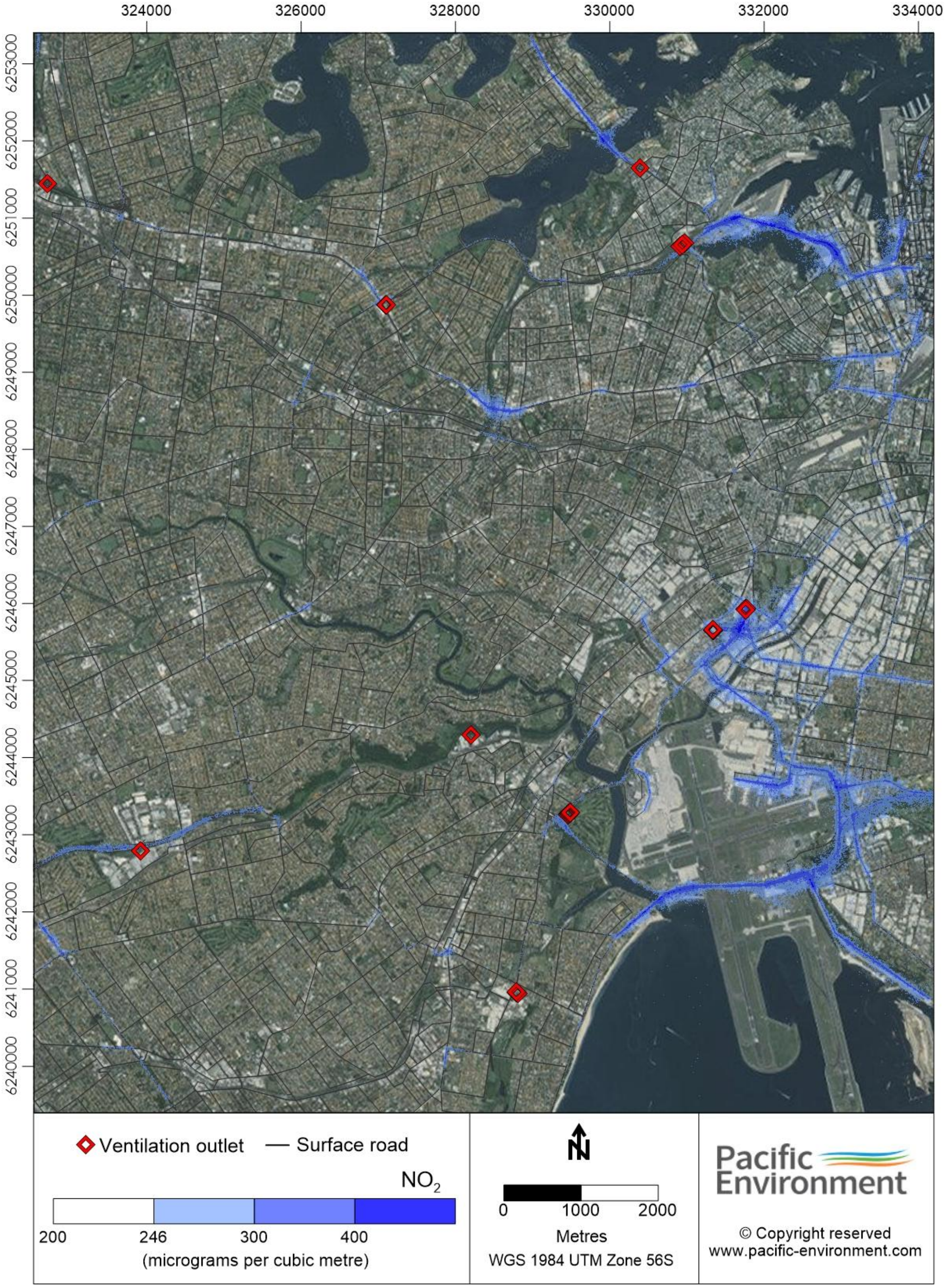


Figure 8-50 Contour plot of maximum one hour NO_2 concentration in the 2033 cumulative scenario (2033-DSC)

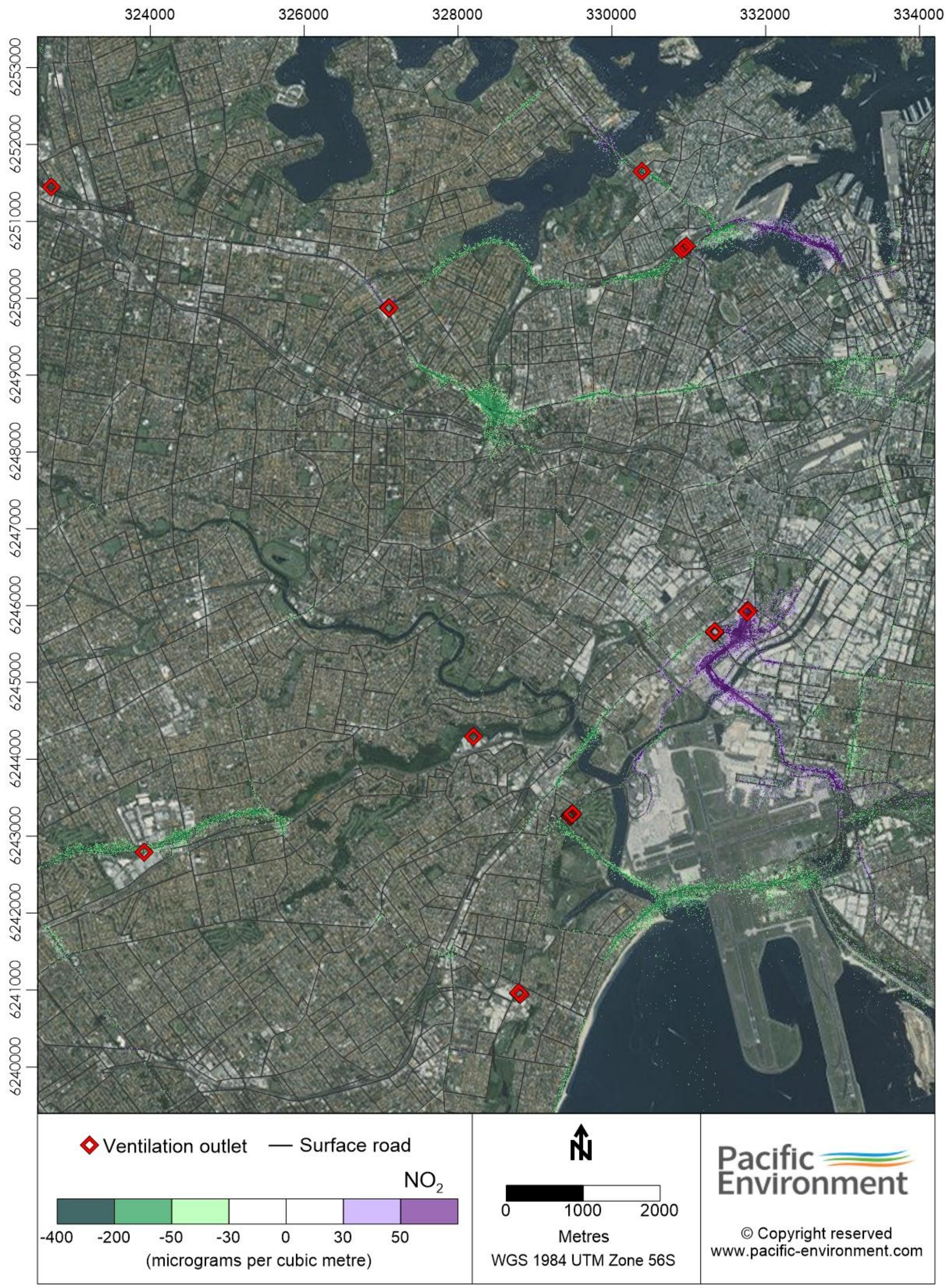


Figure 8-51 Contour plot of change in maximum one hour NO_2 concentration in the 2033 cumulative scenario (2033-DSC minus 2033-DM)

Contour plots - ventilation outlets only

The contour plot for the maximum one hour NO_X from the ventilation outlets only in the 2033-DSC scenario is shown in **Figure 8-52**. The ventilation outlet NO_X increments were low (contributions to NO_2 would be even lower), and their effects were quite localised.

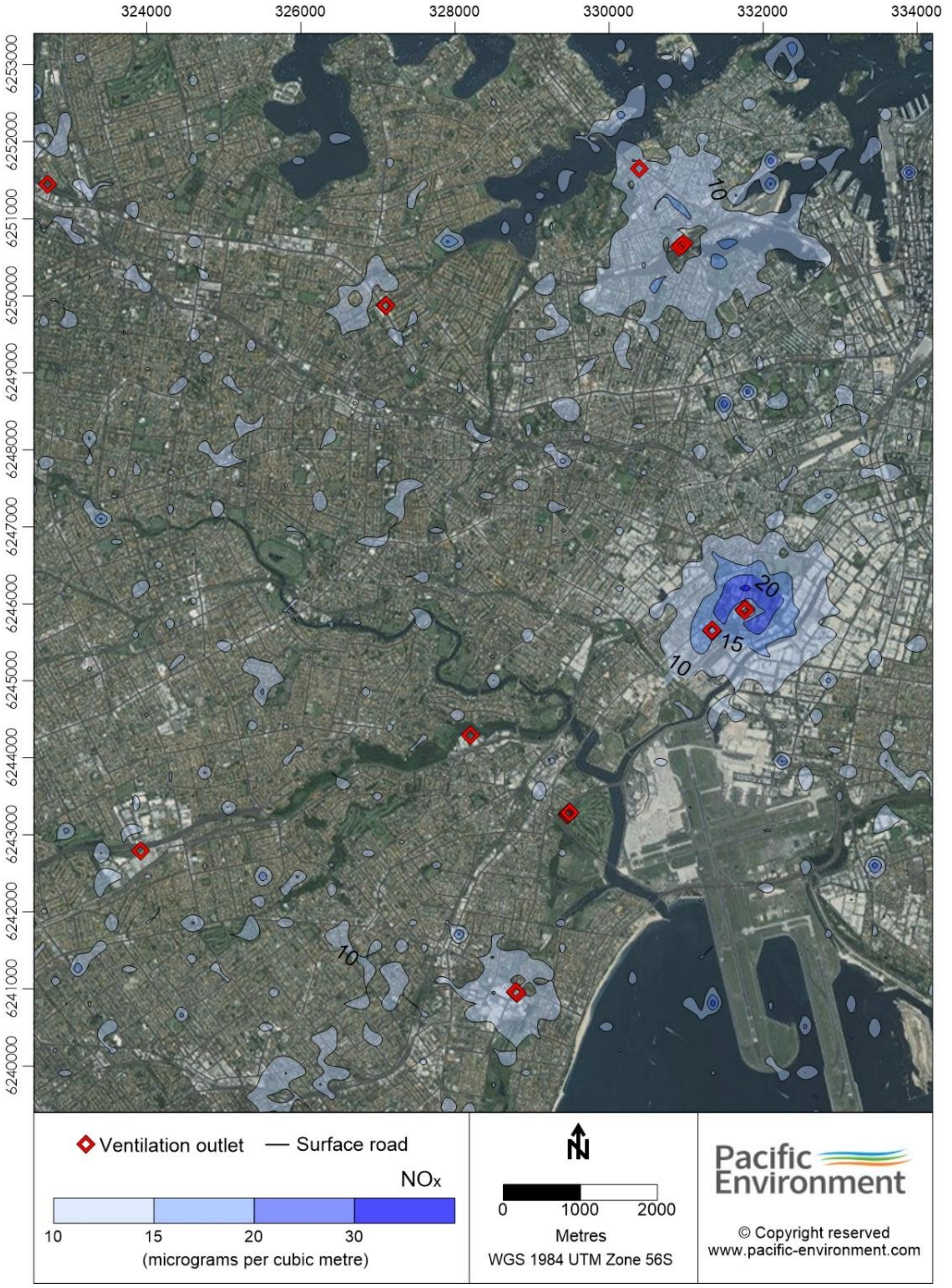


Figure 8-52 Contour plot of maximum one hour NO_X concentration for ventilation outlets only (2033-DSC)

PM_{10} (annual mean)

Results for community receptors

The annual mean PM_{10} concentrations community receptors are shown in **Figure 8-53**. 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).

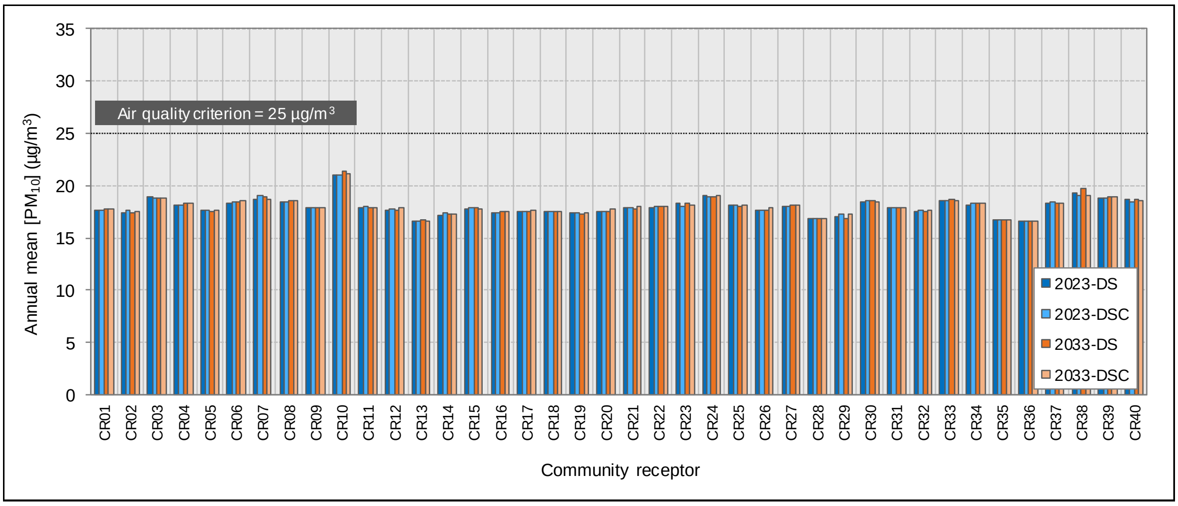


Figure 8-53 Annual mean PM_{10} concentration at community receptors (with-project and cumulative scenarios)

Figure 8-54 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.

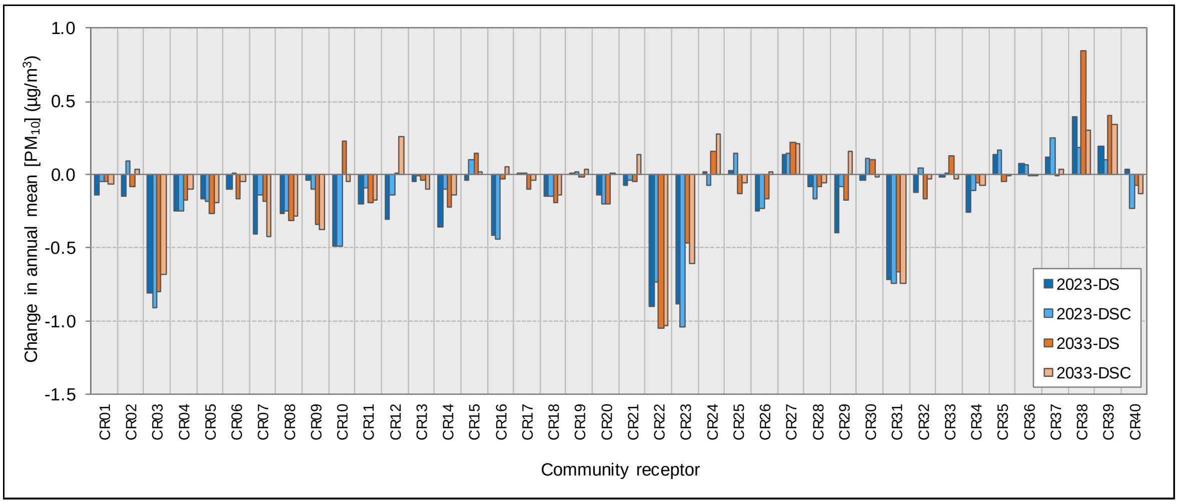


Figure 8-54 Change in annual mean PM_{10} concentration at community receptors (with-project and cumulative scenarios, relative to Do Minimum scenarios)

Concentrations in the with-project and cumulative scenarios were again dominated by the background (**Figure 8-55**), with a small contribution from roads (0.8-4.4 µg/m³) and a negligible contribution from tunnel ventilation outlets (less than around 0.2 µg/m³).

Figure 8-55 Source contributions to annual mean PM_{10} concentration at community receptors (with-project and cumulative scenarios)