WestConnex

Australian Government
BUILDING OUR FUTURE

NSW GOVERNMENT

M4-M5 Link

Environmental Impact Statement

August 2017

Appendix K

Volume 2E

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 2E

Appendix

WestConnex

Appendix K

Technical working paper: Human health risk assessment

WestConnex

Roads and Maritime Services

WestConnex – M4-M5 Link

Technical working paper: Human health risk assessment

August 2017

Prepared for

Roads and Maritime Services

Prepared by

Environmental Risk Sciences Pty Ltd

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Glossary of terms and abbreviations

Term	Definition
ABL	Assessment background noise level
ABS	Australian Bureau of Statistics
ACTAQ	NSW Government 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)
Absorption	The process of taking in. For a person or an animal, absorption is the process of a substance getting into the body through the eyes, skin, stomach, intestines, or lungs
Adverse health effect	A change in body function or cell structure that might lead to disease or health problems
ATSDR	Agency for Toxic Substances and Disease Register
AAQ	Ambient air quality
ANZECC	Australia and New Zealand Environment and Conservation Council
Background level	An average or expected amount of a substance or material in a specific environment, or typical amounts of substances that occur naturally in an environment
BaP	Benzo(a)pyrene
Biodegradation	Decomposition or breakdown of a substance through the action of micro-organisms (such as bacteria or fungi) or other natural physical processes (such as sunlight)
Body burden	The total amount of a substance in the body. Some substances build up in the body because they are stored in fat or bone or because they leave the body very slowly
BTX	Benzene, toluene and total xylenes
Carcinogen	A substance that causes cancer
CASA	Civil Aviation Safety Authority
CBD	Central business district
CCME	Canadian Council of Ministers of the Environment
CCTV	Closed Circuit Television
CEMP	Construction Environmental Management Plan
CHD	Coronary heart disease
Chronic exposure	Contact with a substance or stressor that occurs over a long time (more than one year) [compare with acute exposure and intermediate duration exposure]
CO	Carbon monoxide
Community receptor/receiver	Within the wider community, a number of additional locations, referred to as community receptors, have been identified. Community receptors are locations in the local community within the suburbs close to the project where more sensitive members of the population, such as infants and young children, the elderly or those with existing health conditions or illnesses, may spend a significant period of time. These locations comprise hospitals, child care facilities, schools and aged care homes/facilities
COPD	Chronic Obstructive Pulmonary Disease
CPI	Consumer Price Index
CNVG	*Construction Noise and Vibration Guideline* (Roads and Maritime, 2016)
CTAMP	Construction Traffic and Access Management Plan
dB(A)	A-weighted decibels. A-weighting is applied to instrument-measured sound levels in effort to account for the relative loudness perceived by the human ear, as the ear is less sensitive to low audio frequencies
DE	Diesel exhaust
DECCW	NSW Department of Environment, Climate Change and Water
DEFRA	(UK) Department for Environment, Food and Rural Affairs

Term	Definition
DEH	Australian Department of Environment and Heritage
Detection limit	The lowest concentration of a chemical that can reliably be distinguished from a zero concentration
DIRD	Department of Infrastructure and Regional Development
Do minimum	A model scenario that does not incorporate the proposed project infrastructure
Do something	A model scenario that incorporates the proposed project infrastructure
Do something - cumulative	A model scenario that incorporates the proposed M4-M5 Link project infrastructure, all the WestConnex projects, and other related projects including the proposed future Western Harbour Tunnel and Beaches Link, Sydney Gateway and F6 Extension projects (depending on the year of assessment)
Dose	The amount of a substance to which a person is exposed over some time period. Dose is a measurement of exposure. Dose is often expressed as milligram (amount) per kilogram (a measure of body weight) per day (a measure of time) when people eat or drink contaminated water, food, or soil. In general, the greater the dose, the greater the likelihood of an effect. An 'exposure dose' is how much of a substance is encountered in the environment. An 'absorbed dose' is the amount of a substance that actually got into the body through the eyes, skin, stomach, intestines, or lungs
DP&E	Department of Planning and Environment
DPM	Diesel particulate matter
DSI	Detailed site investigation
EC	European Commission
ED	Emergency department
EIS	Environmental Impact Statement
EMF	Electromagnetic field
EP&A Act	*Environmental Planning and Assessment Act 1979* (NSW)
EU	European Union
Exposure	Contact with a substance by swallowing, breathing, or touching the skin or eyes. Also includes contact with a stressor such as noise or vibration. Exposure may be short term [acute exposure], of intermediate duration, or long term [chronic exposure]
Exposure assessment	The process of finding out how people come into contact with a hazardous substance, how often and for how long they are in contact with the substance, and how much of the substance they are in contact with
Exposure pathway	The route a substance takes from its source (where it began) to its endpoint (where it ends), and how people can come into contact with (or get exposed) to it. An exposure pathway has five parts: a source of contamination (such as chemical leakage into the subsurface); an environmental media and transport mechanism (such as movement through groundwater); a point of exposure (such as a private well); a route of exposure (eating, drinking, breathing, or touching), and a receptor population (people potentially or actually exposed). When all five parts are present, the exposure pathway is termed a completed exposure pathway
Genotoxic carcinogen	These are carcinogens that have the potential to result in genetic (DNA) damage (gene mutation, gene amplification, chromosomal rearrangement). Where this occurs, the damage may be sufficient to result in the initiation of cancer at some time during a lifetime
GRAL	Graz Lagrangian Model
GRAMM	Graz Mesoscale Model
GSP	NSW State Gross Product

Term	Definition
Guideline value	Guideline value is a concentration in soil, sediment, water, biota or air (established by relevant regulatory authorities such as the NSW Department of Environment and Conservation (DEC) or institutions such as the National Health and Medical Research Council (NHMRC), Australia and New Zealand Environment and Conservation Council (ANZECC) and World Health Organization (WHO)), that is used to identify conditions below which no adverse effects, nuisance or indirect health effects are expected. The derivation of a guideline value utilises relevant studies on animals or humans and relevant factors to account for inter and intra-species variations and uncertainty factors. Separate guidelines may be identified for protection of human health and the environment. Dependent on the source, guidelines would have different names, such as investigation level, trigger value and ambient guideline
HHRA	Human health risk assessment
HI	Hazard Index
IARC	International Agency for Research on Cancer
ICNG	*Interim Construction Noise Guideline* (NSW DECC 2009)
IHD	Ischaemic heart disease
Inhalation	The act of breathing. A hazardous substance can enter the body this way [see route of exposure]
INP	*NSW Industrial Noise Policy* (NSW EPA 2000)
Intermediate exposure Duration	Contact with a substance that occurs for more than 14 days and less than a year [compare with acute exposure and chronic exposure]
$L_{A1(1\ minute)}$	The "typical maximum noise level" for an event, used in the assessment of potential sleep disturbance during night-time periods. Alternatively, assessment may be conducted using the LAmax or maximum noise level
L_{A10}	The noise level exceeded for 10% of the measurement period. This is commonly referred to as the average maximum noise level
L_{A90}	The "background noise level" in the absence of construction activities. This parameter represents the average minimum noise level during the daytime, evening and night-time periods respectively. The $LA_{eq(15minute)}$ construction Noise Management Levels (NMLs) are based on the LA90 background noise levels
L_{Aeq}	The 'energy average noise level'
L_{Amax}	The maximum fast time weighted noise level from road traffic noise occurring at a particular location
LGA	Local Government Area
LOAEL	Lowest observed adverse effect level – The lowest tested dose of a substance that has been reported to cause harmful (adverse) health effects in people or animals
LOR	Limit of Reporting
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 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 Widening project	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
Metabolism	The conversion or breakdown of a substance from one form to another by a living organism
NCAs	Noise catchment areas
NCG	Noise Criteria Guideline (various, as referenced in the report)
NEPC	National Environment Protection Council

Term	Definition
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)
NHMRC	National Health and Medical Research Council
NMG	Noise Mitigation Guideline (various, as referenced in the report)
NML	Noise management level
NO_2	Nitrogen dioxide
NOx	Nitrogen oxides
NOAEL	No-observed-adverse-effect-level – The highest tested dose of a substance that has been reported to have no harmful (adverse) health effects on people or animals
NSW	New South Wales
NSW EPA	NSW Environment Protection Authority
NZ	New Zealand
OEH	NSW Office of Environment and Heritage
OEHHA	Office of Environmental Health Hazard Assessment, California Environment Protection Agency (Cal EPA)
OLS	Obstacle limitation surface
PAH	Polycyclic aromatic hydrocarbon
PANS-OPS	Procedures for air navigation systems operations
PIARC	Permanent International Association of Road Congresses
PM	Particulate matter
PM_1	Particulate matter below one micron in diameter, often termed very fine particles
$PM_{2.5}$	Particulate matter of aerodynamic diameter 2.5 µm and less
PM_{10}	Particulate matter of aerodynamic diameter 10 µm and less
Point of exposure	The place where someone can come into contact with a substance present in the environment [see exposure pathway]
Population	A group or number of people living within a specified area or sharing similar characteristics (such as occupation or age)
ppbv	Parts per billion by volume
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
RAP	Remedial action plan
RBL	Rating background level
Receptor population	People who could come into contact with hazardous substances [see exposure pathway]
Risk	The probability that something would cause injury or harm.
RNP	Road Noise Policy
Roads and Maritime	NSW Roads and Maritime Services
Route of exposure	The way people come into contact with a hazardous substance. Three routes of exposure are breathing [inhalation], eating or drinking [ingestion], or contact with the skin [dermal contact]
RWR	Residential, workplace and recreational (RWR). This term refers to all discrete receptor locations along the project corridor, and mainly covers residential and commercial land uses
SA	Statistical area
SEARs	Secretary's Environmental Assessment Requirements

Term	Definition
SMC	Sydney Motorway Corporation
SEIFA	Socio-Economic Index for Areas
SO_2	Sulfur dioxide
T90	Distillation temperature where 90% of the fuel is evaporated
TCEQ	Texas Commission on Environmental Quality
TEQ	Toxicity equivalent
Toxicity	The degree of danger posed by a substance to human, animal or plant life.
Toxicity data	Characterisation or quantitative value estimated (by recognised authorities) for each individual chemical for relevant exposure pathway (inhalation, oral or dermal), with special emphasis on dose-response characteristics. The data are based on based on available toxicity studies relevant to humans and/or animals and relevant safety factors
Toxicological profile	An assessment that examines, summarises, and interprets information about a hazardous substance to determine harmful levels of exposure and associated health effects. A toxicological profile also identifies significant gaps in knowledge on the substance and describes areas where further research is needed
Toxicology	The study of the harmful effects of substances on humans or animals
TSP	Total suspended particulates
Uncertainty factor	Mathematical adjustments for reasons of safety when knowledge is incomplete. For example, factors used in the calculation of doses that are not harmful (adverse) to people. These factors are applied to the lowest-observed-adverse-effect-level (LOAEL) or the no-observed-adverse-effect-level (NOAEL) to derive a minimal risk level (MRL). Uncertainty factors are used to account for variations in people's sensitivity, for differences between animals and humans, and for differences between a LOAEL and a NOAEL. Scientists use uncertainty factors when they have some, but not all, the information from animal or human studies to decide whether an exposure would cause harm to people [also sometimes called a safety factor]
ultrafines	Particulate matter below 0.1 microns in diameter
UK	United Kingdom
US	United States
USEPA	United States Environmental Protection Agency
VDV	Vibration dose values
VOC	Volatile organic compound
WHO	World Health Organization
WRTM	WestConnex Road Traffic Model
β coefficient	Beta coefficient
$\mu g/m^3$	Micrograms per cubic metre

Executive summary

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.

A human health risk assessment is a way of deciding now, what the consequences (to health) of some future action (such as this project) may be. This report includes a detailed review of what impacts may occur, who may be exposed to these impacts and whether there is potential for these impacts to result in adverse health effects within the local community.

The human health risk assessment presented in this report has been conducted in accordance with national guidance (enHealth 2001, 2012b; Harris 2007), which has involved the following:

- Review of predicted impacts to air quality, noise and vibration during construction and operation of the project. In some cases, the issues identified, such as those during construction, are short-term and can be mitigated/managed through the implementation of specific management measures. For other impacts, such as those from operations or for extended periods of construction from a number of projects, the impacts may occur over a longer period of time and require a more detailed assessment of how these impacts affect health
- Identification and characterisation of the community (including the presence of sensitive receptors such as childcare centres, aged care centres, schools and hospitals) who may be affected by these impacts
- Assessment of air quality impacts on health including:
  - Reviewing the key air pollutants (associated with vehicle emissions) that are predicted from the operation of the project (within the tunnel and outside the tunnel)
  - Identifying guidelines that are based on protection of the health of all members of the population for exposure to these pollutants over a short period of time as well as all day, every day
  - Comparing the predicted impacts with the health based guidelines
  - Undertaking a more detailed assessment of potential risks of changes in nitrogen dioxide and particulates, including fine particulate matter or $PM_{2.5}$ (particulate matter of aerodynamic diameter 2.5 microns (µm) and less) and coarse particulate matter or PM_{10} (particulate matter of aerodynamic diameter 10 µm and less). The assessment has addressed specific health effects (or health endpoints) associated with exposures to these pollutants. The assessment conducted has evaluated the impact of the project on these health endpoints within the local community
  - Assessment of the potential for health issues for users of the tunnel, as well as users of the wider tunnel network proposed in all the WestConnex projects as well as other proposed tunnel projects
  - Valuing/costing the impacts on health relevant to particulate matter based on the NSW Environment Protection Authority (NSW EPA) methodology

- Assessment of noise and vibration impacts on health including:
  - Reviewing the impacts that are predicted from the construction and operation of the project
  - Identifying guidelines that are based on the protection of the health and wellbeing (including sleep disturbance) during all phases of the project, both construction and operation
  - Comparing predicted impacts with the health based guidelines. Where the health based guidelines cannot be met, consideration of the implementation of mitigation/management measures and whether these can be effectively implemented to ensure the identified impacts meet the health based guidelines
- Assessment of public safety and contamination:
  - This has involved a qualitative assessment, providing and overview of the potential hazards that may affect public safety during construction and operation, including contamination. This review has considered the implementation of mitigation/management measures and whether these can minimise risks to the community
- Assessment of social changes on health associated with the project:
  - This has involved a qualitative assessment. Aspects of the project that have the potential to result in impacts or changes in the community (including traffic, pedestrian and cycle access, property acquisitions and access, visual changes, community access/cohesion and economic impacts) have been evaluated with respect to potential effects on health and well-being. In addition, the equity of changes associated with the project has also been evaluated within the community
  - An assessment of construction fatigue, related to community exposure to a number of concurrent construction projects, has also been undertaken.

The conclusions of the assessment undertaken and presented in this report are presented below.

In relation to air quality:

- Impacts associated with construction activities require management to ensure impacts to community health are minimised. Measures required to be implemented to minimise dust impacts are to be detailed in a Construction Air Quality Management Plan, as described in the **Appendix I** (Technical working paper: Air quality)
- Impacts in the community outside the tunnel: the project is expected to result in a decrease in total pollutant levels in the community. The project is expected to result in a redistribution of impacts associated with vehicle emissions, specifically in relation to emissions derived from vehicles using surface roads. For much of the community this would result in no change or a small improvement (ie decreased concentrations and health impacts), however for some areas located near key surface roads, a small increase in pollutant concentration may occur. Potential health impacts associated with changes in air quality (specifically nitrogen dioxide and particulates) within the local community have been assessed and are considered to be acceptable
- For the project, future development of land (including re-zonings) in the vicinity of the Campbell Road ventilation facility would require planning controls to be developed to ensure future developments at heights 10 metres or higher are not adversely impacted by the ventilation outlets. Development of planning controls would be supported by detailed modelling addressing all relevant pollutants and averaging periods
- Impacts within the tunnel: while concentrations of pollutants from vehicle emissions are higher within the tunnel (compared with outside the tunnel), and with the completion of a number of tunnel projects (approved or proposed), there is the potential for exposures to occur within a network of tunnels over varying periods of time, depending on the journey. The assessment of potential exposures inside these tunnels, has indicated:
  - Where windows are up and ventilation is on recirculation, exposure to nitrogen dioxide inside vehicles is expected to be below the current health based guidelines. In congested conditions inside the tunnels, it is not considered likely that significant adverse health effects would occur. Placing ventilation on recirculation is also expected to minimise exposures to particulates during travel through the tunnels

- For motorcyclists, where there is no opportunity to minimise exposure through the use of ventilation, there is the potential for higher levels of exposure to nitrogen dioxide. These exposures, under normal conditions, are not expected to result in adverse health effects. When the tunnels are congested it is expected that motorcyclists would spend less time in the tunnels than passenger vehicles and trucks due to lane filtering, limiting the duration of exposure and the potential for adverse health effects.

In relation to noise and vibration, potential impacts during construction and operation have been considered:

- Construction: without implementation of mitigation measures there is the potential for noise and vibration impacts associated with a range of construction activities to result in adverse health effects in the community. Hence it is important that management and mitigation measures are implemented throughout the construction period to minimise the potential for adverse health effects. These management and mitigation measures (including the requirement for noise monitoring) are to be outlined in detail within the Construction Noise and Vibration Management Plan. Additional management measures have been identified to address and minimise noise impacts from multiple projects that may impact on and result in construction fatigue issues in the community
- Operation: during the operation of the project a number of properties have been identified where road noise has the potential to be elevated and adversely affect health. For these properties, management and mitigation measures are required to protect the health of occupants. These management and mitigation measures may include noise barriers and/or at property architectural treatments. The recommended mitigation measures would ensure that the levels of road traffic noise experienced by residents would be reduced as low as feasible and reasonable.

Changes in the urban environment associated with the project have the potential to result in a range of impacts on health and wellbeing of the community. The potential for changes to result in impacts on health and wellbeing is complex. Changes that may occur have the potential to result in both positive and negative impacts. Positive impacts include economic benefits, changes in traffic levels in some areas and increased public open space in the Rozelle Rail Yards. Negative impacts may occur as a result of traffic changes during construction and operation, property acquisitions, visual changes, noise impacts and changes in access/cohesion of local areas. These may result in increased levels of stress and anxiety. In many cases the impacts identified are either short term (associated with construction only) and/or management and mitigation measures have been identified to minimise the impacts on the community.

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.
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.

Project	Description	Status
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.

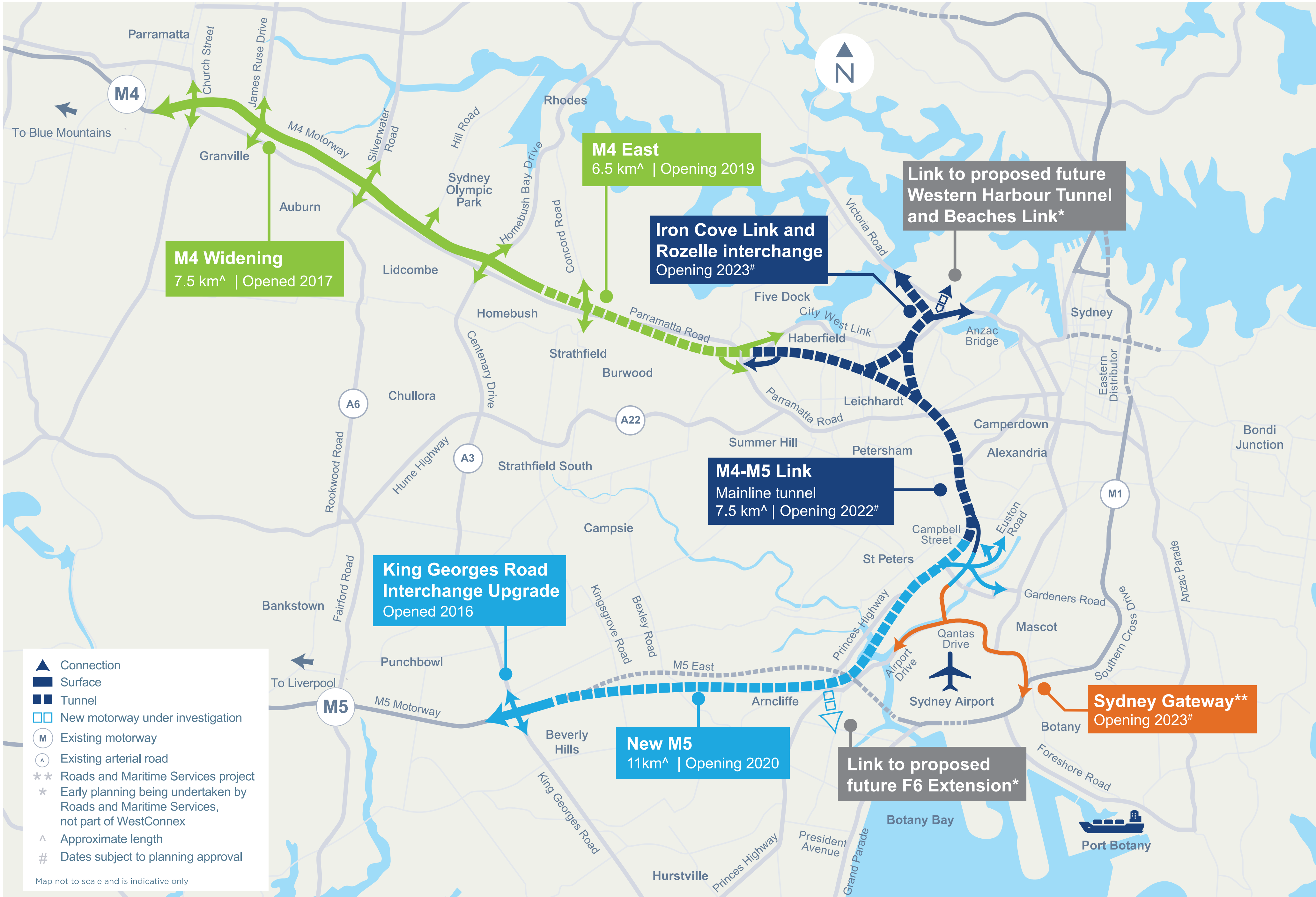


Figure 1-1 Overview of WestConnex and related projects

1.2 Purpose of this report

This technical working paper presents a human health risk assessment (HHRA) associated with impacts identified in relation to air quality, noise and vibration and social aspects, to address the Secretary's Environmental Assessment Requirements (SEARs).

1.3 SEARs

In preparing this technical report for human health impacts, the revised SEARs issued for the M4-M5 Link project (SSI-7485) on 3 May 2017 have been addressed. The key matters raised by the Secretary for consideration in this report are outlined in **Table 1-2**.

Table 1-2 Relevant SEARs addressed in this report

SEARs	
Health and Safety	
Requirements, as per Section 3 of the SEARs	**Section where addressed in report**
1. The Proponent must assess the potential health impacts of the project, in accordance with the current guidelines	**Full report**
2. The assessment must:	
a) Describe how the design of the proposal minimises adverse health impacts	**Section 3.3** and **Sections 6** to **10**
b) Assess human health impacts from the operation and use of the tunnel under a range of conditions, including worst case operating conditions and the full length of all tunnels in the WestConnex scheme	**Sections 6** to **10**
c) Human health risks and costs associated with the proposal, including those associated with air quality, noise and vibration, and social impacts on the adjacent and surrounding areas during the construction and operation of the proposal	**Sections 6** to **10**
d) Include both incremental changes in exposure from existing background pollutant levels and the cumulative* impacts of project specific and existing pollutant levels at the location of receptors (including public open space areas)	**Section 6** and refer to **Chapter 26** (Cumulative impacts) of the EIS
e) Assess the likely risks of the project to public safety, paying particular attention to pedestrian safety, subsidence risks, bushfire risks and the handling and use of dangerous goods	**Section 9**
f) Include a cumulative human health impact assessment inclusive of in-tunnel, local and regional impacts due to the operation of and potential continuous travel through the M4 East and New M5 Motorways and surface roads	**Section 7** and refer to **Chapter 26** (Cumulative impacts) of the EIS

Note: * The assessment of cumulative impacts, to address the SEARs has been undertaken in this report, where the following terminology has been utilised. The term "total" refers to the assessment of exposures to background pollutant levels as well as the project, and the term "cumulative" refers to the assessment of impacts from the M4-M5 Link project as well as the other WestConnex projects and the proposed future Western Harbour Tunnel and Beaches Link, Sydney Gateway and F6 Extension projects.

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, southwest 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.

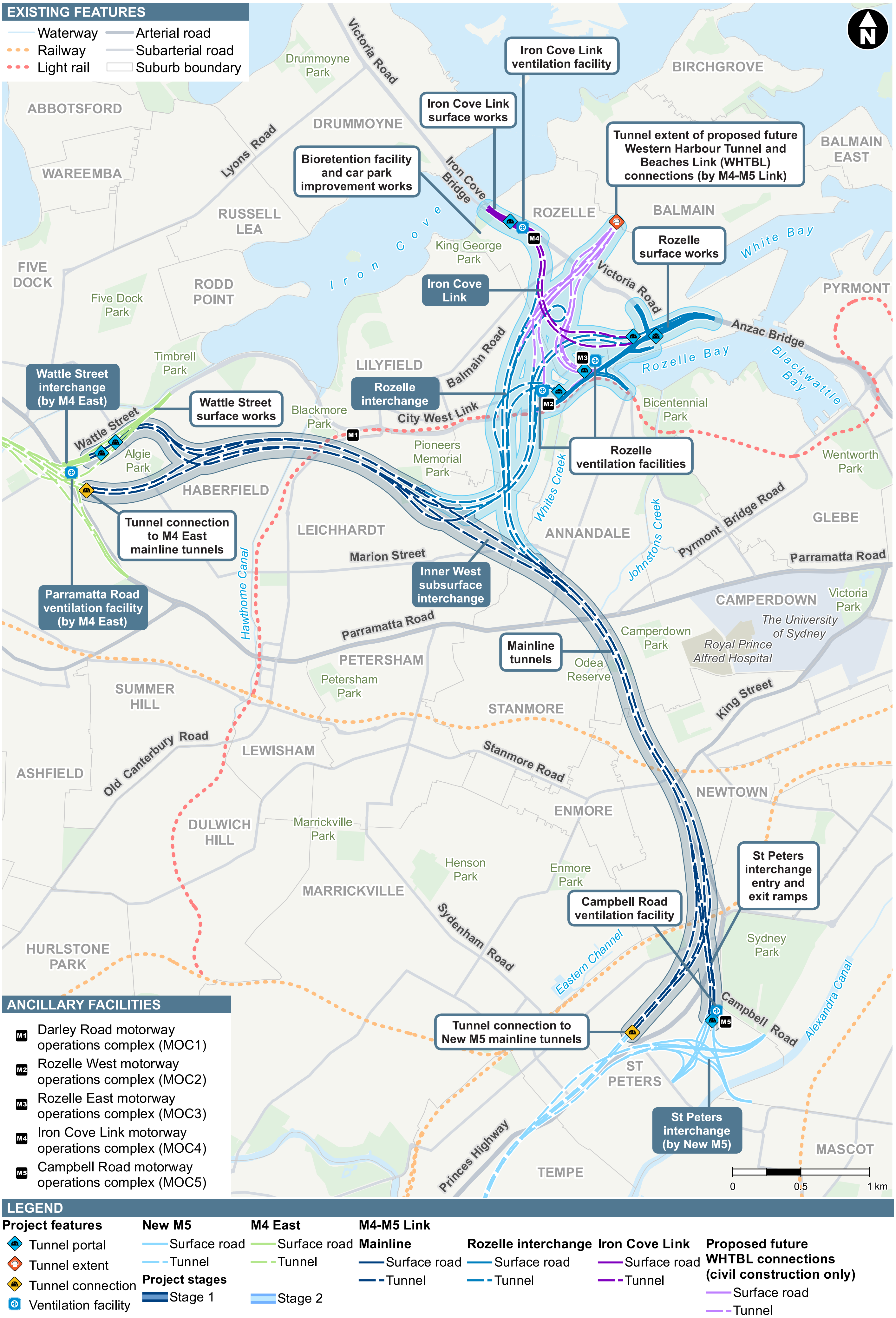


Figure 2-1 Overview of the project

2.3 Construction activities

An overview of the key construction features of the project is shown in **Figure 2-2** and 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

Component	Typical activities
Drainage	• Construct new pits and pipes • Construct new groundwater drainage system • Connect drainage to existing network • Construct sumps in tunnels as required • Construct water quality basins, constructed 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																■	■	■	■	■				
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																			■	■	■	■	■	

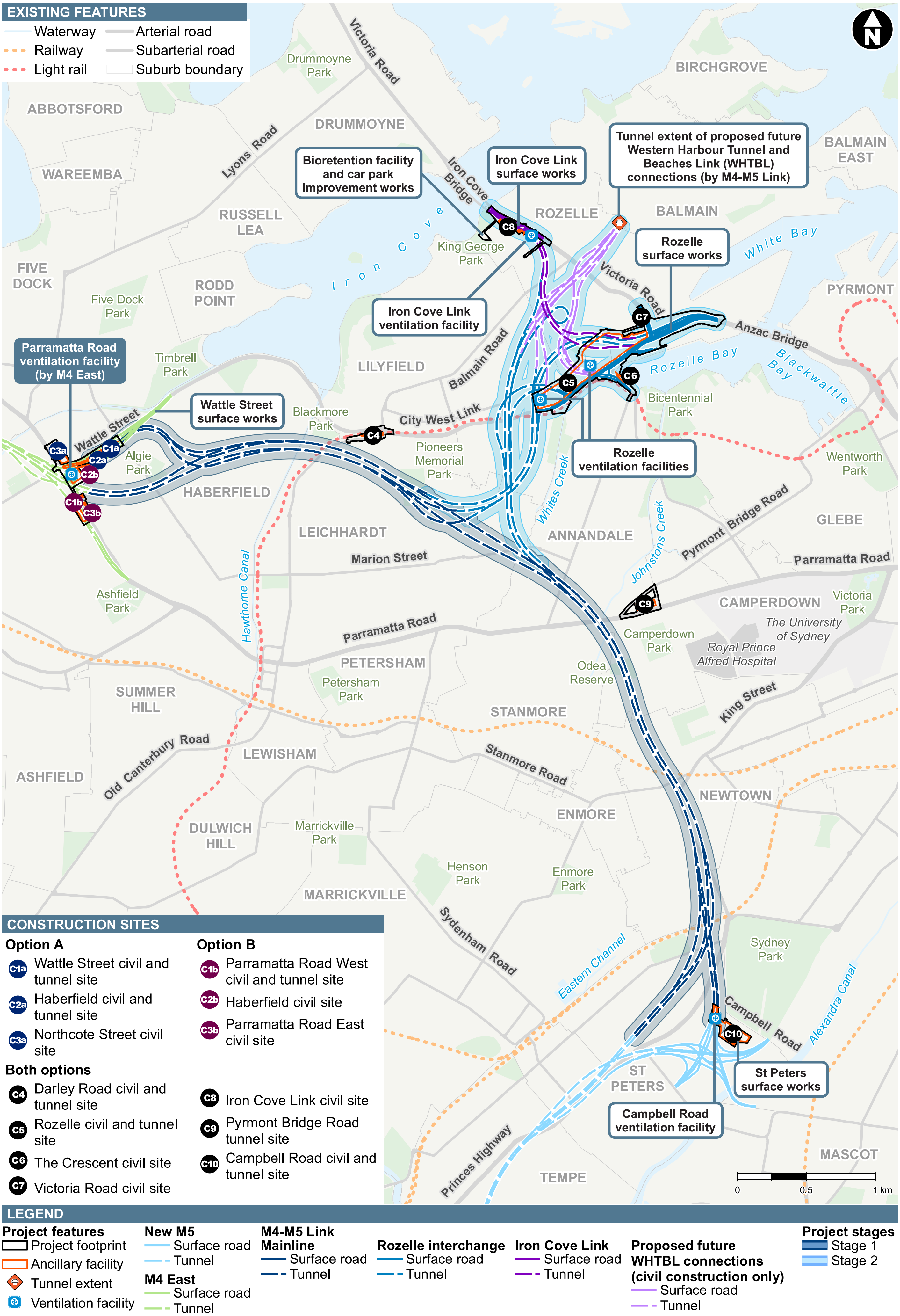


Figure 2-2 Overview of project footprint and ancillary facilities

3 Assessment methodology

3.1 What is a risk or impact assessment?

3.1.1 Risk

Risk assessment is used extensively in Australia and overseas to assist in decision making on the acceptability of the risks associated with the presence of contaminants or stressors in the environment and assessment of potential risks to the public. Risk is commonly defined as the chance of injury, damage, or loss. Therefore, to put oneself or the environment 'at risk' means to participate, either voluntarily or involuntarily, in an activity or activities that could lead to injury, damage, or loss.

Voluntary risks are those associated with activities that we decide to undertake such as driving a vehicle, riding a motorcycle and smoking cigarettes. Involuntary risks are those associated with activities that may happen to us without our prior consent or forewarning. Acts of nature such as being struck by lightning, fires, floods and tornados, and exposures to environmental contaminants are examples of involuntary risks.

3.1.2 Defining risk and impacts

Risks to the public and the environment are determined by direct observation or by applying mathematical models and a series of assumptions to infer risk. No matter how risks are defined or quantified, they are usually expressed as a probability of adverse effects associated with a particular activity. Risk is typically expressed as a likelihood of occurrence and/or consequence (such as negligible, low or significant) or quantified as a fraction of, or relative to, an acceptable risk number.

Risks or impacts from a range of facilities (eg industrial or infrastructure) are usually assessed through qualitative and/or quantitative risk assessment techniques. In general, risk or impact assessments seek to identify all relevant hazards; assess or quantify their likelihood of occurrence and the consequences associated with these events occurring; and provision of an estimate of the risk levels for people who could be exposed, including those beyond the perimeter boundary of a facility.

3.2 Overall approach

3.2.1 General

The methodology adopted for the conduct of the HHRA is in accordance with national and international guidance that is endorsed/accepted by Australian health and environmental authorities, and includes:

- Harris, P., Harris-Roxas, B., Harris, E. & Kemp, L., *Health Impact Assessment: A Practical Guide*, Centre for Health Equity Training, Research and Evaluation (CHETRE). Part of the UNSW Research Centre for Primary Health Care and Equity. University of NSW, Sydney (Harris 2007)
- *Health Impact Assessment Guidelines*. Published by the Environmental Health Committee (enHealth), which is a subcommittee of the Australian Health Protection Committee (AHPC) (enHealth 2001)
- *Environmental Health Risk Assessment: Guidelines for assessing human health risks from environmental hazards,* 2012 (enHealth 2012b)
- *Schedule B8 Guideline on Community Engagement and Risk Communication*, *National Environment Protection (Assessment of Site Contamination) Measure, 1999* (National Environment Protection Council (NEPC) 1999 amended 2013a))
- *National Environmental Protection (Air Toxics) Measure*, *Impact Statement for the National Environment Protection (Air Toxics) Measure, 2003* (NEPC 2003)
- *Risk Assessment Guidance for Superfund, Volume I: Human Health Evaluation Manual* (Part F, Supplemental Guidance for Inhalation Risk Assessment), EPA-540-R-070-002, January 2009 (United States Environment Protection Agency (USEPA) 2009a)).

More specifically, in relation to the assessment of health impacts associated with exposure to nitrogen dioxide and particulate matter, guidelines available from the NEPC ((Burgers & Walsh 2002; NEPC 1998, 2002, 2003, 2009, 2010), World Health Organization (WHO) (Ostro 2004; WHO 2003, 2006a, 2006b, 2013a) and the USEPA (USEPA 2005b, 2009b) have been used as required.

In addition, the following has been considered:

- Building Better Health, Health considerations for urban development and renewal in the Sydney Local Health District (NSW Health 2016)
- Healthy Urban Development Checklist, A guide for health services when commenting on development policies, plans and proposals (NSW Health 2009)
- Methodology for Valuing the Health Impacts of Changes in Particle Emissions (NSW EPA 2013)
- Air Quality in and Around Traffic Tunnels (National Health and Medical Research Council (NHMRC) 2008)
- State Environmental Planning Policy (SEPP) 33 - Hazardous and Offensive Development.

These guidelines have been used to evaluate health impacts associated with the project that relate to:

- Changes in air quality in the tunnels (see **section 7**)
- Changes in air quality around the tunnels (within the community) during construction and operation (see **section 6**)
- Changes in the noise environment during construction and operation (see **section 8**)
- Impacts on public safety (see **section 9**)
- Changes in the social environment, including an overview of the positive and negative impacts of the project on health (see **section 10**).

In following this guidance, the following tasks have been completed and are presented in this technical working paper.

3.2.2 Data evaluation and issue identification

This task involves a review of all available information that relates to the proposed design and outcomes from relevant specialist studies undertaken in relation to air quality within the tunnel itself, air quality within the surrounding community, noise and vibration. Specifically, the assessment has considered existing conditions (in relation to air quality and noise) and estimation of short term (acute) and long term (chronic) impacts during construction and operation of the project.

This aspect of the assessment also considers the available guidelines for air quality and noise, whether these guidelines are based on the protection of community health, and if a more detailed evaluation of specific impacts is required. The HHRA has considered a more detailed evaluation of exposures to nitrogen dioxide and particulate matter emissions within the surrounding community from the operation of the project. Other pollutants have also been considered that include volatile organic compounds, polycyclic aromatic hydrocarbons and carbon monoxide. In addition, a review of health risk impacts associated with air quality within the tunnel itself has been included.

3.2.3 Exposure assessment

This involves the identification of populations located in the project study area (see **section 4**) which may be exposed to impacts from the project. The existing air and noise environments as well as the health of the existing population has been considered in relation to the key health effects (with specific health effects termed health endpoints) consideration in this assessment. The assessment has considered both acute and chronic inhalation exposures relevant to the project.

3.2.4 Hazard assessment

The objective of the hazard or toxicity assessment is to identify the adverse health effects and quantitative toxicity values or exposure-response relationships that are associated with the key pollutants and stressors that have been identified and evaluated as part of this assessment. This has been applied to the assessment of exposures to particulate matter where the following steps have been undertaken:

- Identify the adverse health effects associated with exposure to the pollutants or stressors. Based on the available information, the most robust health endpoints (effects or outcomes) have been identified. The most robust health endpoints are where a relationship has been firmly (based on sound studies and statistical analysis) established between exposure to particulate matter and a specific health endpoint (effect/outcome)
- Identify the most relevant and robust exposure-response relationship for the quantitative assessment of exposure. The exposure-response relationships are derived from published peer reviewed sources and relate to the identified health endpoints (effects/outcomes)
- The health endpoints and associated exposure-response relationships adopted for this assessment, in particular those associated with nitrogen dioxide and particulate matter derived from combustion sources (such as petrol and diesel vehicles) have been discussed with NSW Health prior to the completion of this assessment.

For other pollutants and stressors, national guidelines based on the protection of health have been adopted.

3.2.5 Risk characterisation

Risks have been characterised using quantitative and qualitative assessment methods. For the assessment of nitrogen dioxide and particulate matter, the quantitative assessment involved identification of an exposure concentration that relates to the project (ie the change in particulate concentration associated with the project), use of relevant exposure-response relationships (for the health endpoints/effects assessed) to calculate health impacts. This enabled an assessment of an increased annual risk and an increased incidence of the effect occurring within the population of concern.

In some cases, a qualitative assessment has been undertaken. A qualitative assessment does not specifically require the quantification of risk or exposure. Rather, the assessment provides a relative or comparative evaluation of whether the exposure or impact considered is positive or negative and where there may be a negative impact, whether this impact is acceptable or unacceptable in the local population.

The assessment presented has also considered the level of uncertainty associated with the concept design, and all aspects of the technical studies relied on for the conduct of the HHRA and within the HHRA. The final determination of risks to human health was based on the quantification of risks as well as consideration of these uncertainties.

3.2.6 Features of the risk assessment

The HHRA has been carried out in accordance with international best practice and general principles and methodology accepted in Australia by groups/organisations such as NHMRC, NEPC and enHealth. There are certain features of risk assessment methodology that are fundamental to the assessment of the outputs and to drawing conclusions on the significance of the results. These are summarised below:

- The assessment has relied on assessments completed in other technical working papers, specifically in relation to traffic, air quality, noise and vibration, economic and social impacts
- A risk assessment is a tool (that is systematic) that addresses potential exposure pathways based on an understanding of the nature and extent of the impact assessed and the uses of the local area by the general public. The risk assessment is based on an estimation of maximum, or worst case, impacts (air quality, noise and vibration) in the local community and hence is expected to overestimate the actual risks
- Conclusions can only be drawn with respect to emissions to air, noise and vibration derived from the project as outlined in the respective technical working papers
- Available statistics in relation to the existing health status of the existing community are presented. However, the HHRA does not provide an evaluation of the overall health status of the

community or any individuals. Rather, it is a logical process of calculating and comparing potential exposure concentrations (acute and chronic) in surrounding areas (associated with the project) with regulatory and published acceptable air concentrations that any person may be exposed to over a lifetime without unacceptable risk to their health. It can also involve calculating an incremental impact that can be evaluated in terms of an acceptable level of risk

- The risk assessment reflects the current state of knowledge regarding the potential health effects of chemicals identified and evaluated in this assessment. This knowledge base may change as more insight into biological processes is gained.

This assessment has focused on key impacts on air quality, noise and vibration and social changes. Other impacts relevant to the health of the community, as outlined in the SEARs have also been considered.

3.3 Incorporation of health issues into the project design

The design of the proposed M4-M5 Link project has been undertaken as an iterative approach, with changes made to various aspects of the design to minimise impacts on the community, including on health and wellbeing. Some of the key design changes that have been incorporated into the project that have minimised impacts to community health include:

- The removal of the Camperdown ramps on Parramatta Road near Arundel Street
- Inclusion of the Iron Cove Link to remove surface road traffic from a section of Victoria Road
- Rozelle interchange design was adjusted to be largely below ground with at grade connections minimised and elevated roadways avoided
- No direct impacts to open space at Easton Park and Blackmore Park during construction
- No use of a proposed site at Derbyshire Road located adjacent to an existing school for construction
- Use of existing M4 East and New M5 project footprints for construction sites at Haberfield and St Peters
- Provision of new active transport links at Rozelle and Iron Cove
- Creation of new open space areas at Rozelle, within the Rozelle Rail Yards and south of Victoria Road, near Iron Cove Bridge
- Beneficial reuse or recycling of spoil where practical and possible
- Use of the arterial road network for spoil transport to minimise impacts to local roads
- Use of M4 East tunnels if possible for spoil transport to reduce the impact on the surface road network.

In addition, the ventilation facilities have been designed to meet the in-tunnel air quality criteria, ensure emissions are dispersed and diluted so that there are minimal or no effects on air quality, provide effective management of smoke in the event of a fire and minimise the potential for portal emissions. The design considerations included ensuring the location, height, diameter and emission ventilation rate minimises local air quality impacts

The design has also endeavoured to minimise noise and vibration impacts on residential and commercial properties, including:

- Rozelle interchange design was adjusted to be largely below ground with at grade connections minimised and elevated structures avoided
- At Rozelle interchange, the New M5 and Western Harbour Tunnel ramps are enclosed by cut-and-cover structures with the new landform above. The portal openings for these ramps are located close to City West Link, which is the dominant noise source, with good separation distance provided to the closest receivers to the north and south
- Where the tunnel ramps merge with the surface roads the ramp grades have been minimised. This reduces noise from heavy vehicles climbing to exit the ramps.

Noise mitigation measures (road pavement treatments, noise barriers and/or architectural treatments where necessary) have also been identified to address predicted exceedances of operational noise traffic.

This assessment relates to a concept design that is subject to refinement during the detailed design stage, once a contractor(s) has been engaged. As a result of the approach adopted (as summarised above), the design on which this report is based has been developed to minimise health impacts. Refer to **Chapter 4** (Project development and alternatives) of the EIS for additional details on design considerations.

4 Community profile

4.1 General

This section provides an overview of the communities potentially impacted by the project. The key focus of the assessment presented is the local community evaluated in relation to the project, referred to as the study area. The M4-M5 Link is a tunnel that connects the M4 East at Haberfield to the New M5 at St Peters, with an interchange at Rozelle to connect to City West Link, Victoria Road, Anzac Bridge and Iron Cove Bridge (via the Iron Cove Link) and the proposed future Western Harbour Tunnel and Beaches Link project. Therefore the larger study area interlinks with study areas considered in the M4 East and New M5 projects. The larger study area is generally illustrated in **Figure 4-1**. It is noted that the larger study area relates to the area over which impacts to air quality has been considered (referred to as GRAL domain). A smaller area, within this larger study area, has been considered for the assessment of soil contamination and vibration impacts.

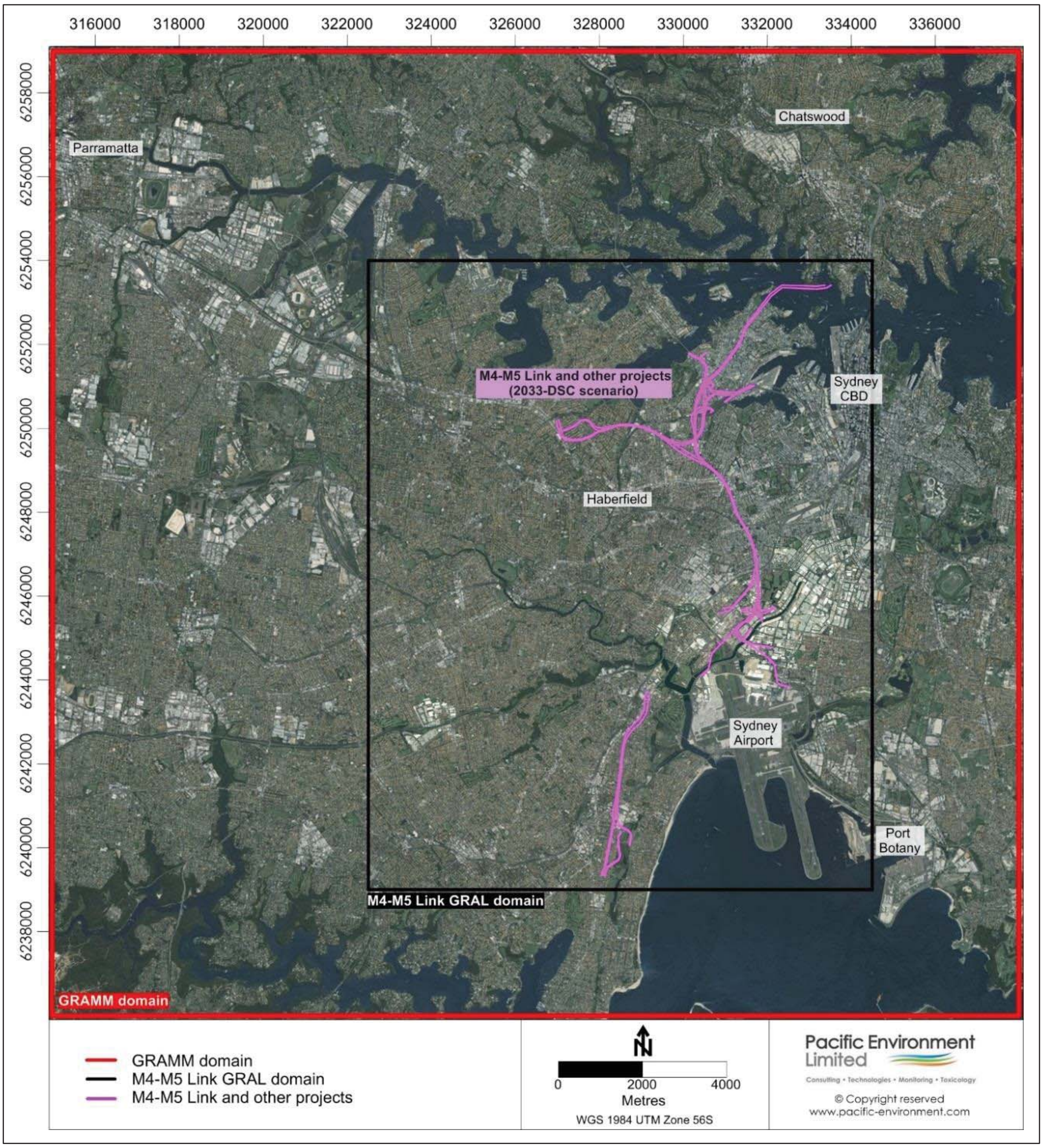


Figure 4-1 HHRA study area

In reviewing key aspects of the local communities that are relevant to the conduct of the HHRA, information has been obtained from the Australian Bureau of Statistics (ABS) Census 2011, information relevant to LGAs and health districts (in particular the Sydney Area Health Service). In some cases, where local data is lacking, information has been obtained (or compared with) data from larger population areas of Sydney and/or NSW.

4.2 Surrounding area and population

The population considered in this assessment include those who live or work within the vicinity of the construction compounds, interchanges (ie where the tunnel interfaces with the surface road network), ventilation facilities and the road network, related to the M4-M5 Link as well as the combined WestConnex project.

The study area covers a large number of individual suburbs that sit within the following LGAs:

- Canada Bay
- Strathfield
- Burwood
- Inner West (amalgamation of former Ashfield, Leichhardt and Marrickville LGAs)
- City of Sydney
- Bayside (amalgamation of former Botany Bay and Rockdale LGAs. It is noted that the statistics are derived from the individual LGAs prior to amalgamation and are reported as such)
- Canterbury-Bankstown
- Georges River (amalgamation of former Hurstville and Kogarah LGAs).

The above list reflects the LGAs as defined in 2016 following amalgamations, and are consistent with the LGAs for which NSW Health provide some data. It is noted that some data is only available for the former LGAs.

4.3 Sensitive receptors

The assessment of potential impacts on the surrounding community, particularly in relation to air quality, has considered the location where maximum impacts from the project may occur. In addition, impacts in the wider community have also been considered. Within the wider community, a number of additional locations, referred to as community receptors, have been identified in the suburbs close to the project.

Community receptors are locations in the local community where more sensitive members of the population, such as infants and young children, the elderly or those with existing health conditions or illnesses, may spend a significant period of time. These locations comprise hospitals, child care facilities, schools and aged care homes/facilities. **Table 4-1** presents a list of the community receptors included in this assessment.

The list relates to receptors considered in the assessment of air quality impacts, for which a quantitative assessment of health impacts has been undertaken in this report. It is noted that this is representative only and is not intended to comprise an exhaustive list of community receptors in the study area. The location of the sensitive or community receptors is presented in **Figure 4-2**.

In addition to these community receptors, about 86,375 individual receptors (residential, workplace and recreational [RWR] receptors also shown in **Figure 4-2**) have been modelled in the streets/suburbs located in the study area. These individual RWR receptors represent a range of uses including residential, workplaces or recreational (open space) areas in the surrounding community, as detailed in **Table 4-2**. The RWR include all other community receptors located in the study area, not only those included in **Table 4-1**.

All these individual receptors have also been considered in this report, so that all sensitive receptors have been adequately addressed.

Table 4-1 Community receptors included in health risk assessment

No.	Receptor name	Type of receptor	Suburb
CR01	The Jimmy Little Community Centre	Community	Lilyfield
CR02	Balmain Cove Early Learning Centre	Child care	Rozelle
CR03	Rosebud Cottage Child Care Centre	Child care	Rozelle
CR04	Sydney Community College	Higher education	Rozelle
CR05	Rozelle Total Health	Health	Rozelle
CR06	Laurel Tree House Child Care Centre	Child care	Glebe
CR07	Bridge Road School	School - Primary	Camperdown
CR08	NHMRC Clinical Trials Centre	Health	Camperdown
CR09	Annandale Public School	School - Primary	Annandale
CR10	The University of Notre Dame Australia - Broadway	Higher education	Chippendale
CR11	Laverty Pathology Annandale	Health	Annandale
CR12	Little VIP's Childcare Centre	Child care	Haberfield
CR13	Dobroyd Point Public School	School - Primary	Haberfield
CR14	Peek A Boo Early Learning Centre Haberfield	Child care	Haberfield
CR15	Rozelle Child Care Centre	Child care	Lilyfield
CR16	Sydney Secondary College Leichhardt Campus	School - Secondary	Leichhardt
CR17	Rose Cottage Child Care Centre	Child care	Leichhardt
CR18	Inner Sydney Montessori - Lilyfield	School - Primary	Lilyfield
CR19	Leichhardt Little Stars Nursery & Early Learning Centre	Child care	Leichhardt
CR20	Leichhardt Montessori Academy	Child-care	Leichhardt
CR21	St Basil's Sister Dorothea Village	Aged care	Annandale
CR22	St Thomas Child Care Centre	Child care	Rozelle
CR23	Billy Kids Lilyfield Early Learning Centre	Child care	Lilyfield
CR24	Little Learning School - Alexandria	Child care	Alexandria
CR25	Newtown Public School Combined Out of School Hours Care	School - Primary	Newtown
CR26	The Athena School	School – K to year 10	Newtown
CR27	Camdenville Public School	School - Primary	Newtown
CR28	St Joan of Arc Home for the Aged	Aged care	Haberfield
CR29	Inner West Education Centre	Education – K to year 8	Haberfield
CR30	St Peters Community Preschool	Pre-school	St Peters
CR31	Rozelle Public School	School - Primary	Rozelle
CR32	Lilyfield Early Learning Centre	Child-care	Lilyfield
CR33	Sydney Secondary College Blackwattle Bay	School – Years 11 and 12	Glebe
CR34	Erskineville Public School	School - Primary	Erskineville
CR35	Haberfield Public School	School - Primary	Haberfield
CR36	The Infants Home	Early childhood including children with special needs	Ashfield
CR37	St Peters Public School	School - Primary	St Peters
CR38	Active Kids Mascot	Child-care	Mascot
CR39	Alexandria Early Learning Centre	Child-care	Alexandria
CR40	Sydney Park Childcare Centre	Child-care	Alexandria

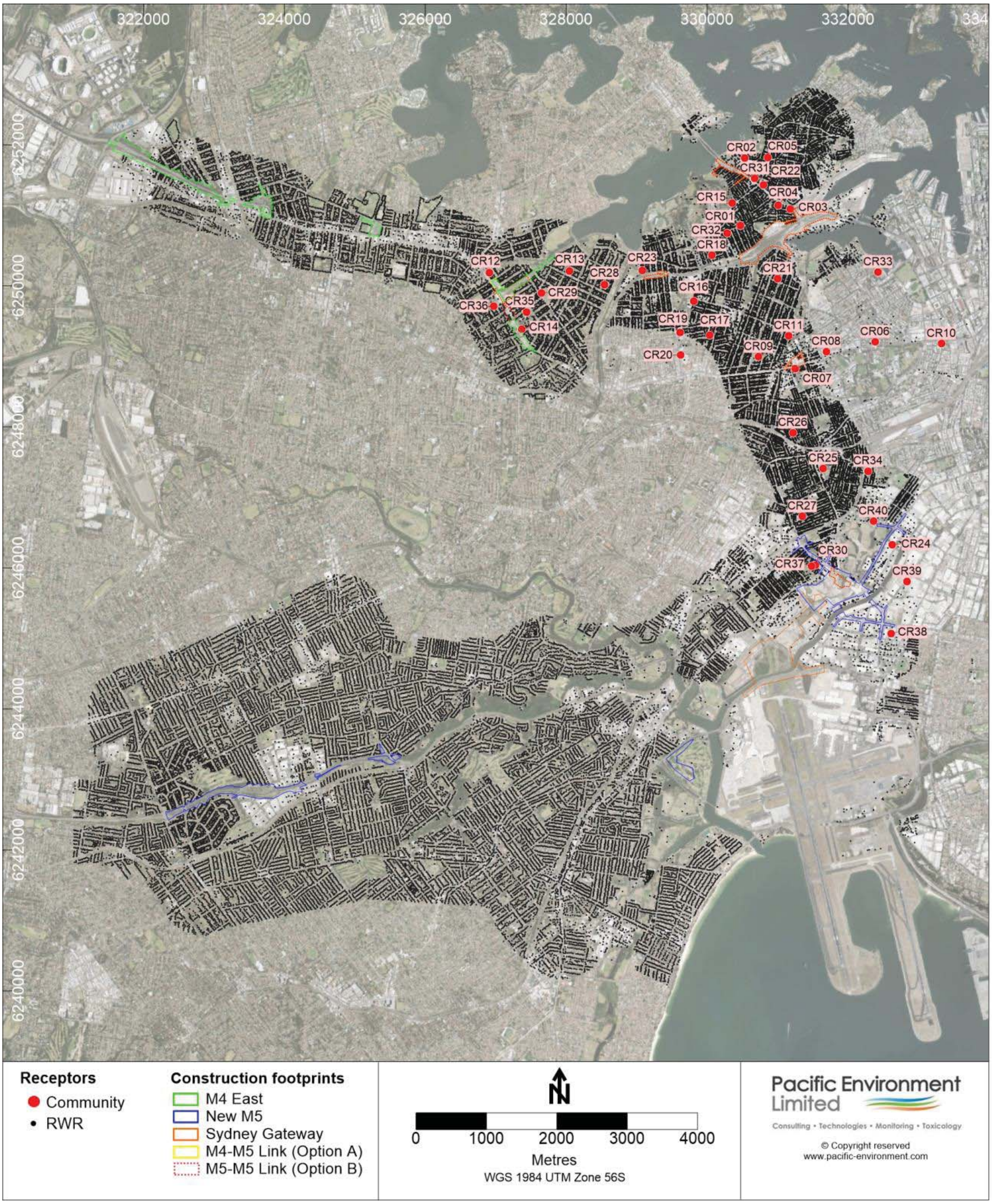


Figure 4-2 Community receptors and RWR receptors evaluated in HHRA

Table 4-2 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

4.4 Population profile

The population within the study area consists of residents and workers as well as those attending schools, day care centres, hospitals and recreational areas. The composition of the populations located within the study area is expected to be generally consistent with population statistics for the larger individual suburbs that are wholly or partially included in the study area. Population statistics for the LGAs (referred to as statistical areas SA3, which now differ from the 2016 LGAs) are available from the ABS for the Census year 2011 and are summarised in **Table 4-3**. For the purpose of comparison, the population statistics presented also include the statistics for larger statistical population groups in the area (defined by the ABS SA4) and the larger statistical areas of Greater Sydney and the rest of the NSW (excluding Greater Sydney) (as defined by the ABS).

Table 4-4 presents a summary of a selected range of demographic measures relevant to the population of interest with comparison to statistical areas of Greater Sydney and the rest of NSW (excluding Greater Sydney).

Table 4-3 Summary of population statistics in study area

Location	Total population		% Population by key age groups					
	Male	Female	0–4	5–19	20–64	65+*	1–14*	30+*
Local statistical areas (SA3)								
Canada Bay	35,938	38,218	6.9	14.9	64.2	14.0	15.5	63.4
Strathfield – Burwood – Ashfield	67,285	69,922	5.7	15.3	65.9	13.1	14.3	59.8
Leichhardt	24,726	27,471	8.2	11.7	69.9	10.2	14.9	67.2
Sydney Inner City	92,089	82,483	3.7	7.0	81.6	7.8	6.2	59.1
Marrickville, Sydenham and Petersham	25,275	25,338	6.5	12.1	70.4	11.1	13.3	63.8
Canterbury	63,067	62,359	7.8	18.9	60.3	13.0	19.2	58.2
Botany	19,492	19,865	6.7	17.1	61.8	14.4	16.8	61.6
Hurstville	56,553	60,050	6.0	17.8	60.8	15.4	16.4	61.2
Kogarah and Rockdale	60,465	62,035	6.6	16.1	62.5	14.8	16.0	61.7
Larger local statistical areas (SA4 – includes SA3 areas)								
Sydney – Inner West	127,950	135,610	6.5	14.5	66.0	12.9	14.8	62.3
Sydney Inner South West	258,320	265,288	7.1	18.6	60.1	14.2	18.2	59.5
Sydney City and Inner South	136,858	127,686	4.7	9.4	76.5	9.4	9.1	60.4
Statistical areas of Sydney and NSW								
Greater Sydney	2,162,221	2,229,453	6.8	18.7	61.7	12.9	17.9	60.0
Rest of NSW (excluding Greater Sydney)	1,239,007	1,273,942	6.3	19.7	55.9	18	18.2	63.0

Ref: Australian Bureau of Statistics, Census Data 2011

SA = statistical area

SA3 are larger statistical areas that are aggregates of SA2 areas with populations between 30,000 and 130,000

SA4 are larger statistical areas that are aggregates of SA3 areas with populations in excess of 100,000

* Age groups specifically relevant to the characterisation of risk

Based on this general population data, the populations in the study area are generally similar to Greater Sydney with the exception of the following:

- Sydney Inner City, as well as the larger area of Sydney City and Inner South have a lower proportion of young children (0-4 years), a higher proportion of working aged individuals and a lower proportion of individuals aged over 65 years
- Areas of Marrickville, Sydenham and Petersham, Strathfield, Burwood and Ashfield, Canada Bay and Leichhardt also have a slightly lower proportion of young children.

The estimated population growth from 2011 to 2036 for these areas are (NSW Department of Planning and Environment (DP&E) 2016):

- Canada Bay: 53.5 per cent growth
- Strathfield: 74.2 per cent growth
- Burwood: 68.3 per cent growth
- Inner West (Ashfield, Leichhardt and Marrickville): 27.7 per cent growth
- Sydney: 72.0 per cent growth
- Botany: 75.2 per cent growth
- Canterbury-Bankstown: 49.7 per cent growth
- Rockdale: 50.2 per cent growth

- Georges River (Hurstville and Kogarah): 28.5 per cent growth.

Table 4-4 Selected demographics of population of interest

Location	Median age	Median household income ($/week)	Median mortgage repayment ($/month)	Median rent ($/week)	Average household size (persons)	Unemployment rate (%)
Local statistical areas (SA3)						
Canada Bay	37	1832	2600	480	2.5	4.2
Strathfield – Burwood – Ashfield	35	1418	2167	380	2.6	6.2
Leichhardt	37	2234	3000	480	2.3	4.0
Sydney Inner City	32	1644	2515	465	2.0	5.7
Marrickville, Sydenham and Petersham	36	1567	2500	360	2.4	5.5
Canterbury	35	1021	1993	300	2.9	8.4
Botany	37	1244	2500	330	2.6	5.3
Hurstville	38	1293	2167	350	2.8	6.0
Kogarah and Rockdale	37	1296	2167	375	2.7	5.9
Larger local statistical areas (SA4 – includes SA3 areas)						
Sydney – Inner West	36	1662	2500	415	2.5	5.2
Sydney Inner South West	36	1169	2127	335	2.8	6.9
Sydney City and Inner South	33	1569	2500	430	2.1	5.6
Statistical areas of Sydney and NSW						
Greater Sydney	36	1447	2167	351	2.7	5.7
Rest of NSW (excluding Greater Sydney)	41	961	1560	220	2.4	6.1

Source: Australian Bureau of Statistics, Census Data 2011

SA = statistical areas

SA3 are larger statistical areas that are aggregates of SA2 areas with populations between 30,000 and 130,000

SA4 are larger statistical areas that are aggregates of SA3 areas with populations in excess of 100,000

The social demographics of an area have some influence on the health of the existing population. As shown in **Table 4-4**, the population located in the Canterbury area generally has higher unemployment with lower income, mortgage repayments and rental costs compared with other populations in the study area. There are some areas such as Canada Bay and Leichhardt that have lower levels of unemployment, higher incomes and mortgage repayments when compared with the other population areas and Greater Sydney.

4.5 Existing health of population

4.5.1 General

The assessment presented in this report has focused on key pollutants that are associated with construction and combustion sources (from vehicles), including volatile organic compounds, polycyclic aromatic hydrocarbons, carbon monoxide, nitrogen dioxide and particulate matter (namely $PM_{2.5}$ and PM_{10}). For these pollutants, there are a large number of sources in the study area including other combustion sources (wood-fired heating, domestic cooking, industrial emissions), non-combustion sources including other local construction/earthworks. Other aspects that affect the health of an individual include personal exposures (such as smoking) and risk taking behaviours.

When considering the health of a local community there are a large number of factors to consider. The health of the community is influenced by a complex range of interacting factors including age, socio-economic status, social networks, behaviours, beliefs and lifestyle, life experiences, country of origin, genetic predisposition and access to health and social care. Hence, while it is possible to review existing health statistics for the local areas surrounding the project, and compare them to the Greater Sydney area and NSW, it is not possible or appropriate to be able to identify a causal source, particularly individual or localised sources.

Information relevant to the health of populations in NSW is available from NSW Health for populations grouped by local area health service (where most of the project area is located in the Sydney Area Health Service and the South Eastern Sydney Area Health Service) or LGA. Not all of the health data is available for all of these areas.

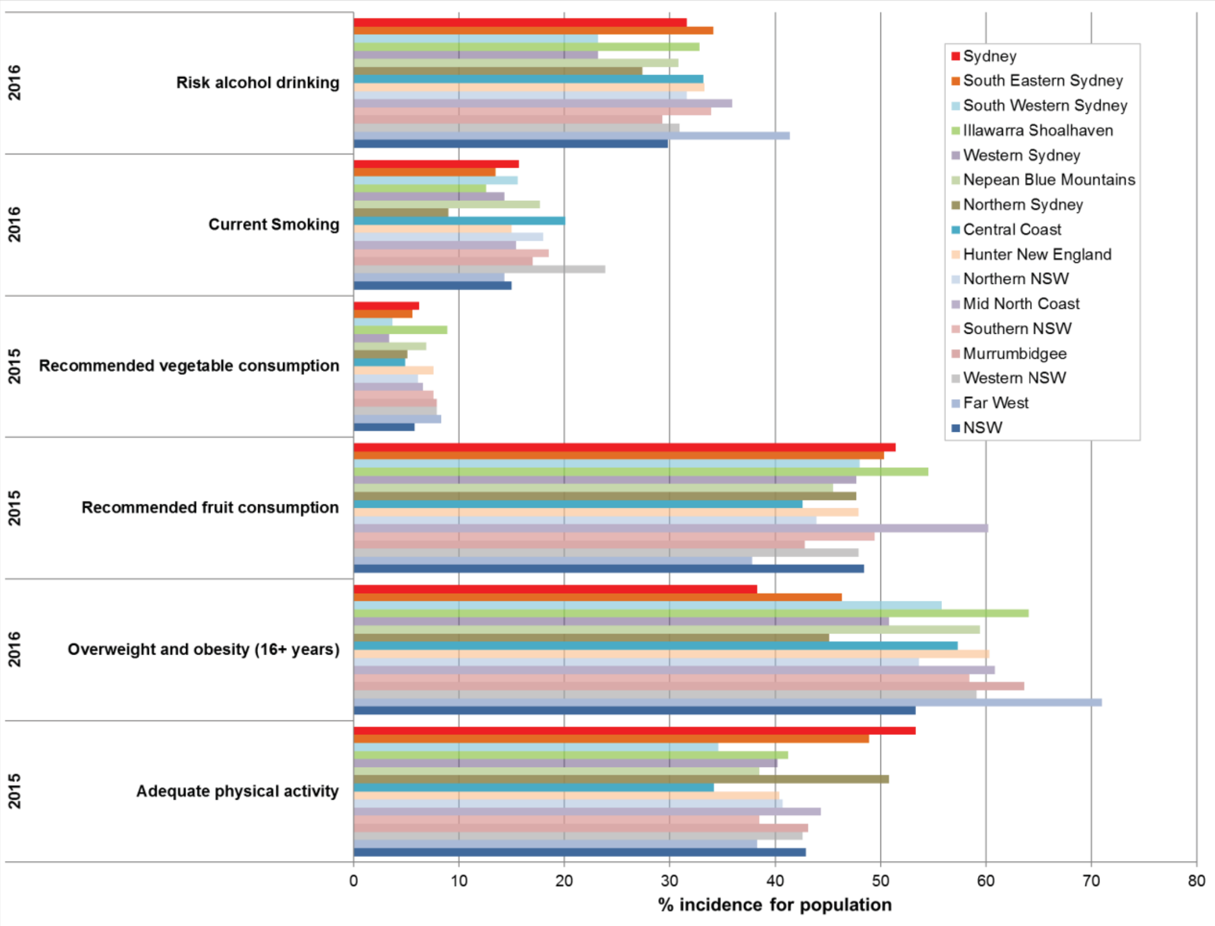
Most of the health indicators presented in this report are not available for each of the smaller suburbs/statistical areas surrounding the site. Health indicators are only available from a mix of larger areas (that incorporate the study area), namely the Sydney Area Health Service and the South Eastern Sydney Area Health Service. There are few health statistics that are reported for the smaller local government areas relevant to this project. The health statistics for these larger areas (and in some cases data for the Greater Sydney area) are assumed to be representative of the smaller population located in the vicinity of the western and eastern interchanges given the similar demographics of these populations to Greater Sydney.

4.5.2 Health related behaviours

Information in relation to health related behaviours (that are linked to poorer health status and chronic disease including cardiovascular and respiratory diseases, cancer, and other conditions that account for much of the burden of morbidity and mortality in later life) is available for the larger populations within the local area health services in Sydney and NSW. This includes risky alcohol drinking, smoking, consumption of fruit and vegetables, being overweight or obese, and adequate physical activity. The study population is largely located within the Sydney Area Health Service and the South Eastern Sydney Area Health Service. The incidence of these health-related behaviours in this area, compared with other health areas in NSW, and the state of NSW (based on data from 2015 and 2016) is illustrated in **Figure 4-3**.

Review of this data generally indicates the population in the Sydney and South Eastern Sydney Area Health Service areas (that include the study area):

- Have similar rates of risky alcohol drinking and smoking and similar intakes of recommended consumption of fruit and vegetables compared with NSW
- Have higher rates of adequate physical activity and lower rates of being overweight and obese compared with NSW.



Note: these health related behaviours include those where the behaviour/factor may adversely affect health (eg alcohol drinking, smoking, being overweight/obese) and others where the behaviour/factor may positively affect (enhance) health (eg adequate fruit and vegetable consumption and adequate physical activity)

Study area is located in the Sydney Area Health Service (Sydney in the graph) and South Eastern Sydney Area Health Service

Figure 4-3 Summary of incidence of health-related behaviours (Source: NSW Health 2017)

4.5.3 Health indicators

Figure 4-4 presents a comparison of the rates of the key mortality indicators based on data from 2011 to 2015 (depending on the available data) for all causes, potentially avoidable, cardiovascular disease, lung cancer and chronic obstructive pulmonary disease (COPD), reported in the larger Sydney and South Eastern Sydney Area Health Services, with comparison to other NSW area health services (in urban and regional areas) as well as NSW as a whole.

Figure 4-5 presents a comparison of the rates of the hospitalisations for key health effects based on data from 2013-2014 for diabetes, cardiovascular disease, asthma (5–34 years) and COPD (65+ years) reported in the larger Sydney and South Eastern Sydney Area Health Services, with comparison to other NSW area health services (in urban and regional areas) as well as NSW as a whole.

It is noted that the data reported in these figures is based on statistics that are publicly available from NSW Health. Hence some of the statistics for mortality and hospitalisations relate to slightly different health endpoints and/or different age groups. The statistics are included for general comparison and discussion. Actual health statistics considered in the characterisation of risk are presented in **Table 4-5.**

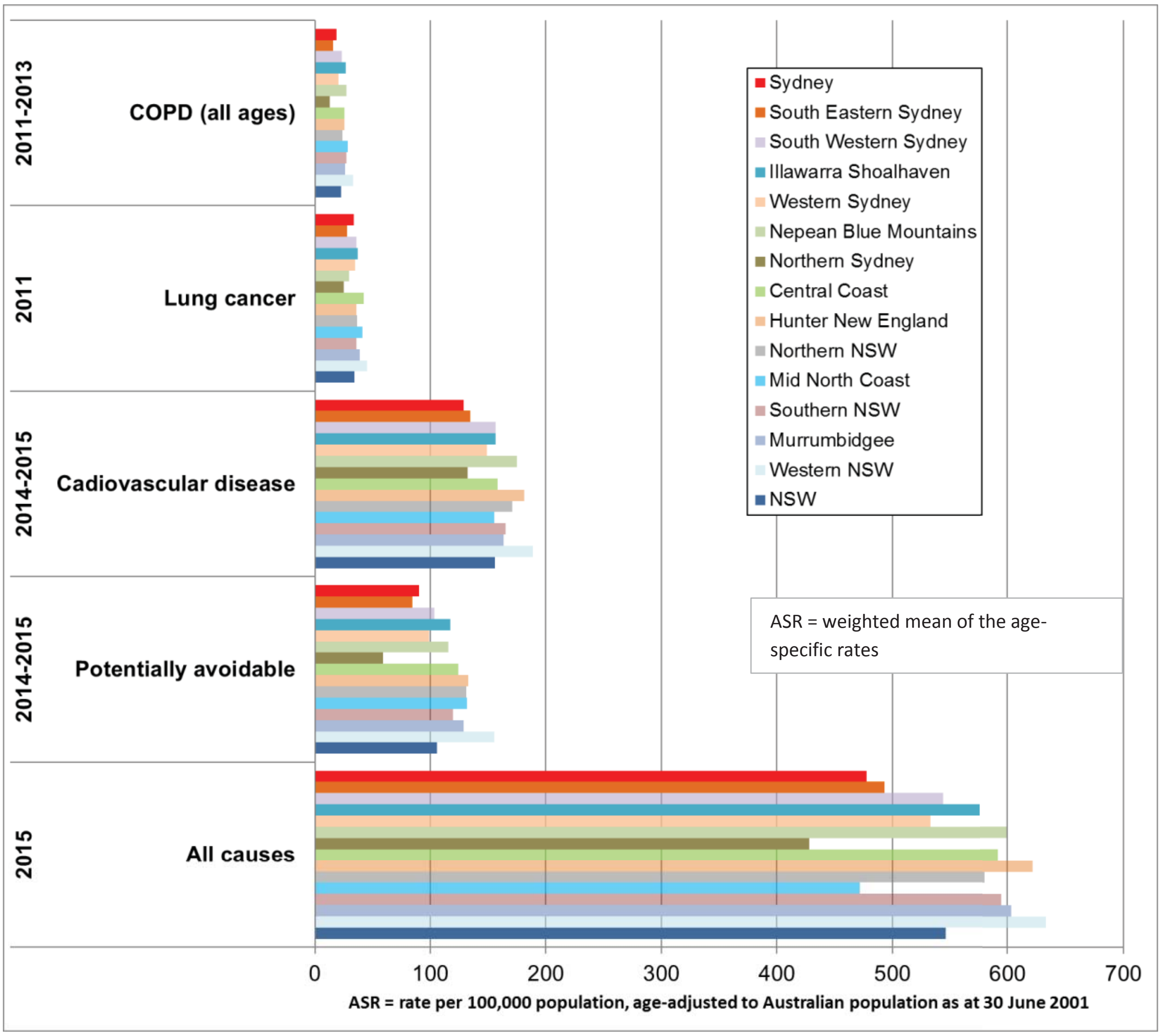


Figure 4-4 Summary of mortality data 2011–2015 (Source: NSW Health 2015)

Review of the figures presented above indicate that the rate of mortality for the indicators presented in the Sydney and South Eastern Sydney Area Health Services are slightly lower than but similar to that reported for NSW.

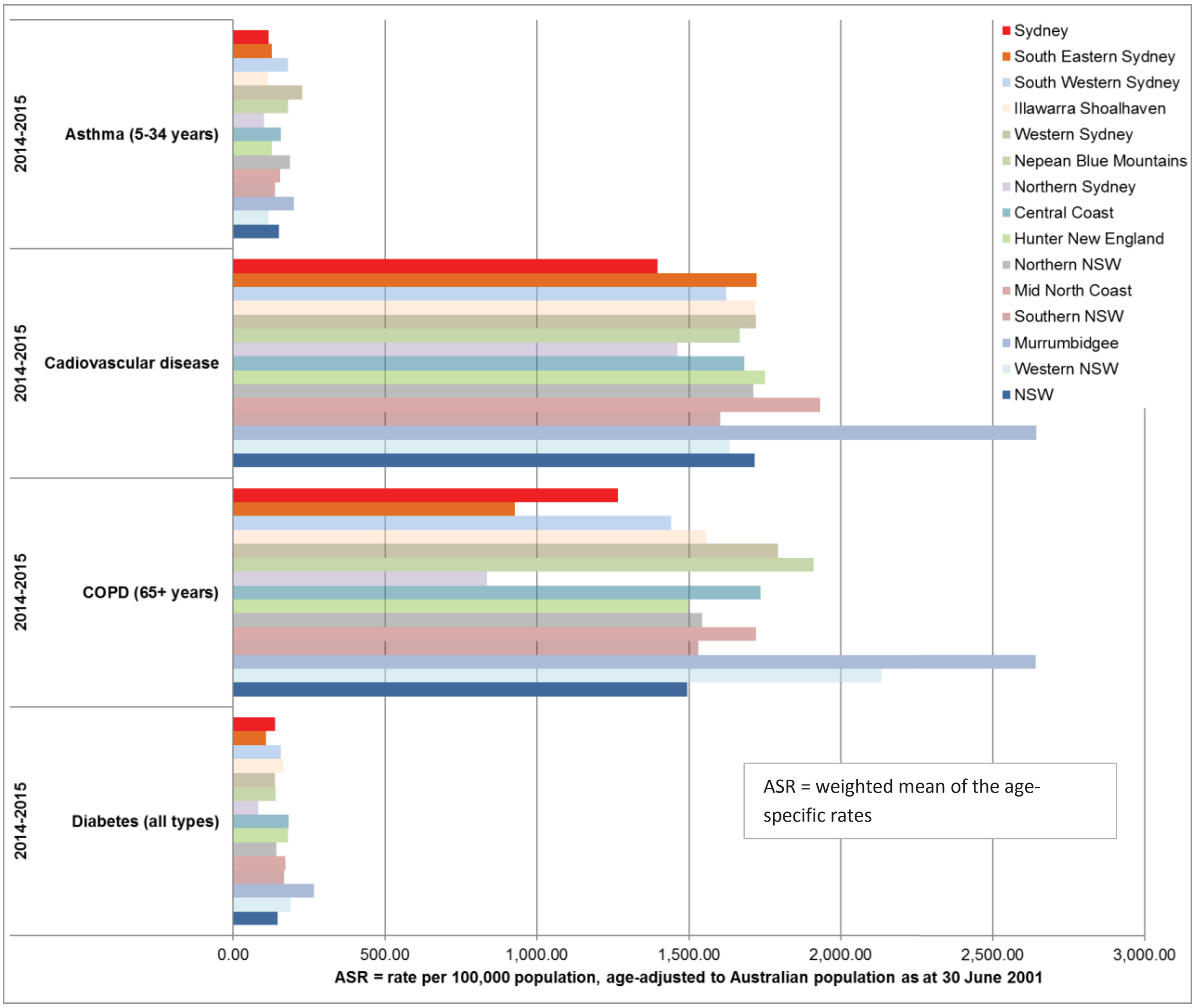


Figure 4-5 Summary of hospitalisation data 2013–2014 (Source: NSW Health 2015)

Review of the figures presented above indicate that the rate of hospitalisations for the indicators presented in the Sydney and South Eastern Sydney Area Health Services is slightly lower than but similar to that reported for NSW, with the exception for COPD hospitalisations in South Eastern Sydney, that are significantly lower than in Sydney or NSW.

In relation to mental health, data from NSW Health indicates the following for adults:

- The rate of high or very high psychological distress reported in 2015 in the Sydney Area Health Service (13.9 per cent) is a little higher than the state average (11.8 per cent), with the rate reported for South Eastern Sydney Area Health Service (9.3 per cent) a little lower
- The rate of high or very high psychological distress in Sydney Area Health Service has varied a little but remained between 10 and 15 per cent between 2003 and 2015. In the South Eastern Sydney Area Health Service, the rate has steadily declined from around 14 per cent in 2003 to less than 10 per cent in 2015.

In relation to some more specific health indicators **Table 4-5** presents the available data for the slightly smaller population areas in the LGAs in the study area. These have been compared with available data for the Sydney Area Health District, South Eastern Sydney Area Health District, Sydney and NSW. It is noted that health statistics are not available for the LGAs for all the health endpoints considered in this assessment. Where available, they have been presented for the purpose of comparison with statistics from Sydney and NSW.

The health indicators presented in the table include those that are specifically relevant to the quantification of exposure to nitrogen dioxide and particulate matter presented in **section 6**.

Review of the data presented in **Table 4-5** generally indicates that for the population in project area, the health statistics (including mortality rates and hospitalisation rates for most of these categories) are variable but generally similar to those reported in the larger area health services of Sydney and south-eastern Sydney, the wider Sydney metropolitan area and the whole of NSW.

For the assessment of potential health impacts from the project, where specific health statistics for the smaller populations within the project area is not available (and not reliable due to the small size of the population), adopting health statistics from the whole of NSW is considered to provide a representative, if not cautious (eg overestimating existing health issues), summary of the existing health of the population of interest.

There are a number of statistics where no more specific or recent data than for the Sydney Metropolitan Area in 2010 is available. Where data is available from 2010 as well as more recently, it is observed that the rate of disease or mortality is reducing with time. Hence use of data from Sydney Metropolitan Area for 2010 in this assessment is conservative and is expected to overestimate risk.

The rate of antidepressant medication prescriptions is an indicator that can be used to review changes in stress and anxiety levels within a community, and these are presented in **Table 4-6**. While these data were not directly used in the HHRA, to evaluate specific impacts, the data is relevant to assist in ongoing monitoring of potential indicators of changes that increase or decrease stress and anxiety in the community. In relation to the rate of medication prescriptions for antidepressants, the following is noted:

- For all ages, the rates reported are highest in Leichhardt, Marrickville-Sydenham-Petersham and Sydney Inner City. The rates reported in Leichhardt for 17 years and under, and 65 years and older are higher than the state average
- The rates reported in LGAs away from the inner city and inner west are lower.

Table 4-5 Summary of key health indicators

Health indicator	Data available for population of LGAs (rate per 100,000 population)												
	Canada Bay	Strathfield	Burwood	Inner West	City of Sydney	Botany Bay	Rockdale	Canterbury-Bankstown	Georges River	Sydney area Health	South Eastern Sydney area Health	Sydney (wider metro area)*	NSW
Mortality													
All causes – all ages	403.3 [C]	443.1 [C]	555.6 [C]	534.2 [C]	508.0 [C]	523.8 [C]	534.5 [C]	490.6 [C]	465.5 [C]	477.4 [C]	**493.0 [C]**	--	546.0 [C]
All causes (non-trauma) ≥30 years										--	--	**976.5**	--
All causes ≥30 years										--	--	**1026**	--
Cardiopulmonary ≥30 years										--	--	**412**	
Cardiovascular – all ages	113.4 [C]	135.2 [C]	138 [C]	146.4 [C]	138.9 [C]	150 [C]	150 [C]	139.2 [C]	131.3 [C]	128.7 [C]	**134.7 [C]**	191.8	155.7 [C]
Respiratory – all ages										**49.4 [A]**	39.9 [A]	51.5	48.2 [A]
Hospitalisations													
Coronary heart disease	293.2 [B]	342 [B]	302.5 [B]	284.7 [B]	373.6 [B]	726.4 [B]	455.3 [B]	457.8 [B]	456.1 [B]	342.5 [C]	**585 [C]**	--	533.4 [C]
COPD >65 years										1266.6 [C]	927.4 [C]	--	1494 [C]
COPD All ages	130.5 [B]	157.4 [B]	122.9 [B]	190.2 [B]	284.1 [B]	166.3 [B]	143.8 [B]	187.6 [B]	115.4 [B]	197 [C]	140.9 [C]	--	245.2 [C]
Cardiovascular disease													
All ages	1244.6 [B]	1168.5 [B]	1173.6 [B]	1294.3 [B]	1454.7 [B]	2028.8 [B]	1468.8 [B]	1491.5 [B]	1394 [B]	1397.1 [C]	**1722.3 [C]**	1976	1716 [C]
>65 years				--	--	--	--			--	--	**9235**	
Respiratory disease													
All ages				--	--	--	--			1460.3 [C]	**1462.5 [C]**	2003	1716.8 [C]
>65 years				--	--	--	--			--	--	**3978**	
Asthma													
Asthma hospitalisations (ages 5–34 years)				--	--	--	--			117.5 [C]	127.2 [C]	--	151.6 [C]
Asthma emergency department hospitalisations (1–14 years)				--	--	--	--			--	--	**1209**	--
Asthma prevalence (current) for children aged 2–15 years				--	--	--	--			6.2% [C]	10.2% [C]	--	13.5% [C]
Current asthma for ages 16 and over				--	--	--				9.7% [D]	9.0% [D]	--	11.3% [D]

* Data for Sydney Metropolitan area for 2010 based on hospital statistics as reported for 2010 and population data from the ABS for 2011 (relevant to each age group considered) used in review of exposure and risks to inform recommendations for updating the National Environment Protection Measure (NEPM) Ambient Air Quality (AAQ) (Golder 2013)

All other data has been obtained from Health Statistics New South Wales, where: A: 2011–2013 data B: 2013 – 2015 data C: 2014-2015 or 2015 data D: 2016 data

-- No data available **Bold and shaded**: Data used in the characterisation of risk

Table 4-6 Summary of key health indicators: Mental health

Age group	Number of prescriptions for antidepressants per 100,000 people, by LGA in 2014-2015								
	Canada Bay	Strathfield Burwood Ashfield	Leichhardt	City of Sydney	Marrickville Sydenham Petersham	Botany	Kogarah Rockdale	Canterbury	NSW average
17 years and under	5,448	5,367	11,195	7,284	6,531	4,988	3,502	3,294	8,187
18 to 64 years	58,768	56,578	82,370	76,303	79,279	65,100	58,780	54,776	90,959
65 years and over	139,261	139,177	182,025	159,584	158,224	149,818	152,210	143,705	179,771

Data from Australian Atlas of Healthcare Variation, Atlas 2015 (note that the Atlas 2017 did not include mental health data)

5 Community concerns

A range of community engagement activities have been, and continue to be undertaken as part of the M4-M5 Link project, as outlined in **Chapter 7** (Consultation) of the EIS. Issues raised during community consultation have covered a range of different aspects of the project, with the following graphic showing the proportion of feedback received for key issue categories (based on recent community consultation):

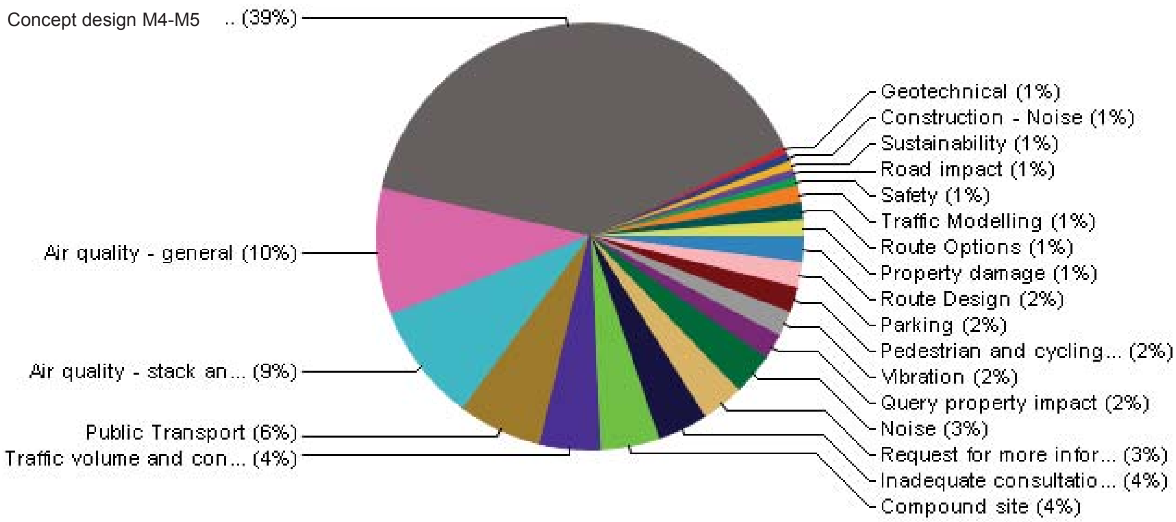


Figure 5-1 Issues raised in recent community consultation

None of the issues raised and grouped as above directly refer to health concerns, however issues such as air quality and noise are related to health. In addition, a number of other issues raised may also indirectly affect health and wellbeing. The following provides further detail in relation to feedback received that relates to impacts that have the potential to affect health:

- Location of three ventilation outlets at Rozelle in the middle of a large passive and active recreation area where children would be playing
- General concern about unfiltered ventilation outlets and in-tunnel air quality
- Air quality impacts for drivers/passengers within the tunnel, including during extended tunnel journeys
- Air quality and human health impacts from the unfiltered ventilation outlets
- Concern about the decline in air quality from an increase in vehicle exhaust pollution
- Proximity of ventilation facilities to residential homes and multi-storey buildings
- Concerns about health impacts due location of ventilation outlets near schools
- How fine particle risks are being assessed
- Air quality monitoring, locations, pollutants monitored and access to data
- Concern that the air quality emission limits set in the conditions of approval were not best practice when considered in a global perspective
- Concerns about noise impacts to properties along Lilyfield Road
- Question about what mitigation will be considered for noise and vibration during construction and upon operation

- Concern about proximity of construction sites to people’s homes
- Concern about adding more trucks to already busy roads eg Parramatta Road
- Concern about the scale of the permanent infrastructure, particularly number and indicative height of ventilation outlets, and the associated visual impact
- Concern about duration of tunnelling impacts including the construction access tunnels
- Concern about construction impacts on local roads
- Concern about increased traffic on the road network surrounding the Rozelle interchange (Johnston St and The Crescent) and surrounding the St Peters interchange (Euston Road, Canal Road, Princes Highway, Sydney Park Road, King Street)
- Concern about the cumulative impacts (traffic, air quality, noise/vibration) associated with the proposed future Western Harbour Tunnel and Beaches Link project
- Consideration of cumulative impacts to the Haberfield and St Peters communities (stress/anxiety from construction fatigue)
- Impacts on residents and communities for up to seven years of disruption from construction works.

6 Assessment of changes in air quality on community health

6.1 General

The characterisation of changes in air quality as a result of the project is complex. Full details of the assessment undertaken are presented in **Appendix I** (Technical working paper: Air quality) of the EIS. This section presents an overview of the key aspects of the assessment undertaken and an assessment of potential health impacts associated with the predicted changes in air quality in the local community.

6.2 Existing air quality

When predicting the impact of any new or modified source of air pollution, it is necessary to take into account the way in which the emissions from the source would interact with existing pollutant levels. Defining these existing levels and the interactions can be challenging, especially in a large urban area such as Sydney where there is a complex mix of sources. It is important to consider both the temporal and spatial variation in pollutant concentrations; these fluctuate a great deal on short time scales, but also show cyclical variations. Moreover, in large urban areas there is usually a complex mix of pollution sources, and substantial concentration gradients. Short term meteorological conditions and local topography are also important.

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 carbon monoxide 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 carbon monoxide concentrations in central Sydney have significantly reduced, and the last exceedance of the air quality standard for carbon monoxide in NSW was recorded in 1998 (NSW Department of Environment, Climate Change and Water (DECCW) 2010).

While levels of nitrogen dioxide, sulfur dioxide (SO_2) and carbon monoxide continue to be below national standards, levels of ozone and particulate matter (PM) can exceed the standards adopted in NSW (NSW EPA 2016) from time to time.

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 (NSW Office of Environment and Heritage (OEH) 2015).

The project lies within an urbanised area of Sydney and hence it is important that the background air quality considered is representative of existing conditions in the local area. Assessment of background air quality, including meteorological data, requires the use of data that has been collected from equipment that complies with Australian Standards (to ensure that data is reliable and comparable).

OEH operates a number of monitoring stations in the Sydney area (see **Figure 6-1**), with the closest stations being located at Chullora, Earlwood and Rozelle. The OEH sites at Lindfield, Liverpool, Randwick and Prospect were further away (between around 11 and 17 kilometres from the project), but were still considered important in terms of characterising air quality in the Sydney region.

In addition, Roads and Maritime has established several long term monitoring stations in response to community concerns relating to the ventilation outlet of the M5 East Motorway tunnel, and to monitor operational compliance of the tunnel with ambient air quality standards. Four of the Roads and Maritime sites (shown on **Figure 6-1** as CBMS, T1, U1, X1) were in the vicinity of the M4 East ventilation outlet. Two Roads and Maritime sites (shown on **Figure 6-1** as F1 and M1) were much closer to busy roads near the M5 East Motorway tunnel portals. Other Roads and Maritime ambient air modelling locations established as part of the NorthConnex project (five locations, shown on **Figure 6-1** as NC: 01 to 05) and near the intersection of Epping Road and Longueville Road (to assess impacts form the Lane Cove Tunnel) were also considered.

SMC has established a WestConnex monitoring network to address some of the gaps in the OEH and Roads and Maritime monitoring in terms of pollutants and locations. The WestConnex network includes monitoring stations at both urban background and near-road sites. Five new monitoring stations were introduced in the M4 East area, seven new stations in the New M5 area, and two new stations in the M4-M5 Link area to support the development and assessment of the respective projects. Some of the M4 East and New M5 monitoring stations were subsequently relocated or decommissioned due to construction of those projects.

These monitoring stations are shown on **Figure 6-1**.

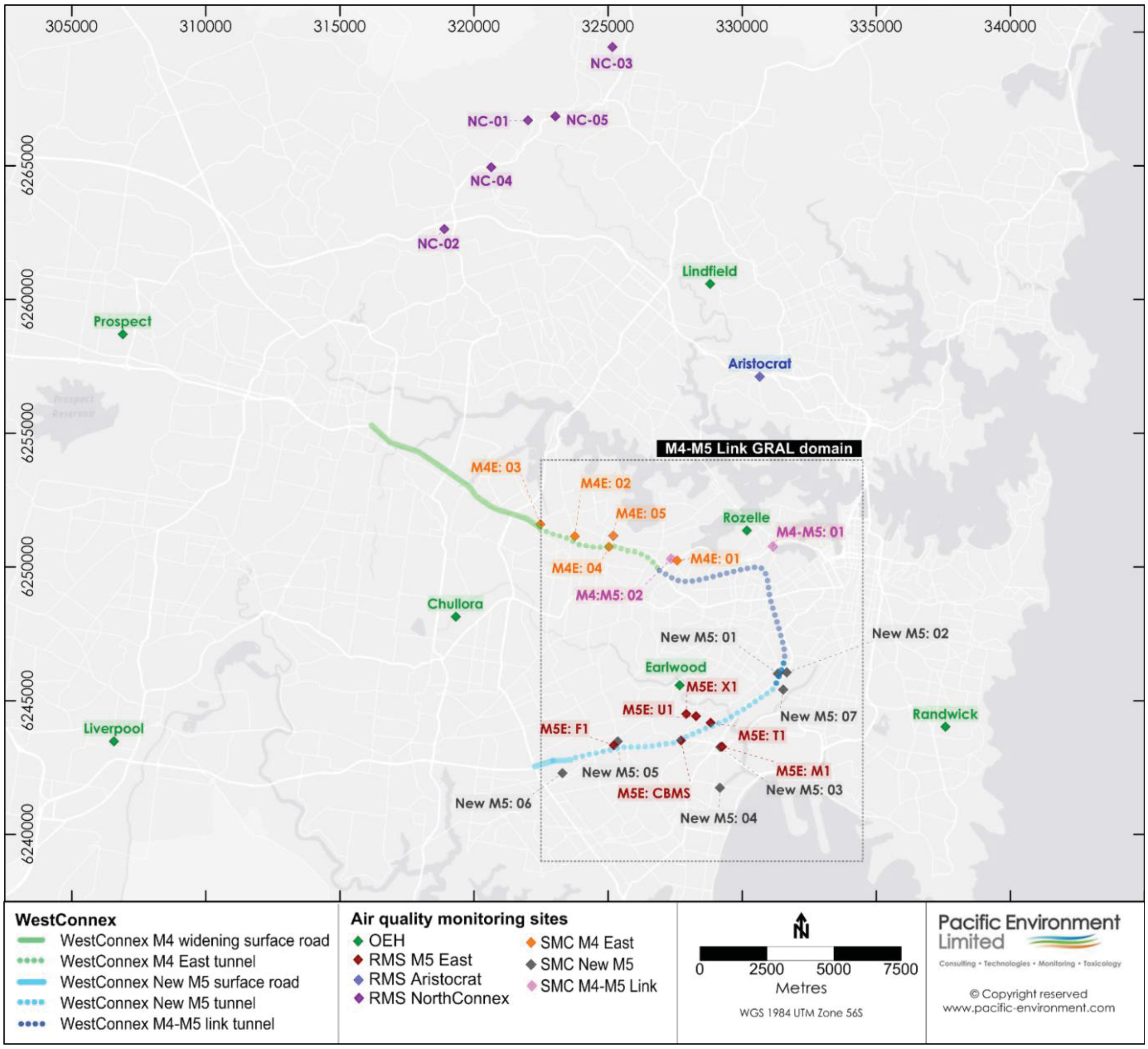


Figure 6-1 Locations of air quality monitoring sites

Background air quality relevant to the assessment of carbon monoxide, nitrogen dioxide and particulate matter were determined in **Appendix I** (Technical working paper: Air quality) of the EIS on the basis of data from these monitoring stations. The background air quality considered in **Appendix I** (Technical working paper: Air quality) of the EIS related to air quality in areas away from major roadways.

In relation to the background air quality considered in **Appendix I** (Technical working paper: Air quality) of the EIS for the project area, the following is noted:

- **Carbon monoxide**: background air concentrations (as one hour and eight hour averages) were below the current air quality guidelines at any of the background air monitoring sites. A general downward trend in background air concentrations was observed
- **Nitrogen dioxide**: background air concentrations (as one hour and annual averages) were below the current air quality guidelines both at all background air monitoring sites and at roadside monitoring locations. The concentration of nitrogen dioxide has been observed to be generally stable over time. The concentrations reported at roadside monitoring stations were noted to be equal to the highest levels reported at the background monitoring locations
- **PM_{10}**: background concentrations of PM_{10} (as an annual average) were below the current air quality guidelines. However, there were exceedances of the 24 hour average criterion, most notably in the warm and dry year 2009
- **$PM_{2.5}$**: $PM_{2.5}$ is only measured at three OEH sites in the study area. Concentrations at the two OEH sites close to WestConnex – Chullora and Earlwood – showed a broadly 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 (as the reporting of $PM_{2.5}$ in air varies depending on the type of equipment used). The increases meant that background $PM_{2.5}$ concentrations in the study area during 2014 and 2015 were already very close to or above the annual average criterion of eight micrograms per cubic metre. There have been a number of exceedances of the 24 hour average criterion of 25 micrograms per cubic metre.

6.3 Overview of air quality impact assessment

6.3.1 Construction

Appendix I (Technical working paper: Air quality) of the EIS evaluated impacts on air that may occur during construction. The assessment considered impacts that may occur during tunnelling activities and surface works and involved a qualitative assessment approach. The assessment of construction activities addressed seven different construction scenarios or areas, as outlined below.

Table 6-1 M4-M5 Link construction scenarios

Scenario	Compound(s) included	Construction period (indicative)
S1	C1a = Wattle Street civil and tunnel site C2a = Haberfield civil and tunnel site C3a = Northcote Street civil site	Q3 2019 – Q4 2022 Q3 2019 – Q4 2022 Q4 2019 – Q4 2022
S2	C1b = Parramatta Road West civil and tunnel site C2b = Haberfield civil site C3b = Parramatta Road East civil site	Q4 2018 – Q2 2022 Q3 2019 – Q3 2022 Q4 2018 – Q3 2022
S3	C4 = Darley Road civil and tunnel site	Q3 2018 – Q4 2022
S4	C5 = Rozelle civil and tunnel site C6 = The Crescent civil site C7 = Victoria Road civil site	Q4 2018 – Q3 2023 Q1 2019 – Q4 2021 Q1 2019 – Q4 2022
S5	C8 = Iron Cove Link civil site	Q4 2018 – Q3 2023
S6	C9 = Pyrmont Bridge Road tunnel site	Q3 2018 – Q4 2022
S7	C10 = Campbell Road civil and tunnel site	Q4 2018 – Q4 2022

The assessment identified the range of activities and equipment proposed to be used during construction, potential emissions from these activities and the location of these activities in relation to sensitive receptors. **Figure 6-2** illustrates the location of the sensitive receptors considered in **Appendix I** (Technical working paper: Air quality) of the EIS during construction works. The figure also shows the location of the compounds considered in each of the construction scenarios.

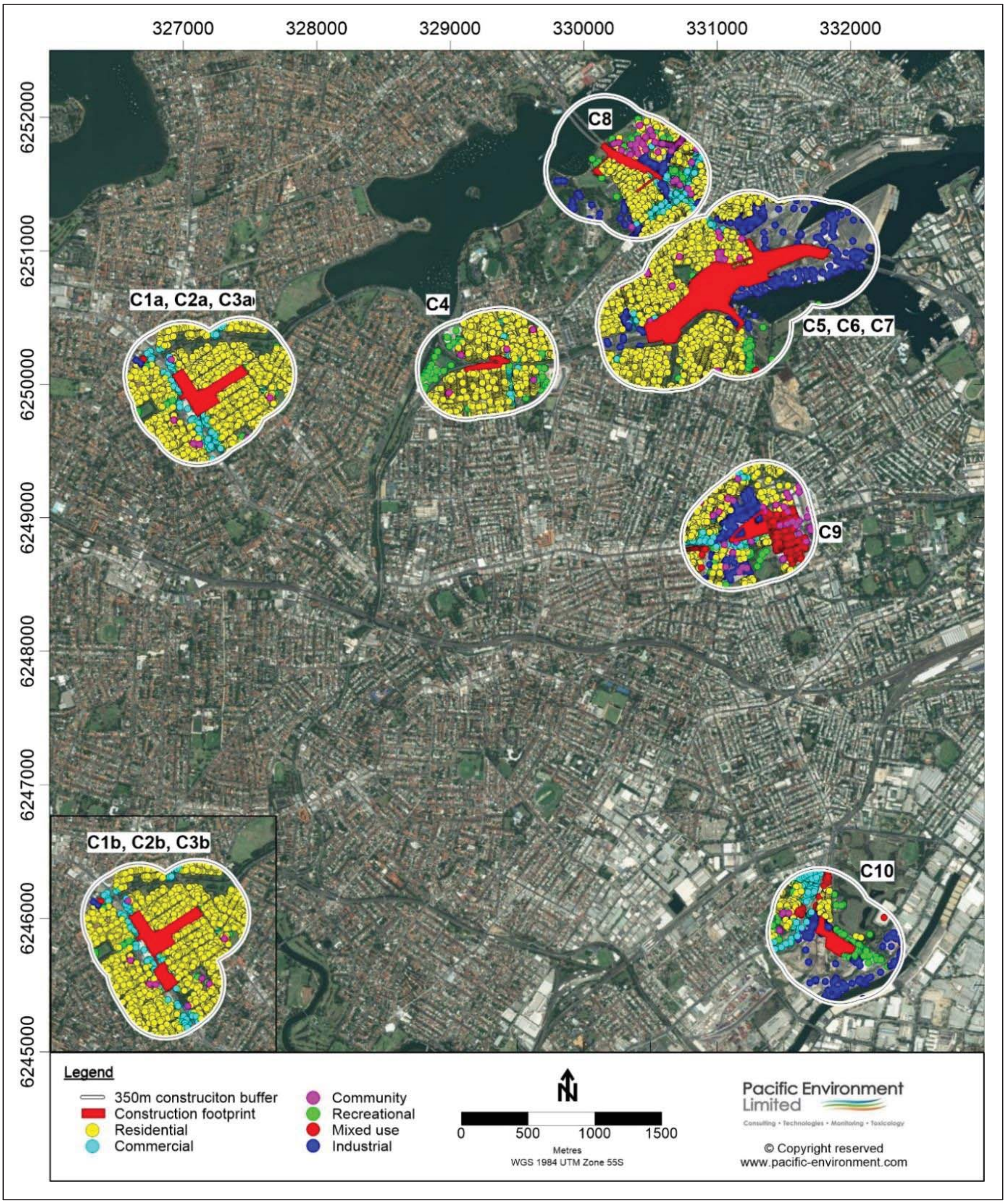


Figure 6-2 Location of sensitive human receptors near the construction of the M4-M5 Link project

It is noted that for demolition activities, the Work Health and Safety Regulation 2011 (NSW) requires that all hazardous materials are properly removed from buildings prior to any demolition works occurring. This is to prevent workers and the public from being exposed these materials and contaminants during the demolition and other construction works. Hence there is no need to further assess the presence of hazardous building materials during construction activities.

This approach then allocated a risk associated with the generation of dust and impacts on human health in the adjacent community. This approach considered the proximity to the source area and the number and type of receptors present. Impacts associated with nuisance dust, health impacts on the community were evaluated. For all demolition, earthworks, construction and track-out activities, where no mitigation measures are implemented, the risk of impacts on human health were evaluated and considered in terms of the location of sensitive receptors. Risk ratings that varied from low to high were adopted in the review presented in **Appendix I** (Technical working paper: Air quality) of the EIS. In relation to health impacts, high levels of risk were identified for the following scenarios (see **Table 6-1** for scenario details):

- 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
- Scenario 5 (C8): Earthworks and construction for dust soiling
- Scenario 6 (C9): All activities for dust soiling, and demolition
- Scenario 7 (C10): Earthworks, construction and track-out for dust soiling.

On this basis, appropriate mitigation measures are required to minimise impacts on the local community during construction.

For almost all construction activities, the aim should be to prevent significant impacts on receptors through the use of effective mitigation. Experience from similar construction projects shows that this is normally possible. Hence, where mitigation measures are appropriately implemented, **Appendix I** (Technical working paper: Air quality) of the EIS concluded that the residual risk level would normally be ‘not significant’.

A Dust Management Plan will be produced as part of the Construction Air Quality Management Plan to cover construction of the project. These measures include site management, monitoring, preparing and maintaining the construction sites, maintenance and controls on vehicles and machinery and waste management. Chapter 9 of **Appendix I** (Technical working paper: Air quality) of the EIS provides additional details on the dust management measures proposed.

However, even with a rigorous Dust Management Plan in place as part of the Construction Air Quality Management Plan, it is not possible to guarantee that the dust mitigation measures will 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 imply 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’.

Issues related to health impacts from construction fatigue, where the community may be located close to construction facilities for extended periods of time, as a result of the number of construction projects being undertaken for WestConnex, are further addressed in **section 10.8**

6.3.2 Operation

The assessment of changes in air quality associated with the operation of the project has been undertaken on the basis of the tunnel designs specifications and forecasts of tunnel and surface road traffic volumes (and speeds) as outlined in the WestConnex Road Traffic Model (WRTM). The project does not include portal emissions (ie emissions from the tunnel entrances and exits), hence emissions associated with the operation of the tunnel relate to the discharge of air from within the tunnel to atmosphere via 14 ventilation outlets (not all for the M4-M5 Link project) outlined below, and shown on **Figure 6-3**:

- Existing facility:
  - Outlet A — M5 East tunnel outlet at Turrella
- Facilities currently under construction for WestConnex 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
  - Outlet E — New M5 facility at Arncliffe
  - Outlet F — New M5 facility at Kingsgrove
- Proposed ventilation facilities for WestConnex M4-M5 Link (subject of this EIS):
  - Ventilation facility at Haberfield:
    - Outlet G — Parramatta Road facility at Parramatta Road, Haberfield (this ventilation facility is being constructed as part of the M4 East project however the mechanical and electrical fitout would be undertaken as part of the M4-M5 Link project)
  - Ventilation facility at Rozelle:
    - Outlet H — Western Harbour Tunnel and Beaches Link facility at Rozelle
    - Outlets I and J — M4-M5 Link/Iron Cove Link facility at Rozelle
  - Ventilation facility at St Peters:
    - Outlet K — M4-M5 Link facility at St Peters
  - 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 (noting that the locations are yet to be finalised):
  - Outlet M — F6 Extension facility at Arncliffe
  - Outlet N — F6 Extension facility at Rockdale

Other ventilation outlets that may be required for the Western Harbour Tunnel and Beaches Link project are not included on **Figure 6-3**, as these are outside the study area evaluated.

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.

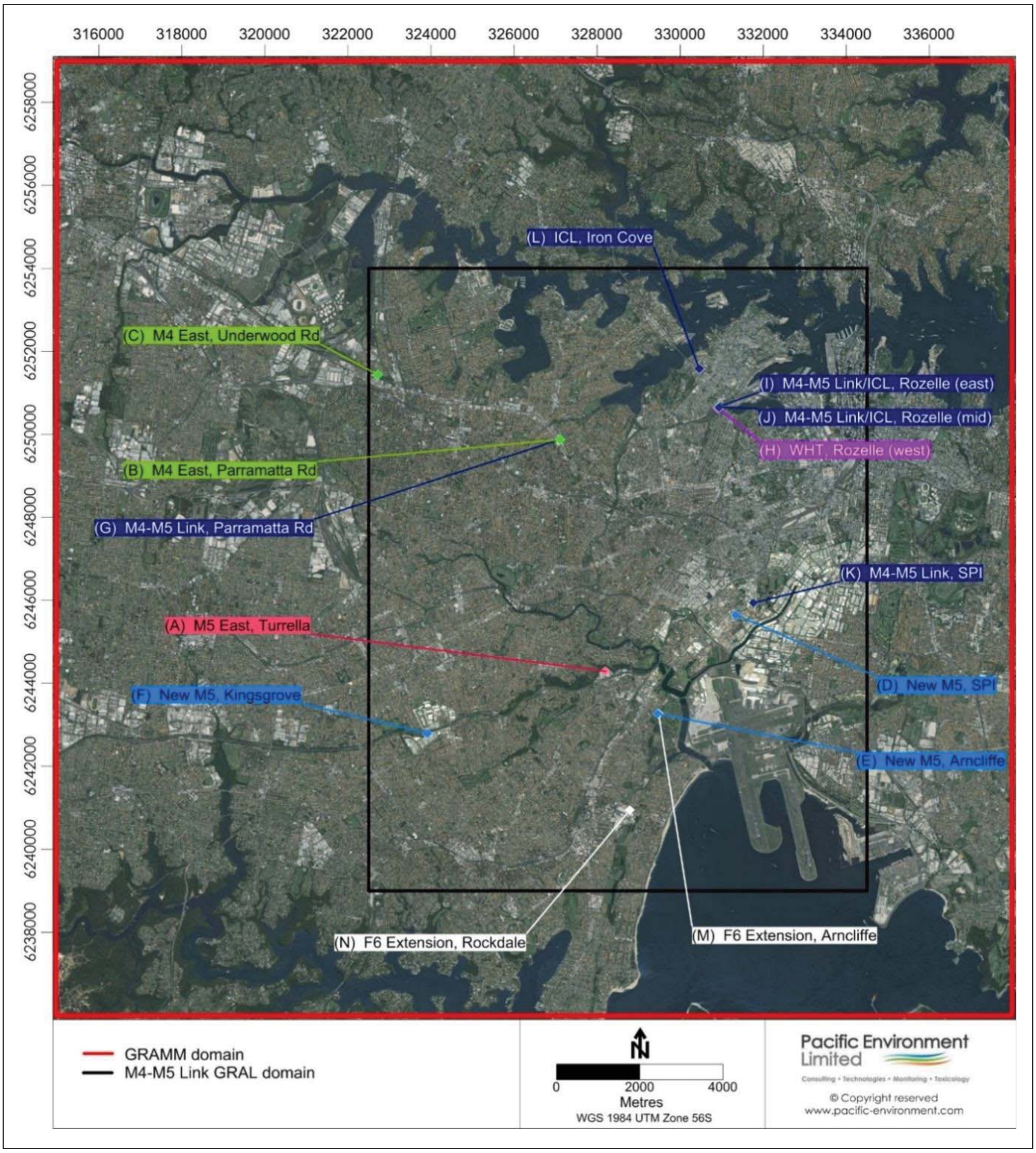


Figure 6-3 Locations of all tunnel ventilation outlets included in the assessment of air quality

The assessment of potential impacts associated with the project utilised an air dispersion model to predict changes in ambient air quality within the study area (or modelling domain) associated with a range of emissions scenarios. The model used for the assessment was GRAL (Graz Lagrangian Model). This model was selected as it has been shown to provide robust/validated results for assessing air quality in complex urban environments and the model enables simultaneous consideration of all the different types of emission sources in the study area (ie local and regional roads, ventilation outlets and other emissions sources of various types). The model has also been used to evaluate the cumulative air quality impacts associated with all WestConnex projects by considering a larger study area. The air modelling domain (study area) considered for the project is shown in **Figure 4-1**.

The modelling considered meteorology relevant to a larger area (red box, or GRAMM (Graz Mesoscale Model) domain, on **Figure 6-3**) that includes the study area, local terrain, and project-specific emission sources.

The emission sources relevant to the project addressed in the modelling included the following:

- Emissions from the traffic on the surface road network, including any new roads associated with the project and projects already approved and under construction
- Emissions from the existing and proposed ventilation outlets outlined above.

The assessment of cumulative impacts, from the operation of all WestConnex projects, evaluated changes in air quality in the study area from all changes in surface traffic and ventilation outlets associated with all projects in the wider area.

When determining the potential emissions to air that may require ventilation from the tunnel, the assessment has considered a range of factors associated with the tunnel design, traffic volumes, vehicle mix and age. In addition, in-tunnel air quality limits have also been considered as discussed further in **section 7**. These have been taken to be limits/criteria that are required to be met under all operational circumstances (except emergencies such as fire). The tunnel ventilation system and tunnel operational parameters have been designed to ensure the in-tunnel concentration limits are not exceeded.

The assessment of air quality impacts involved estimation of emissions from vehicles using the tunnel, and other WestConnex tunnels under expected traffic conditions (ie operating normally with traffic volumes fluctuating over the day with peak and out of peak traffic loads). In addition, a regulatory worst case scenario has been evaluated. The regulatory worst case relates to modelling of emissions from the ventilation facilities at the limit expected to be set by the regulators. This is an upper limit that would essentially mean the tunnel is always full of vehicles and trucks. This is not a realistic scenario, but it is required to demonstrate compliance with regulatory air quality objectives.

Additional details on the assessment scenarios and the emission sources considered in **Appendix I** (Technical working paper: Air quality) of the EIS are summarised in the following sections.

6.4 Assessment scenarios

The assessment of impacts on air quality associated with operation of the project has considered a range of scenarios that include the existing situation, construction works and various future operational scenarios both with and without the project. In addition, a cumulative scenario, associated with impacts from all the WestConnex projects was assessed.

In all of the air modelling scenarios considered, changes in emissions to air from the surface road network as well as the ventilation facilities (as relevant to each scenario) have been included.

The air modelling scenarios have included the following:

- **2015 'Base Year'**: This represents 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 pollution monitoring data
- **2023 'Without project' or 'Do Minimum'**: The 2023 'Do minimum' case assumes that the M4 Widening, M4 East, New M5 and the King Georges Road Interchange Upgrade projects are complete, but the M4-M5 Link is not built. It is called 'do minimum' rather than 'do nothing' as it assumes that ongoing improvements would be made to the broader transport network including some new infrastructure and intersection improvements to improve capacity and cater for traffic growth
- **2023 'With project' or 'Do Something'**: As for the 2023 'Do Minimum', but with the M4-M5 Link also completed and operational
- **2023 'With project' or 'Do Something' – cumulative**: As for the 2023 'Do Minimum', but with the M4-M5 Link and the proposed future Sydney Gateway and Western Harbour Tunnel projects completed and operational

- **2033 ‘Without project’ or ‘Do Minimum’**: A future network, as for the 2023 ‘Do Minimum’, but for 10 years after project opening (without the M4-M5 Link)
- **2033 ‘With project’ or ‘Do Something’**: As for the 2033 ‘Do Minimum’, but with the M4-M5 Link also completed and operational
- **2033 ‘With project’ or ‘Do Something’ – cumulative**: As for the 2033 ‘Do Minimum’, with the M4-M5 Link and the proposed future Sydney Gateway, Western Harbour Tunnel and Beaches Link and F6 Extension all completed and operational.

More specific details associated with each of these scenarios is outlined in **Appendix H** (Technical working paper: Traffic and transport) of the EIS.

Assessment scenarios evaluated in the health risk assessment

Health impacts that may be associated with changes in air quality that are associated with the project have been assessed for the following years:

- Project operation and cumulative impacts in 2023
- Project operation and cumulative impacts in 2033.

The assessment has considered total impacts (ie background plus the project) and changes in air quality associated with the project. The assessment of changes in air quality is based on the predicted air quality impacts for all the local roads plus the project (the 'Do Something’ scenario) minus the air quality impacts for all the local roads without the project (the 'Do Minimum' scenario). The net change in air quality assessed relates to emissions directly from the project as well as changes in emissions on surface roads.

In relation to the operation of the project considered in each of the above scenarios the air quality modelling has been undertaken to consider expected traffic volumes within the tunnel. The number of vehicles moving through the tunnel varies depending on the hour of the day. Air modelling predictions associated with the expected traffic movements through the tunnel have been used for the assessment of long term/chronic exposures in the local community.

6.5 Vehicle emissions

Emissions from vehicles using the tunnel have been estimated based on an emissions inventory model developed by the NSW Environment Protection Authority (NSW EPA) (as described in **Appendix I** (Technical working paper: Air quality) of the EIS).

6.6 Assessment of volatile organic compounds and polycyclic aromatic hydrocarbons

6.6.1 General

Appendix I (Technical working paper: Air quality) of the EIS has considered emissions of volatile organic compounds (VOCs) and polycyclic aromatic hydrocarbons (PAHs) to air from the project. Both VOCs and PAHs refer to a group of compounds with a mix of different proportions and toxicities. It is the individual compounds within the group that are of importance for evaluating adverse health effects. The composition of individual compounds in the VOCs and PAHs evaluated would vary depending on the source of the emissions. Hence it is important that the key individual compounds present in emissions considered for this project are speciated (ie identified and quantified as a percentage of the total VOCs or total PAHs) to ensure that potential impacts associated with exposure to these compounds can be adequately assessed.

VOCs in air in Sydney (OEH 2012) are primarily derived from domestic/commercial sources (54 per cent) with on-road vehicles contributing approximately 24 per cent, industrial emissions eight per cent with the remainder from off-road mobile sources and other commercial sources.

VOCs and PAHs from the project are associated with emissions from vehicles assumed to be using the tunnel (and approaches) and surface roads. The makeup of the VOCs and PAHs emissions would depend on the mix of vehicles considered as these pollutants would be emitted in different proportions from petrol and diesel powered vehicles. In addition, the age and the fuel used by the vehicle fleet would affect these emissions. The vehicle fleet mix considered in this project is summarised in **Table 6-2**.

6.6.2 Volatile organic compounds

VOCs have been modelled in **Appendix I** (Technical working paper: Air quality) of the EIS based on emissions from all vehicles considered. The proportion of each of the individual VOCs that may be present in the air is then estimated based on the assumed composition of the vehicle fleet during the different years and the type of fuel used.

Most of the VOC emissions comprise a range of hydrocarbons that are of low toxicity (such as methane, ethylene, ethane, butenes, butanes, pentenes, pentanes and heptanes) (NSW EPA 2012). From a toxicity perspective the key VOCs that have been considered for the vehicle emissions are BTX, 1,3-butadiene, acetaldehyde and formaldehyde (consistent with those identified and targeted in studies conducted in Australia on vehicle emissions (Australian Department of Environment and Heritage (DEH) 2003; NSW EPA 2012)).

The proportion of each of the key VOCs considered are derived from the 2008 Calendar Year Air Emissions Inventory for the Greater Metropolitan Region in NSW (NSW EPA 2012), for the vehicle fleet assessed in **Appendix I** (Technical working paper: Air quality) of the EIS (as summarised above). In relation to passenger vehicles it has been assumed that 60 per cent[1] of fuel used is E10. It is conservatively assumed that the composition of VOCs in vehicle emissions remains the same over time, and does not improve with enhanced vehicle emissions technology.

Table 6-2 presents a summary of VOCs speciation profile considered for the different vehicle types considered in the project as well as the weighted mass fraction for these VOCs considered for the project in 2023 and 2033.

Table 6-2 Volatile organic compounds speciation profile for vehicle emissions

VOC	Mass fraction (VOC)					Mass fraction for vehicle fleet in project (VOC)		
	Passenger vehicles		Light duty vehicles		Heavy goods vehicles	2015–current	2023	2033
	No ethanol	E10	Petrol	Diesel*	Diesel			
1,3-butadiene	1.27	1.2	1.27	0.4	0.4	1.1	1.1	0.97
Acetaldehyde	0.46	1.3	0.46	3.81	3.81	1.3	1.9	1.8
Benzene	4.95	4.54	4.95	1.07	1.07	4.3	4.15	3.6
Formaldehyde	1.46	1.82	1.46	9.85	9.85	2.5	2.9	4.2
Xylenes	7.6	7.22	7.6	0.38	0.38	6.6	6.3	5.2
Toluene	9.18	8.79	9.18	0.47	0.47	8.0	7.7	6.3

Volatile organic compounds speciation from NSW EPA (2012)

* Speciation for diesel emissions also adopted for diesel passenger vehicles

1 The value of 60 per cent of ethanol in total fuel volume sales comes from the requirement that a minimum of 6% ethanol in the total volume of petrol sold in NSW as outlined in the *Biofuels Act 2007* (NSW). This equates to selling 60% E10 fuel.

6.6.3 Polycyclic aromatic hydrocarbons

PAHs have been considered in **Appendix I** (Technical working paper: Air quality) of the EIS as key pollutants that may be derived from diesel powered heavy goods vehicles. The total PAH concentration that may be derived from the project has been determined on the basis of a proportion of the total VOCs. While not all of the PAHs would be volatile the approach adopted provides an estimate of potential levels of total PAHs that may be in air, as a result of the change in emissions derived from the project.

For the year 2023 and 2033, total PAHs have been estimated to comprise 0.66 per cent of the total VOCs. In relation to the toxicity of PAHs, this differs significantly for the different individual PAHs that may be present. The detailed review of the potential health impacts associated with exposures to PAHs in air from the project requires an assessment of the key individual PAHs.

The presence of PAHs in diesel exhaust (DE) has been found to be more a function of the PAH content of the fuel than of engine technology. For a given refinery and crude oil, diesel fuel PAH levels correlate with total aromatic content and T90 (distillation temperature where 90 per cent of the fuel is evaporated). Representative data on aromatic content for diesel fuels in Australia is limited, however emissions tests have been conducted on a range of light and heavy vehicles under different traffic congestion conditions (DEH 2003). The data presented from these emissions tests is assumed to include fuels commonly used in Australia and are considered to provide an indication of the likely proportions of individual PAHs in DE.

The PAHs reported in DE by the DEH (now the Australian Department of Environment and Energy) (2003) comprise the 16 most commonly reported (and highest proportion) PAHs present in exhaust. The data available from this study is dated (from vehicles manufactured from 1990 to 1996) and use of this data is likely to provide an overestimation of PAH emissions from current (and future) diesel vehicles. The evaluation of potential health impacts associated with exposure to PAHs from the project requires consideration of the 16 individual PAHs, present at the highest levels in exhaust and which have the most information on chronic health effects.

The toxicity of individual PAHs varies significantly, with some considered to be carcinogenic while others are not carcinogenic. For the carcinogenic PAHs, these are commonly assessed as a group with the total carcinogenic PAH concentration calculated using weighting factors that relate the toxicity of individual carcinogenic PAHs to the most well studied PAH, benzo(a)pyrene. For the carcinogenic PAHs the weighting factors presented by the Canadian Council of Ministers of the Environment (CCME 2010) have been adopted. Other PAHs that are not carcinogenic have been considered separately.

On the basis of this approach the speciation of individual PAHs (as per cent of total PAHs) has been calculated based on the data from DEH (2003). The data presented relates to emissions that occur in congested or stop/start traffic. This data has been used to be representative of the worst case situation of heavy congested traffic in the project area and is considered to be conservative for expected traffic conditions in the motorway tunnels.

Table 6-3 presents a summary of the PAH speciation profile considered in this assessment for the above traffic conditions.

Table 6-3 Polycyclic aromatic hydrocarbon speciation profile for diesel vehicle emissions

Individual PAH	Per cent of total PAH emissions (PAHs) Used to evaluate emissions in 2023 and 2033
Non-carcinogenic PAHs	
Naphthalene	70
Acenaphthalene	4.9
Acenaphthene	2.0
Fluorene	5.0
Phenanthrene	3.4
Anthracene	0.49
Fluoranthene	0.45
Pyrene	0.71
Carcinogenic PAHs	
Benzo(a)pyrene TEQ	4.6

6.6.4 Assessment of health impacts

The maximum increase in total VOCs and PAHs in the community is equal to or lower where the project is operating compared with the situation of no project (ie the project results in no change or a lower total impact of VOCs and PAHs in the community). The change in VOC and PAH concentrations associated with the project is a decrease for most receptors, however in some areas there is an increase in concentrations. These changes relate to the redistribution of emissions from vehicles, primarily associated with surface roads. The following evaluation has been undertaken to assess the potential health impacts associated with the maximum increases predicted.

The assessment of potential health impacts associated with exposure to changes in VOCs and PAHs concentrations (calculated for individual VOCs and PAHs based on the speciation outlined above) in air within the community has been assessed on the basis of the following:

- For VOCs and PAHs that are considered to be genotoxic carcinogens (consistent with guidance provided by enHealth (enHealth 2012b) an incremental lifetime carcinogenic risk has been calculated. For the VOCs and PAHs evaluated in this assessment a carcinogenic risk calculation has been adopted for the assessment of maximum potential (incremental) increase in benzene, 1,3-butadiene and carcinogenic PAHs (as a benzo(a)pyrene toxicity equivalent or TEQ). The assessment undertaken has adopted the calculation methodology outlined in **Annexure B**, adopting the inhalation unit risk values presented in **Table 6-5**
- For other VOCs and PAHs, where the health effects are associated with a threshold (ie a level below which there are no effects), the maximum predicted concentration from all sources (ie background plus the project) of individual VOCs and PAHs associated with the project have been compared against published peer-reviewed health based guidelines that are relevant to acute and chronic exposures (where relevant). The health based guidelines adopted (identified on the basis of guidance from enHealth 2012) are relevant to exposures that may occur to all members of the general public (including sensitive individuals) with no adverse health effects. The guidelines available relate to the duration of exposure and the nature of the health effects considered where:
  - Acute guidelines are based on exposures that may occur for a short period of time (typically between an hour or up to 14 days). These guidelines are available to assess peak exposures (based on the modelled one hour average concentration) that may be associated with volatile organic compounds in the air, and are presented in **Table 6-4**
  - Chronic guidelines are based on exposures that may occur all day, every day for a lifetime. These guidelines are available to assess long term exposures (based on the modelled annual average concentration) that may be associated with volatile organic compounds and PAHs in the air, and are presented in **Table 6-5**.

Table 6-4 Adopted acute inhalation guidelines based on protection of public health

Compound assessed	Acute health based guideline (µg/m^3)	Basis
Volatile organic compounds		
Benzene	580	Acute 1 hour health based guideline, based on depressed peripheral lymphocytes from Texas Commission on Environmental Quality (TCEQ) evaluation (TCEQ 2013b).
Toluene	15000	Acute 1 hour health based guideline, based on eye and nose irritation, increased occurrence of headache and intoxication in human male volunteers from TCEQ evaluation (TCEQ 2013c).
Xylenes	7400	Acute 1 hour health based guideline, based on mild respiratory effects and subjective symptoms of neurotoxicity in human volunteers from TCEQ evaluation (TCEQ 2013e).
1,3-Butadiene	660	Acute 1 hour health based guideline, based on developmental effects derived by the California Office of Environmental Health Hazard Assessment (OEHHA 2013). The guideline developed is lower than developed by TCEQ (TCEQ 2007) based on the same critical study.
Formaldehyde	50	Acute 1 hour health based guideline, based on eye and nose irritation in human volunteers from TCEQ evaluation (TCEQ 2014). This guideline is noted to be lower than the acute guideline available from the WHO (WHO 2000a, 2010) of 100 µg/m3 for formaldehyde.
Acetaldehyde	470	Acute 1 hour health based guideline, based on effects on sensory irritation, bronchoconstriction, eye redness and swelling derived by the California OEHHA (OEHHA 2013).

Table 6-5 Adopted chronic guidelines and carcinogenic unit risk values based on protection of public health

Compound assessed	Chronic health based guideline (µg/m^3)	Basis
Threshold guidelines for volatile organic compounds		
Benzene	30	The most significant chronic health effect associated with exposure to benzene is the increased risk of cancer, specifically leukaemia, which is assessed separately (below). The assessment of other health effects (other than cancer) has been undertaken using a chronic guideline derived by the USEPA (USEPA 2002b) based on haematological effects in an occupational inhalation study (converted to public health value using safety factors). This is the most current evaluation of effects associated with chronic inhalation exposure to toluene and is consistent with the value used to derive the NEPM (NEPC 1999 amended 2013b) health based guidelines.
Toluene	5000	Chronic guideline derived by the USEPA (USEPA 2005a) based on neurological effects in an occupational study (converted to public health value using safety factors). This is the most current evaluation of effects associated with chronic inhalation exposure to toluene and is consistent with the value used to derive the NEPM (NEPC 1999 amended 2013b) health based guidelines.
Xylenes	220	Chronic guideline derived by the Agency for Toxic Substances and Disease Register (ATSDR) (ATSDR 2007) based on mild subjective respiratory and neurological symptoms in an occupational study (converted to public health value using safety factors).

Compound assessed	Chronic health based guideline (µg/m^3)	Basis
Formaldehyde	3.3	Formaldehyde is classified by IARC as carcinogenic to humans. The guideline developed by TCEQ (TCEQ 2013a) is derived on the basis of irritation of the eyes and airway discomfort in humans, with review of carcinogenic and other non-carcinogenic effects found to be adequately protected by this guideline. The guideline is more conservative than derived by the WHO (WHO 2010).
Acetaldehyde	9	Chronic guideline derived by the USEPA (USEPA database) based on nasal effects (in a rat study) (converted to a public health value using safety factors). Value is more conservative that more recent evaluations from WHO and Californian OEHHA.
Threshold guidelines for polycyclic aromatic hydrocarbons		
Naphthalene	3	Chronic guideline from USEPA (USEPA 1998) based on nasal effects (in a mice study) (converted to a public health value using safety factors) and is consistent with the value used to derive the NEPC (NEPC 1999 amended 2013b) health based guidelines.
Acenaphthylene	200#	These are the non-carcinogenic PAHs. Guideline available from the USEPA (USEPA). Chronic guidelines are based on criteria derived from oral studies (for critical effects on the liver, kidney and haematology) which are then converted to an inhalation value (relevant for the protection of public health, including the use of safety factors) for use in this assessment. The value presented in the above table has been converted from an acceptable dose in mg/kg/day to an acceptable air concentration assuming a body weight of 70 kg and inhalation of 20 m3/day (as per (USEPA 2009a). # No guideline available for individual PAHs, hence a surrogate compound has been used for the purpose of assessment. The surrogate compound is a PAH of similar structure and toxicity. In relation to the surrogates adopted in this evaluation, acenaphthene has been adopted as a surrogate for acenaphthylene, fluoranthene has been adopted as a surrogate for phenanthrene.
Acenaphthene	200	
Fluorene	140	
Phenanthrene	140#	
Anthracene	1000	
Fluoranthene	140	
Pyrene	100	
Carcinogenic inhalation unit risk values adopted for carcinogenic risk calculation		
Benzene	6x10-6 (µg/m3)-1	Benzene is classified as a known human carcinogen by the International Agency for Research on Cancer (IARC). Inhalation unit risk value is from the WHO (WHO 2000a, 2010) and is based on excess risk of leukaemia from epidemiological studies.
1,3-Butadiene	5x10-7 (µg/m3)-1	1,3-Butadiene is classified as a known human carcinogen by the International Agency for Research on Cancer (IARC). Inhalation unit risk values are available from a number of agencies, including the WHO, USEPA and TCEQ. The most current evaluation has been undertaken by TCEQ (TCEQ 2013d). This has considered the same studies as WHO and USEPA, but included more recent studies and more relevant dose-response modelling.

Compound assessed	Chronic health based guideline ($\mu g/m^3$)	Basis
Benzo(a)pyrene TEQ	0.087 (µg/m3)-1	BaP is classified by IARC as a known human carcinogen, which relates to BaP as well as all the other carcinogenic PAHs assessed as a BaP toxicity equivalent (TEQ) value. Inhalation unit risk value is from the WHO (WHO 2010) and is based on protection from lung cancer for an occupational study associated with coke oven emissions, which are very different from those from diesel emissions, and is expected to be conservative. It is noted that carcinogenic risks associated with lung cancer from diesel particulate matter (which is dominated by the presence of carcinogenic PAHs) is also assessed as outlined in section 6.9.5 and Annexure B).

Table 6-6 to Table 6-11present a summary of the maximum predicted one hour or annual average concentrations of VOCs and PAHs assessed on the basis of a threshold with comparison against acute and chronic health based guidelines. The table also presents a Hazard Index (HI) which is the ratio of the maximum predicted concentration to the guideline. Each individual HI is added up to obtain a total HI for all the threshold VOCs and PAHs considered. The total HI is a sum of the potential hazards associated with all the threshold VOCs and PAHs together assuming the health effects are additive, and is evaluated as follows (enHealth 2012b):

- A total HI less than or equal to one means that all the maximum predicted concentrations are below the health based guidelines and there are no additive health impacts of concern
- A total HI greater than one means that the predicted concentrations (for at least one individual compound) are above the health based guidelines, or that there are at least a few individual VOCs or PAHs where the maximum predicted concentrations are close to the health based guidelines such that there is the potential for the presence of all these together (as a sum) to result in adverse health effects.

The assessment of acute exposures, presented in **Table 6-6** and **Table 6-7**, has compared the maximum predicted total (background plus existing roads and project) one-hour average concentration against the relevant acute guidelines. This is the maximum one-hour average concentration reported anywhere in the project area, regardless of land use.

The assessment of chronic exposures, presented in **Table 6-8** and **Table 6-9**, has compared the maximum predicted total annual average concentration relevant to residential land use against the relevant chronic guidelines. For exposures in other areas **Table 6-8** and **Table 6-9** also presents the maximum calculated HI relevant to exposures in commercial/industrial areas, where the maximum change in VOC concentrations is predicted. The calculated HI takes into account that these exposures occur for eight hours per day over 240 days per year.

Table 6-10 and **Table 6-11** presents a summary of the calculated incremental lifetime carcinogenic risk associated with exposure to the maximum predicted change in concentrations of benzene, 1,3-butadiene and carcinogenic PAHs (as benzo(a)pyrene TEQ) in residential areas. The calculation presented assumes residents are exposed to these pollutants all day, every day for a lifetime. The calculated carcinogenic risk for these compounds has been summed, in accordance with enHealth guidance where the following has been considered (enHealth 2012b). The table also presents the calculated total carcinogenic risk relevant to exposures in commercial/industrial areas, where the maximum change in VOCs and PAHs is predicted to occur. This calculation assumes workers are exposed eight hours per day, 240 days per year for 30 years. The calculated risks are considered in conjunction with what are considered negligible, tolerable/acceptable and unacceptable risks as outlined in **Annexure C**.

The values presented in the tables have been rounded to two significant figures for individual calculations and one significant figure for the total HI and total carcinogenic risk, reflecting the level of uncertainty in the calculations presented.

The following evaluation is based on the maximum predicted concentration in air for the relevant assessment scenarios for 2023 and 2033 as modelled in **Appendix I** (Technical working paper: Air quality) of the EIS. The concentrations models are the total concentration, namely background plus emissions from surface roads plus emissions from ventilation outlets. Concentrations in all other areas of the surrounding community are lower than the maximum as evaluated in this assessment. In many locations, the change due to the project is a lowering of VOC and PAH concentrations in air (ie a benefit).

Table 6-6 Assessment of acute exposures to VOCs – maximum impacts in community associated with project: 2023

Key VOC	Maximum predicted 1 hour average concentration associated with project (background plus project) and calculated HI					
	2023: Without project		2023: With project		2023: Cumulative	
	Maximum concentration (µg/m^3)	HI	Maximum concentration (µg/m^3)	HI	Maximum concentration (µg/m^3)	HI
Benzene	17.3	0.030	21.3	0.037	16.5	0.028
Toluene	31.8	0.0021	39.3	0.0026	30	0.0020
Xylenes	26.2	0.0035	32.4	0.0044	25	0.0034
1,3-Butadiene	4.6	0.0070	5.7	0.0086	4.4	0.0067
Formaldehyde	12.1	0.24	15.0	0.30	11.6	0.23
Acetaldehyde	7.8	0.017	9.6	0.020	7.0	0.015
Total HI		**0.3**	**0.4**		**0.3**	

Table 6-7 Assessment of acute exposures to VOCs – maximum impacts in community associated with project: 2033

Key VOC	Maximum predicted 1 hour average concentration associated with project (background plus project) and calculated HI					
	2033: Without project		2033: With project		2033: Cumulative	
	Maximum concentration (µg/m^3)	HI	Maximum concentration (µg/m^3)	HI	Maximum concentration (µg/m^3)	HI
Benzene	9.7	0.017	9.4	0.016	8.3	0.014
Toluene	17.2	0.0011	16.7	0.0011	14.7	0.0010
Xylenes	14.2	0.0019	13.7	0.0019	12.1	0.0016
1,3-Butadiene	2.6	0.0039	2.6	0.0039	2.3	0.0035
Formaldehyde	11.4	0.23	11.0	0.22	9.7	0.19
Acetaldehyde	5.1	0.011	4.9	0.010	4.1	0.0087
Total HI		**0.3**	**0.3**		**0.2**	

Table 6-8 Assessment of chronic exposures to VOCs and PAHs – maximum impacts in community associated with project: 2023

Key VOCs and PAHs	Maximum predicted annual average concentration associated with project (background plus project) and calculated HI – Residential exposures					
	2023: Without project		2023: With project		2023: Cumulative	
	Max concentration (µg/m^3)	HI	Max concentration (µg/m^3)	HI	Max concentration (µg/m^3)	HI
Benzene	2.2	0.075	2.1	0.071	2.2	0.073
Toluene	9.3	0.0019	9.0	0.0018	9.1	0.0018
Xylenes	6.2	0.028	6.0	0.027	6.1	0.028
Formaldehyde	0.53	0.16	0.43	0.13	0.47	0.14
Acetaldehyde	0.24	0.026	0.28	0.031	0.29	0.033
Naphthalene	0.085	0.028	0.069	0.023	0.076	0.025
Acenaphthylene	0.0059	3.0×10^{-5}	0.0048	2.4×10^{-5}	0.0053	2.7×10^{-5}
Acenaphthene	0.0024	1.2×10^{-5}	0.002	9.9×10^{-6}	0.0022	1.1×10^{-5}
Fluorene	0.0060	4.3×10^{-5}	0.0049	3.5×10^{-5}	0.0054	3.9×10^{-5}
Phenanthrene	0.0041	2.9×10^{-5}	0.0034	2.4×10^{-5}	0.0037	2.6×10^{-5}
Anthracene	0.00059	5.9×10^{-7}	0.00048	4.8×10^{-7}	0.00053	5.3×10^{-7}
Fluoranthene	0.00054	3.9×10^{-6}	0.00045	3.2×10^{-6}	0.00049	3.5×10^{-6}
Pyrene	0.00086	8.6×10^{-6}	0.00070	7.0×10^{-6}	0.00077	7.7×10^{-6}
Total HI – Residential		**0.2**		**0.2**		**0.2**
Max HI – Commercial/Industrial		**0.06**		**0.06**		**0.06**

Table 6-9 Assessment of chronic exposures to VOCs and PAHs – maximum impacts in community associated with project: 2033

Key VOCs and PAHs	Maximum predicted annual average concentration associated with project (background plus project) and calculated HI – Residential exposures					
	2033: Do minimal		2033: With project		2033: Cumulative	
	Max concentration (µg/m^3)	HI	Max concentration (µg/m^3)	HI	Max concentration (µg/m^3)	HI
Benzene	1.9	0.063	1.8	0.062	1.8	0.061
Toluene	8.6	0.0017	8.5	0.0017	8.5	0.0017
Xylenes	5.7	0.026	5.6	0.026	5.6	0.025
Formaldehyde	0.46	0.14	0.41	0.12	0.41	0.12
Acetaldehyde	0.14	0.016	0.19	0.021	0.17	0.019
Naphthalene	0.085	0.028	0.069	0.023	0.076	0.025
Acenaphthylene	0.0059	3.0×10^{-5}	0.0048	2.4×10^{-5}	0.0053	2.7×10^{-5}
Acenaphthene	0.0024	1.2×10^{-5}	0.002	9.9×10^{-6}	0.0022	1.1×10^{-5}
Fluorene	0.0060	4.3×10^{-5}	0.0049	3.5×10^{-5}	0.0054	3.9×10^{-5}
Phenanthrene	0.0041	2.9×10^{-5}	0.0034	2.4×10^{-5}	0.0037	2.6×10^{-5}
Anthracene	0.00059	5.9×10^{-7}	0.00048	4.8×10^{-7}	0.00053	5.3×10^{-7}
Fluoranthene	0.00054	3.9×10^{-6}	0.00045	3.2×10^{-6}	0.00049	3.5×10^{-6}
Pyrene	0.00086	8.6×10^{-6}	0.00070	7.0×10^{-6}	0.00077	7.7×10^{-6}
Total HI – Residential		**0.2**		**0.2**		**0.2**
Max HI – Commercial/Industrial		**0.05**		**0.05**		**0.05**

Table 6-10 Assessment of incremental lifetime carcinogenic risk – maximum impacts in community associated with project: 2023

Key VOC	Maximum predicted change in annual average concentration associated with project and cancer risk – Residential			
	2023: With project		2023: Cumulative	
	Maximum concentration (µg/m^3)	ILCR	Maximum concentration (µg/m^3)	ILCR
Benzene	0.061	2×10^{-7}	0.095	2×10^{-7}
1,3-Butadiene	0.016	3×10^{-9}	0.025	5×10^{-9}
Benzo(a)pyrene TEQ	0.00045	2×10^{-5}	0.00070	2×10^{-5}
Total carcinogenic risk – Residential		**2×10^{-5}**		**2×10^{-5}**
Maximum carcinogenic risk – Commercial/Industrial		**6×10^{-6}**		**2×10^{-5}**

Note: ILCR = incremental lifetime carcinogenic risk (refer to **Annexure B** for calculation methodology and **Table 6-5** for inhalation unit risk values)

Table 6-11 Assessment of incremental lifetime carcinogenic risk – maximum impacts in community associated with project: 2033

Key VOC	Maximum predicted change in annual average concentration associated with project and cancer risk – Residential			
	2023: With project		2023: Cumulative	
	Maximum concentration (µg/m^3)	ILCR	Maximum concentration (µg/m^3)	ILCR
Benzene	0.04	1×10^{-7}	0.054	1×10^{-7}
1,3-Butadiene	0.011	2×10^{-9}	0.014	3×10^{-9}
Benzo(a)pyrene TEQ	0.00034	1×10^{-5}	0.00046	2×10^{-5}
Total carcinogenic risk – Residential		**1×10^{-5}**		**2×10^{-5}**
Maximum carcinogenic risk – Commercial/Industrial		**5×10^{-6}**		**1×10^{-5}**

Note: ILCR = incremental lifetime carcinogenic risk (refer to **Annexure B** for calculation methodology and **Table 6-5** for inhalation unit risk values)

For the assessment of acute exposures to VOCs (**Table 6-6** and **Table 6-7**), the calculated HI associated with exposure to the maximum concentrations predicted is less than one for 2023, 2033 and the cumulative scenario. On this basis, there are no acute risk issues in the local community associated with the project.

For the assessment of chronic exposures to VOCs and PAHs (**Table 6-8** to **Table 6-11**), the calculated HI associated with exposure to the maximum concentrations predicted is less than or equal to one for 2023, 2033 and the cumulative scenario. The calculated lifetime cancer risks associated with the maximum change in benzene, 1,3-butadiene and carcinogenic PAHs (as benzo(a)pyrene TEQ) are less than or equal to 2×10^{-5} and are considered to be tolerable. It is noted that the calculations undertaken for PAHs is based on a conservative estimate of the fraction of emissions from vehicles that comprises PAHs (as a percentage of total VOCs). The approach adopted is expected to overestimate concentrations of PAHs in air. Hence the calculations presented are considered to be a conservative upper limit estimate.

On this basis, there are no chronic risk issues in the local community associated with the project.

6.7 Assessment of carbon monoxide

Motor vehicles are the dominant source of carbon monoxide in air (DECCW 2009). Adverse health effects of exposure to carbon monoxide are linked with carboxyhaemoglobin (COHb) in blood. In addition, association between exposure to carbon monoxide and cardiovascular hospital admissions and mortality, especially in the elderly for cardiac failure, myocardial infarction and ischemic heart disease, and some birth outcomes (such as low birth weights) have been identified (NEPC 2010).

Guidelines are available in Australia from NEPC (NEPC 2003) and NSW EPA that are based on the protection of adverse health effects associated with carbon monoxide. Review of these guidelines by NEPC (2010) identified additional supporting studies[2] for the evaluation of potential adverse health effects and indicated that these should be considered in the current review of the National Ambient Air Quality NEPM (no interim or finalisation date available). The air guidelines currently available from NEPC are consistent with health based guidelines currently available from the WHO (2005) and the USEPA (2011)[3], specifically listed to be protective of exposures by sensitive populations including asthmatics, children and the elderly). On this basis, the current NEPC guidelines are considered appropriate for the assessment of potential health impacts associated with the project.

The NEPC ambient air quality guideline for the assessment of exposures to carbon monoxide has considered lowest observed adverse effect level (LOAEL) and no observed adverse effect level (NOAEL) associated with a range of health effects in healthy adults, people with ischemic heart disease and foetal effects. In relation to these data, a guideline level of carbon monoxide of nine parts per million (ppm) by volume (or ten milligrams per cubic metre or 10,000 micrograms per cubic metre) over an eight-hour period was considered to provide protection (for both acute and chronic health effects) for most members of the population. An additional 1.5-fold uncertainty factor to protect more susceptible groups in the population was included. On this basis, the NEPC (and the USEPA) guideline is protective of adverse health effects in all individuals, including sensitive individuals.

The NSW EPA has also established a guideline for 15-minute average (100 milligrams per cubic metre) and one-hour average (30 milligrams per cubic metre) concentrations of carbon monoxide in ambient air. These guidelines are based on criteria established by the WHO (WHO 2000c) using the same data used by the NEPC to establish the guideline (above) with extrapolation to different periods of exposure on the basis of known physiological variables that affect carbon monoxide uptake.

Table 6-12 presents a summary of the maximum predicted cumulative one-hour average and eight-hour average concentrations of carbon monoxide for the assessment years 2023 and 2033, without the project, with the project and for the cumulative scenario.

Table 6-12 Review of potential acute and chronic health impacts – carbon monoxide (CO)

Scenario	Maximum 1-hour average concentration of CO (mg/m^3)			Maximum 8 hour average concentration of CO (mg/m^3)		
	Without project	With project	Cumulative	Without project	With project	Cumulative
2023						
Maximum	7.8	7.7	7.4	5.4	5.3	5.2
2033						
Maximum	6.4	6.9	6.0	4.4	4.8	4.2
Relevant health based guideline	30			10		

2 Many of the more current studies are epidemiology studies that relate to a mix of urban air pollutants (including particulate matter) where it is more complex to determine the effects that can be attributed to carbon monoxide exposure only.

3 Most recent review of the Primary National Ambient Air Quality Standards for Carbon Monoxide published by the USEPA in the Federal Register Volume 76, No. 169, 2011, available from: http://www.gpo.gov/fdsys/pkg/FR-2011-08-31/html/2011-21359.htm.

All the concentrations of carbon monoxide presented in the above table are below the relevant health based guidelines. On the basis of the assessment undertaken there are no adverse health effects expected in relation to exposures (acute and chronic) to carbon monoxide in the local area surrounding the project footprint.

6.8 Assessment of nitrogen dioxide

6.8.1 Approach

Nitrogen oxides (NOx) refers to nitrogen oxide and nitrogen dioxide, which are highly reactive gases containing nitrogen and oxygen. Nitrogen oxide gases form when fuel is burnt. Motor vehicles, along with industrial, commercial and residential (eg gas heating or cooking) combustion sources, are primary producers of nitrogen oxides.

In Sydney, OEH (2012) estimated that on-road vehicles account for about 62 per cent of emissions of nitrogen oxides, industrial facilities account for 12 per cent, other mobile sources account for about 22 per cent, with the remainder from domestic/commercial sources.

In terms of health effects, nitrogen dioxide is the only oxide of nitrogen that may be of concern (WHO 2000b). Nitrogen dioxide can cause inflammation of the respiratory system and increase susceptibility to respiratory infection. Exposure to elevated levels of nitrogen dioxide has also been associated with increased mortality, particularly related to respiratory disease, and with increased hospital admissions for asthma and heart disease patients (WHO 2013b). Asthmatics, the elderly and people with existing cardiovascular and respiratory disease are particularly susceptible to the effects of nitrogen dioxide (Morgan, Broom & Jalaludin 2013; NEPC 2010). The health effects associated with exposure to nitrogen dioxide depend on the duration of exposure as well as the concentration.

Guidelines are available from the NSW EPA and NEPC (NEPC 2003) which indicate acceptable concentrations of nitrogen dioxide. These guidelines are based on protection from adverse health effects following both short term (acute) and longer term (chronic) exposure for all members of the population including sensitive populations like asthmatics, children and the elderly. Recently these guidelines have been reviewed by NEPC (Golder 2013; NEPC 2010, 2014). The review identified additional supporting studies for the evaluation of potential adverse health effects. The reviews undertaken to date have not recommended any change to the existing health based guidelines.

When reviewing the available literature on the health effects associated with exposure to nitrogen dioxide it is important to consider the following:

- Whether the evidence suggests that associations between exposure to nitrogen dioxide concentrations and effects on health are causal. The most current review undertaken by the USEPA (USEPA 2015) specifically evaluated evidence of causation. The review identified that a causal relationship existed for respiratory effects (for short term exposure with long term exposures also likely to be causal). All other associations related to exposure to nitrogen dioxide (specifically cardiovascular effects, mortality and cancer) were considered to be suggestive
- Whether the reported associations are distinct from, and additional to, those reported and assessed for exposure to particulate matter. Co-exposures to nitrogen dioxide and particulate matter complicates review and assessment of many of the epidemiology studies as both these air pollutants occur together in urban areas. There is sufficient evidence (epidemiological and mechanistic) to suggest that some of the health effect associations identified relate to exposure to nitrogen dioxide after adjustment/correction for co-exposures with particulate matter (COMEAP 2015)
- Whether the assessment of potential health effects associated with exposure to different levels of nitrogen dioxide can be undertaken on the basis of existing guidelines, or whether specific risk calculations are required to be undertaken. The current guidelines in Australia for the assessment of nitrogen dioxide in air relate to cumulative (total) exposures, and adopt criteria that are considered to be protective of short and long term exposures. Hence, it is relevant that these guidelines be considered in this assessment
- In addition, it is noted that in areas of high traffic congestion (as is the case with the project area evaluated in this assessment) background levels of nitrogen dioxide may already be elevated such that use of the existing guideline is limited for the purpose of assessing health impacts from

a particular project or activity. For these situations, it is relevant to also evaluate the impact on community health of the change in nitrogen dioxide concentration in the local community using appropriate risk calculations. For the conduct of risk assessments in relation to exposure to nitrogen dioxide, the WHO (WHO 2013b) identified that the strongest evidence of health effects related to respiratory hospitalisations and to a lesser extent mortality (associated with short term exposures) and recommend that these health endpoints should be considered in any core assessment of health impacts associated with exposure.

On the basis of the above, potential health effects associated with exposure to nitrogen dioxide would be undertaken for this project using both comparison with guidelines (assessing total exposures) and an assessment of incremental impacts on health (associated with changes in air quality from the project).

6.8.2 Assessment of total exposures

Assessment of acute exposures

The NEPC ambient air quality guideline for the assessment of acute (short term) exposures to nitrogen dioxide relates to the maximum predicted total (cumulative) one-hour average concentration in air. The guideline of 246 micrograms per cubic metre (or 120 parts per billion by volume) is based on a LOAEL of 409–613 micrograms per cubic metre derived from statistical reviews of epidemiological data suggesting an increased incidence of lower respiratory tract symptoms in children and aggravation of asthma. An uncertainty factor of two to protect susceptible people (ie asthmatic children) was applied to the LOAEL (NEPC 1998). On this basis, the NEPC (and Environment Protection Authority) acute guideline is protective of adverse health effects in all individuals, including sensitive individuals.

Table 6-13 presents a summary of the maximum predicted cumulative one-hour average concentration of nitrogen dioxide the modelled scenarios.

Table 6-13 Review of potential acute health impacts – nitrogen dioxide (NO_2)

Location and scenario	Maximum 1-hour average concentration of NO_2 (µg/m^3)		
	Without the project	With the project	Cumulative
2023			
Maximum	487	516	435
2033			
Maximum	387	430	415
Acute health based guideline	**246**	**246**	**246**

The maximum cumulative concentrations of nitrogen dioxide presented in the above table exceed the acute NEPC guideline of 246 micrograms per cubic metre for all the scenarios, with and without the project. The elevated levels listed above are not considered to be representative of exposure concentrations that would occur within the study area. This is due to the combined effect of the approach adopted for converting NOx to nitrogen dioxide (that overestimates short-term one-hour average concentrations), and the use of a contemporaneous assessment of background and project impacts. The contemporaneous approach assumes that the highest background concentrations may occur during the same hour as the maximum incremental change from the project. This results in a very high estimate of total nitrogen dioxide concentrations that is not likely to ever occur (refer to **Appendix I** (Technical working paper: Air quality) of the EIS for more detailed discussion). As a result, the magnitude of the maximum total concentrations reported for nitrogen dioxide over a one-hour average cannot be used to evaluate the potential for adverse health effects in the community.

As assessment of total concentrations to nitrogen dioxide cannot be used to determine the potential for adverse health impacts in the community, and because there is no clear threshold established for community exposures to nitrogen dioxide, the assessment of incremental exposures is of most relevance. This assessment is presented in **section 6.8.3**.

Assessment of chronic exposures

The NEPC ambient air quality guideline for the assessment of chronic (long term) exposures to nitrogen dioxide relates to the maximum predicted total (cumulative) annual average concentration in air. The guideline of 62 micrograms per cubic metre (or 30 ppbv [parts per billion by volume]) is based on a LOAEL of the order of 40–80 parts per billion by volume (around 75–150 micrograms per cubic metre) during early and middle childhood years which can lead to the development of recurrent upper and lower respiratory tract symptoms, such as recurrent 'colds', a productive cough and an increased incidence of respiratory infection with resultant absenteeism from school. An uncertainty factor of two was applied to the LOAEL to account for susceptible people within the population resulting in a guideline of 20-40 parts per billion by volume (38–75 micrograms per cubic metre) (NEPC 1998). On this basis, the NEPC (and OEH) chronic guideline is protective of adverse health effects in all individuals, including sensitive individuals.

Table 6-14 presents a summary of the maximum predicted cumulative annual average concentration of nitrogen dioxide for the modelled scenarios.

Table 6-14 Review of potential chronic health impacts – Nitrogen dioxide (NO_2)

Location and scenario	Maximum annual average concentration of NO_2 (µg/m^3)		
	Without the project	With the project	Cumulative
2023			
Maximum	44.3	43.7	42.9
2033			
Maximum	40.3	37.3	39.1
Chronic health based guideline	**62**		

All the concentrations of nitrogen dioxide presented in the above table are below the chronic NEPC guideline of 62 micrograms per cubic metre. In addition, the concentrations of nitrogen dioxide are lower with the project (in both assessment years) and for the cumulative scenario. Hence there are no adverse health effects expected in relation to chronic exposures to nitrogen dioxide in the local area surrounding the project.

6.8.3 Assessment of incremental exposures

The evidence base supports quantification of effects of short term exposure to nitrogen dioxide, using the averaging time as in the relevant studies. The strongest evidence is for respiratory effects, in particular exacerbation of asthma, with some support also for all-cause mortality. These health endpoints have been evaluated in relation to changes in nitrogen dioxide concentrations in air associated with the project within the local community in 2023 and 2033.

The approach adopted for the assessment of incremental exposures is consistent with that adopted for particulates as outlined in **section 6.9.5**. This involves the calculation of a change in individual risk, as well as the change in incidence, or the number of cases, that occur in the community as a result of the project.

Table 6-15 presents a summary of the health endpoints considered in this assessment, the β coefficient relevant to the calculation of a relative risk (refer to **Annexure A** for details on the calculation of a β coefficient from published studies). The coefficients adopted for the assessment of impacts on mortality and asthma emergency department admissions are derived from the detailed assessment undertaken for the current review of health impacts of air pollution undertaken by NEPC (Golder 2013) and are considered to be robust.

Table 6-15 Adopted exposure-responses relationships for assessment of changes in nitrogen dioxide concentrations

Health endpoint	Exposure period	Age group	Adopted β coefficient (also as per cent) for 1 μg/m^3 increase in NO_2	Reference
Mortality, all causes (non-trauma)	Short term	30+	0.00188 (0.19%)	Relationship derived for from modelling undertaken for 5 cities in Australia and 1 day lag (EPHC 2010; Golder 2013)
Mortality, respiratory	Short term	All ages*	0.00426 (0.43%)	Relationship derived for from modelling undertaken for 5 cities in Australia and 1 day lag (EPHC 2010; Golder 2013)
Asthma emergency department (ED) admissions	Short term	1–14 years	0.00115 (0.11%)	Relationship established from review conducted on Australian children (Sydney) for the period 1997 to 2001 (Golder 2013; Jalaludin et al. 2008)

Note: * Relationships established for all ages, including young children and the elderly

It is noted that while the maximum concentrations of nitrogen dioxide are lower in the local community with the operation of the project, the concentrations at individual receptors vary. While the concentrations at most receptors decrease with the operation of the project, there are some receptors where there is an increase, associated with the redistribution of emissions from vehicles using surface roads.

Table 6-16 presents the change in individual risk associated with changes in nitrogen dioxide at the maximum impacted receptors relevant to the various land use in the community, as well as the community receptors, for the operational years 2023 and 2033, including the cumulative scenario (refer to **Annexure A** for methodology for the calculation of individual risks). The assessment assumes an individual is exposed at each maximum impacted location over all hours of the day, regardless of the land use. This has been undertaken to address any future changes in land use that may occur. Risks for all other receptors (including other sensitive receptors) are lower than the maximums presented.

All risks are presented to one significant figure, reflecting the level of uncertainty associated with the calculations presented. **Figure 6-4** presents a summary of the calculated change in individual risk associated with changes in nitrogen dioxide concentrations at each community receptor location evaluated. **Annexure C** presents a discussion on levels of the levels of risk that are considered to be negligible, tolerable/acceptable and unacceptable. A summary of these risk levels is included in **Table 6-16**. Calculations relevant to the characterisation of risks associated with changes in nitrogen dioxide concentrations in the community are presented in **Annexure D**.

Table 6-17 presents a summary of the calculated change in incidence of the relevant health effects for the population living in the LGAs within the study area, associated with changes in nitrogen dioxide concentrations for 2023 and 2033. All calculations relevant to the LGAs, including calculation for each individual suburb considered in the LGAs, are presented in **Annexure E.**

Table 6-16 Maximum calculated risks associated with short term exposure to changes in nitrogen dioxide concentrations with operation of the project

Scenario and receptor	Maximum change in individual risk from short term exposure to nitrogen dioxide for the following health endpoints		
	Mortality: All causes (ages 30+)	**Mortality: Respiratory (all ages)**	**Asthma ED Admissions (1–14 years)**
2023 – with project			
Maximum residential	5×10^{-5}	6×10^{-6}	4×10^{-5}
Maximum workplace	1×10^{-4}	1×10^{-5}	8×10^{-5}
Maximum childcare and schools	3×10^{-5}	4×10^{-6}	2×10^{-5}
Maximum aged care	4×10^{-6}	5×10^{-7}	3×10^{-6}
Maximum hospitals/medical	3×10^{-5}	3×10^{-6}	2×10^{-5}
Maximum open space	5×10^{-5}	6×10^{-6}	4×10^{-5}
Maximum from sensitive receptors	3×10^{-5}	3×10^{-6}	2×10^{-5}
2023 – cumulative			
Maximum residential	5×10^{-5}	6×10^{-6}	4×10^{-5}
Maximum workplace	2×10^{-4}	2×10^{-5}	1×10^{-4}
Maximum childcare and schools	1×10^{-5}	2×10^{-6}	1×10^{-5}
Maximum aged care	2×10^{-6}	2×10^{-7}	2×10^{-6}
Maximum hospitals/medical	8×10^{-6}	1×10^{-6}	6×10^{-6}
Maximum open space	2×10^{-5}	2×10^{-6}	1×10^{-5}
Maximum from sensitive receptors	1×10^{-5}	1×10^{-6}	9×10^{-6}
2033 – with project			
Maximum residential	6×10^{-5}	7×10^{-6}	5×10^{-5}
Maximum workplace	1×10^{-4}	1×10^{-5}	9×10^{-5}
Maximum childcare and schools	4×10^{-5}	5×10^{-6}	3×10^{-5}
Maximum aged care	7×10^{-6}	8×10^{-7}	5×10^{-6}
Maximum hospitals/medical	4×10^{-5}	4×10^{-6}	3×10^{-5}
Maximum open space	6×10^{-5}	6×10^{-6}	4×10^{-5}
Maximum from sensitive receptors	4×10^{-5}	3×10^{-6}	2×10^{-5}
2033 – cumulative			
Maximum residential	4×10^{-5}	5×10^{-6}	3×10^{-5}
Maximum workplace	2×10^{-4}	2×10^{-5}	1×10^{-4}
Maximum childcare	2×10^{-5}	2×10^{-6}	1×10^{-5}
Maximum aged care	7×10^{-6}	8×10^{-7}	5×10^{-6}
Maximum hospitals/medical	1×10^{-5}	1×10^{-6}	1×10^{-5}
Maximum open space	3×10^{-5}	3×10^{-6}	2×10^{-5}
Maximum from sensitive receptors	7×10^{-6}	8×10^{-7}	5×10^{-6}
Negligible risks	$< 1 \times 10^{-6}$		
Tolerable/acceptable risks	$\geq 1 \times 10^{-6}$ and $\leq 1 \times 10^{-4}$		
Unacceptable risks	$> 1 \times 10^{-4}$		

Note: Shaded cell (purple) exceeds the criteria adopted for acceptable risks, refer to the discussion below

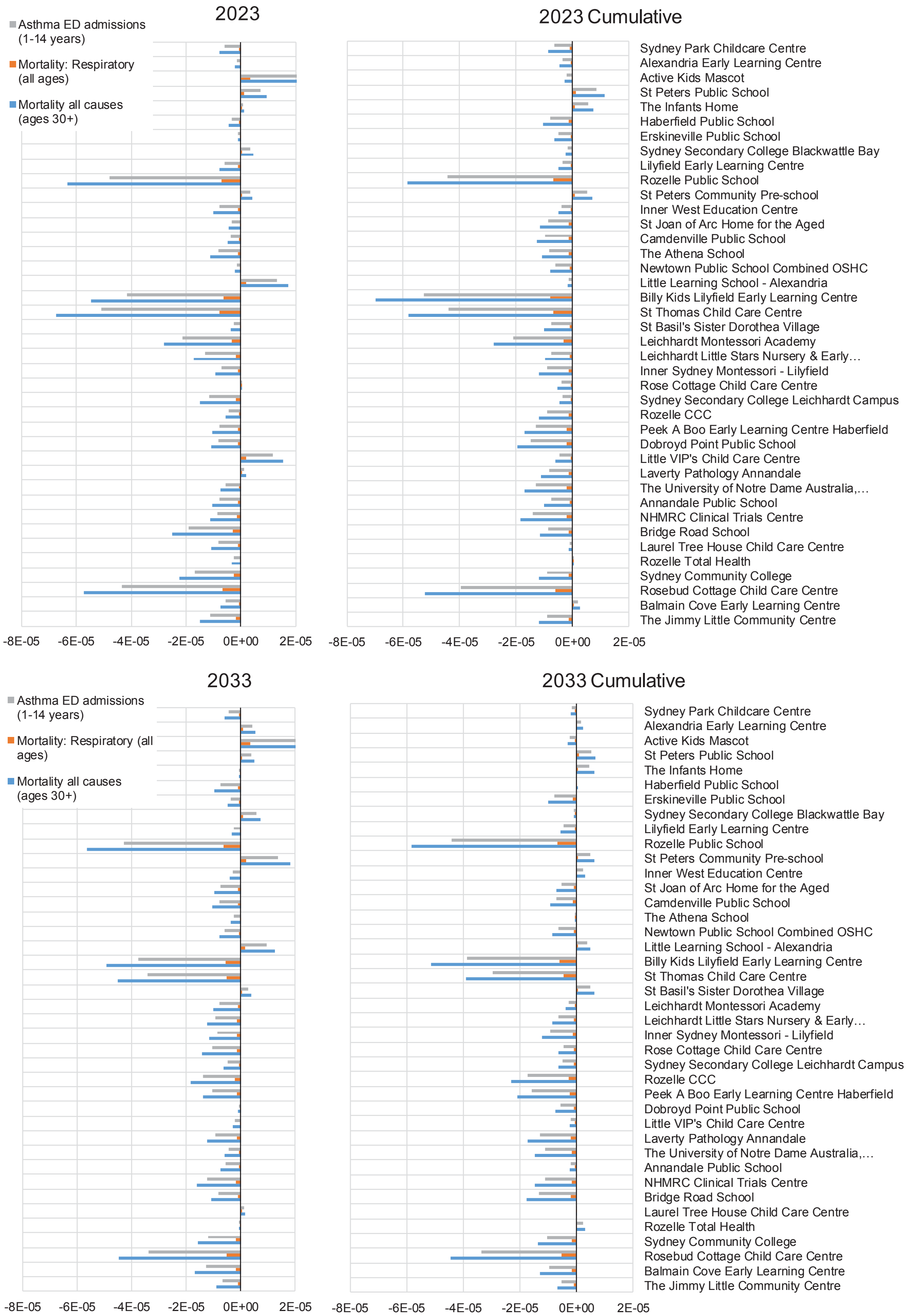


Figure 6-4 Change in calculated risk for key health endpoints associated with changes in nitrogen dioxide concentrations at community receptors (2023 and 2033).

Table 6-17 Calculated changes in incidence of health effects in population associated with changes in NO_2 concentrations

LGA/Local statistical area	Change in population incidence – number of cases					
	2023			2033		
	Mortality – All Causes	Mortality – Respiratory	Morbidity – Asthma ED Admissions	Mortality – All Causes	Mortality – Respiratory	Morbidity – Asthma ED Admissions
	≥ 30 years	All ages	1-14 years	≥ 30 years	All ages	1–14 years
With Project						
Canada Bay	-0.024	-0.0044	-0.0045	-0.041	-0.0074	-0.0076
Strathfield*	0.0030	0.00058	0.00055	0.018	0.0034	0.0032
Burwood	-0.016	-0.0031	-0.0029	-0.019	-0.0036	-0.0034
Sydney Inner West	-1.2	-0.20	-0.19	-1.1	-0.19	-0.18
Sydney	-0.35	-0.067	-0.027	-0.15	-0.028	-0.012
Botany	0.15	0.027	0.030	0.21	0.038	0.043
Rockdale	-0.18	-0.034	-0.036	-0.21	-0.039	-0.041
Canterbury-Bankstown	-0.13	-0.026	-0.033	-0.13	-0.025	-0.032
Georges River	-0.098	-0.018	-0.020	-0.12	-0.022	-0.0236
Total for all LGAs	**-2**	**-0.3**	**-0.3**	**-2**	**-0.3**	**-0.3**
Cumulative						
Canada Bay	0.011	0.0020	0.0021	-0.020	-0.0035	-0.0036
Strathfield*	-0.032	-0.0062	-0.0058	-0.019	-0.0037	-0.0035
Burwood	-0.025	-0.0047	-0.0045	-0.023	-0.0045	-0.0042
City of Sydney	-1.2	-0.20	-0.20	-1.2	-0.20	-0.19
Sydney	-0.60	-0.12	-0.048	-0.70	-0.14	-0.056
Botany	-0.053	-0.0099	-0.011	-0.022	-0.0041	-0.0046
Rockdale	-0.26	-0.048	-0.051	-0.36	-0.067	-0.071
Canterbury-Bankstown	-0.19	-0.038	-0.048	-0.20	-0.039	-0.050
Georges River	-0.14	-0.026	-0.029	-0.15	-0.028	-0.031
Total for all LGAs	**-2**	**-0.5**	**-0.4**	**-3**	**-0.5**	**-0.4**

Notes: * Includes suburbs in Auburn LGA

Negative value indicates that there is a decrease in incidence associated with the project

Review of the individual risks calculated for changes in nitrogen dioxide levels associated with the M4-M5 Link, indicates the following:

- The maximum risks calculated for exposures in residential areas are less than $1x10^{-4}$ and are therefore considered to be tolerable/acceptable
- The maximum risks calculated for exposures in commercial/industrial areas are between $8x10^{-7}$ and $2x10^{-4}$. The maximum risk level of $2x10^{-4}$ exceeds the adopted criteria for determining unacceptable risks. Impacts that result in exceedance of the adopted risk criteria occur only in the existing industrial location north and northwest of Sydney Airport, between Airport Drive/Alexandria Canal and the Princes Highway. It is noted that the calculation presented relates to exposures that occur at this maximum location for all hours of the day, all of the time. As this area is a workplace, not somewhere people live, the calculated risk is expected to overestimate risks by a factor of about 4.5[4], hence actual risks in theses industrial areas are expected to be lower and tolerable. Given the proximity of these areas to Sydney Airport (runways and flight paths) it is considered unlikely that they would be rezoned for residential use, hence it is not relevant to evaluate potential future residential exposures at this location. In addition, it is noted that the calculated risks relate to predicted increases in nitrogen dioxide, principally related to the proposed future Sydney Gateway project. Emissions to air related to the proposed future Sydney Gateway project have been estimated on the basis of provisional information in relation to roadway layout only. The maximum impacts predicted are on roadways/locations that may be within the future roadway alignments. The proposed future Sydney Gateway project would be subject to separate environmental assessment and approval, where more detailed assessment of impacts in this area is expected to be undertaken
- It is noted that the worst-case scenario for potential exposure is where a resident works at the maximum impacted workplace and lives at the maximum impacted residential location. Where this may occur, the maximum risk is less than $1x10^{-4}$, which is in any event considered tolerable/acceptable
- All maximum risks calculated for continuous exposures in childcare centres, schools, aged care homes and open space areas are below $1x10^{-4}$ and considered to be tolerable/acceptable
- All risks calculated for exposures at community receptors are below $1x10^{-4}$ and considered to be tolerable/acceptable. It is noted that for most community receptors the impact of the project is a lowering of risk (negative risk values presented in **Figure 6-4**).

Review of the calculated impacts in terms of the change in incidence of the relevant health effects associated with exposure to nitrogen dioxide in the community, indicates the following:

- The total change in the number of cases relevant to the health effects evaluated, for both 2023 and 2033 is negative, meaning a decrease in incidence as a result of the project. The number of cases, however is small, with a decrease of up to three cases. These changes would be unlikely to be measurable within the community
- Most individual LGAs show a total decrease in health incidence. There are a few LGAs (Canada Bay, Strathfield and Botany) where there is an increase. These increases and decreases are also small, less than two (as a decrease) in individual LGAs for all health effects considered. As a result, these changes would be unlikely to be measurable in the community
- The incidence calculations presented in **Table 6-17** are the totals for each LGA. Within these LGAs are a number of smaller suburbs. The calculated change in incidence relevant to each of these suburbs has also been evaluated, as presented in **Annexure E**. Review of the incidence calculated for the individual suburbs indicates that these predominantly relate to small decreases in health incidence with some suburbs showing and increase. The largest increase in health incidence for any individual suburb is less than 0.25 case/person. Hence there are no individual

[4] Conversion of 365 days per year to 240 days per year and 24 hours per day to 8 hours per day exposure (ie 365/240 x 24/8 = 4.5)

suburbs within the LGAs where there is a change incidence that is of significance or would be measurable.

6.9 Assessment of particulate matter

6.9.1 Particle size

Particulate matter is a widespread air pollutant with a mixture of physical and chemical characteristics that vary by location (and source). Unlike many other pollutants, particulate matter includes a broad class of diverse materials and substances, with varying morphological, chemical, physical and thermodynamic properties, with sizes that vary from less than 0.005 micrometres (or microns) to greater than 100 microns. Particles can be derived from natural sources such as crustal dust (soil), pollen and moulds, and other sources that include combustion and industrial processes. Secondary particulate matter is formed via atmospheric reactions of primary gaseous emissions. The gases that are the most significant contributors to secondary particulates include nitrogen oxides, ammonia, sulfur oxides, and certain organic gases (derived from vehicle exhaust, combustion sources, agricultural, industrial and biogenic emissions).

Numerous epidemiological studies[5] have reported significant positive associations between particulate air pollution and adverse health outcomes, in particular mortality as well as a range of adverse cardiovascular and respiratory effects.

The potential for particulate matter to result in adverse health effects is dependent on the size and composition of the particulate matter. The common measures of particulate matter that are considered in the assessment of air quality and health risks are:

- Total suspended particulates (TSP): This refers to all particulate matter with an equivalent aerodynamic particle[6] size generally below 50 to 100 microns in diameter[7]. It is a fairly gross indicator of the presence of dust with a wide range of sizes. Larger particles (termed 'inspirable', comprise particles around 10 microns and larger) are of less concern and more of a nuisance as they would deposit out of the air (measured as deposited dust) close to the source and, if inhaled, are mostly trapped in the upper respiratory system[8] and do not reach the lungs. Smaller particles (smaller than 10 microns, termed 'respirable') tend to be transported further from the source and are of greater concern with respect to human health as these particles can penetrate into the lungs (see following point). Hence not all of the dust characterised as total suspended particulates is relevant for the assessment of health impacts, and total suspended particulates as a measure of impact, has not been further evaluated in this assessment. The assessment has only focused on particulates of a size where significant associations have been identified between exposure and adverse health effects
- PM_{10} (particulate matter below 10 microns in diameter), $PM_{2.5}$ (particulate matter below 2.5 microns in diameter), PM_1 (particulate matter below one micron in diameter, often termed very fine particles) and ultrafines (particulate matter below 0.1 microns in diameter): These particles are small and have the potential to penetrate beyond the body's natural clearance mechanisms of cilia and mucous in the nose and upper respiratory system, with smaller particles able to further

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5 Epidemiology is the study of diseases in populations. Epidemiological evidence can only show that this risk factor is associated (correlated) with a higher incidence of disease in the population exposed to that risk factor. The higher the correlation the more certain the association. Causation (ie that a specific risk factor actually causes a disease) cannot be proven with only epidemiological studies. For causation to be determined a range of other studies need to be considered in conjunction with the epidemiology studies.

6 The term equivalent aerodynamic particle is used to reference the particle to a particle of spherical shape and particle of density one gram per cubic metre.

7 The size, diameter, of dust particles is measured in micrometers (microns).

8 The upper respiratory tract comprises the mouth, nose, throat and trachea. Larger particles are mostly trapped by the cilia and mucosa and swept to the back of the throat and swallowed.

penetrate into the lower respiratory tract[9] and lungs. Once in the lungs adverse health effects may result (OEHHA 2002).

Evaluation of size alone as a single factor in determining the potential for particulate toxicity is difficult since the potential health effects are not independent of chemical composition. There are certain particulate size fractions that tend to contain certain chemical components, such as metals in fine particulates (less than $PM_{2.5}$) and crustal materials (like soil) in the coarse mode ($PM_{2.5}$ to PM_{10}). In addition, different sources of particulates have the potential to result in the presence of other pollutants in addition to particulate matter. For example, combustion sources, prevalent in urban areas, result in the emission of particulate matter (more dominated by $PM_{2.5}$) as well as gaseous pollutants (such as nitrogen dioxide and carbon monoxide). This results in what is referred to as co-exposure, and is an issue that has to be accounted for when evaluating studies that come from studying health effects in large populations exposed to pollution from many sources (as is the case in urban air).

Where co-exposure is accounted for, the available science supports that exposure to fine particulate matter (less than 2.5 microns, $PM_{2.5}$) is associated (and shown to be causal in some cases) with health impacts in the community (USEPA 2012). A more limited body of evidence suggests an association between exposure to larger particles, PM_{10} and adverse health effects (USEPA 2009b; WHO 2003).

It is noted that when assessing potential health impacts associated with changes in particulate matter concentrations the studies relied upon for establishing associations (between changes in concentrations in air and health effects) are large epidemiological studies. These studies relate changes in health indicators with changes in measured concentrations of particulate matter. As a result, the particle size fractions addressed in these studies relate to the fractions measured in the urban air environment studies. In relation to measuring particulate matter in urban air, the following should be noted:

- The measurement of particulate matter in urban air most commonly reports PM_{10}. This is the concentration of particulate matter less than or equal to 10 microns in diameter (and includes the smaller fractions of $PM_{2.5}$ and very fine particles). The measurement techniques for PM_{10} are well established and provide stable, robust, verifiable data that is considered to be consistently reported across all countries. In addition, there is a longer and more extensive history/database of PM_{10} data. This means this data on PM_{10} collected in different parts of a city, in different parts of a country and by different countries can be compared against each other. This is the key reason why many of the epidemiological studies have looked at associations between PM_{10} and various health effects
- The measurement of $PM_{2.5}$ is becoming more common in urban environments. This is the concentration of particulate matter less than or equal to 2.5 microns in diameter (and includes the smaller fractions of very fine particles and ultrafines). The measurement techniques used for $PM_{2.5}$ are less well established resulting in data that varies depending on the type of equipment used and how it is set up and maintained. Due to either a lack of monitoring data or the inconsistency of monitoring data some epidemiology studies have assessed associations between $PM_{2.5}$ and health effects by using PM_{10} data and assuming that a certain percentage of PM_{10} comprises $PM_{2.5}$. Some studies have directly used measurements of $PM_{2.5}$ in urban air. Even where these measurement issues are considered, the studies still clearly show strong relationships between changes in $PM_{2.5}$ concentrations and health effects
- The measurement of ultrafine particles is difficult (using equipment that is less robust/stable and provides variable data) and has not been undertaken in most urban air environments. As a result, there are no robust epidemiological studies that relate changes in ultrafine particle levels and health effects that can be used in a risk assessment. There is sufficient data available to confirm that motor vehicles are a key source of ultrafine particles. Available studies in animals and humans have identified a range of adverse health effects associated with exposure to ultrafine

9 The lower respiratory tract comprises the smaller bronchioles and alveoli, the area of the lungs where gaseous exchange takes place. The alveoli have a very large surface area and absorption of gases occurs rapidly with subsequent transport to the blood and the rest of the body. Small particles can reach these areas, be dissolved by fluids and absorbed.

particulates. However the studies do not show that short term exposure to ultrafine particulates have effects that are significantly different from those associated with exposure to $PM_{2.5}$ (HEI 2013).

When assessing health impacts from fine particulates, the robust associations of effects (that are based on large epidemiology studies primarily from the US and Europe) have been determined on the basis of $PM_{2.5}$, as $PM_{2.5}$ is what is commonly measured in urban air. No robust associations (that can be used in a quantitative assessment) are available for PM_1 and the current science is inconclusive in relation to ultrafine particulates. The associations developed for $PM_{2.5}$ would include a significant contribution from PM_1 (as PM_1 comprises a significant proportion of $PM_{2.5}$) and hence health effects observed for PM_1 would be captured in the studies that have been conducted on the basis of $PM_{2.5}$. It is important that the quantitative evaluation of potential health impacts adopts robust health effects associations and utilises particulate matter measures that are collected in the urban air environment. Hence the further assessment of exposure to fine particulate matter has focused on particulates reported/evaluated as $PM_{2.5}$.

6.9.2 Health effects

Adverse health effects associated with exposure to particulate matter have been well studied and reviewed by Australian and International agencies. Most of the studies and reviews have focused on population-based epidemiological studies in large urban areas in North America, Europe and Australia, where there have been clear associations determined between health effects and exposure to $PM_{2.5}$ and to a lesser extent, PM_{10}. These studies are complemented by findings from other key investigations conducted in relation to the characteristics of inhaled particles; deposition and clearance of particles in the respiratory tract; animal and cellular toxicity studies; and studies on inhalation toxicity by human volunteers (NEPC 2010).

Particulate matter has been linked to adverse health effects after both short term exposure (days to weeks) and long term exposure (months to years). The health effects associated with exposure to particulate matter vary widely (with the respiratory and cardiovascular systems most affected) and include mortality and morbidity effects.

In relation to mortality, for short term exposures in a population this relates to the increase in the number of deaths due to existing (underlying) respiratory or cardiovascular disease. For long term exposures in a population this relates to mortality rates over a lifetime, where long term exposure is considered to accelerate the progression of disease or even initiate disease.

In relation to morbidity effects, this refers to a wide range of health indicators used to define illness that have been associated with (or caused by) exposure to particulate matter. In relation to exposure to particulate matter, effects are primarily related to the respiratory and cardiovascular system and include (Morawska, Moore & Ristovski 2004; USEPA 2009b):

- Aggravation of existing respiratory and cardiovascular disease (as indicated by increased hospital admissions and emergency room visits)
- Changes in cardiovascular risk factors such as blood pressure
- Changes in lung function and increased respiratory symptoms (including asthma)
- Changes to lung tissues and structure
- Altered respiratory defence mechanisms.

These effects are commonly used as measures of population exposure to particulate matter in community epidemiological studies (from which most of the available data in relation to health effects is derived), and are more often grouped (through the use of hospital codes) into the general categories of cardiovascular morbidity/effects and respiratory morbidity/effects. The available studies provide evidence for increased susceptibility for various populations, particularly older populations, children and those with underlying health conditions (USEPA 2009b).

There is consensus in the available studies and detailed reviews that exposure to fine particulates, $PM_{2.5}$, is associated with (and causal to) cardiovascular and respiratory effects and mortality (all causes) (USEPA 2012). Similar relationships have also been determined for PM_{10}, however, the supporting studies do not show relationships as clear as those shown with $PM_{2.5}$ (USEPA 2012).

There are a number of studies that have been undertaken where other health effects have been evaluated. These studies are suggestive (but do not show effects as clearly as the effects noted above) of an association between exposure to $PM_{2.5}$ and reproductive and developmental effects as well as cancer, mutagenicity and genotoxicity (USEPA 2012). IARC (2013) has classified particulate matter as carcinogenic to humans based on data relevant to lung cancer.

Other studies have been reviewed to determine relationships/associations between particulate matter exposure (either PM_{10} or $PM_{2.5}$) and a wide range of other health effects and health measures including mortality (for different age groups), chronic bronchitis, medication use by adults and children with asthma, respiratory symptoms (including cough), restricted work days, work days lost, school absence and restricted activity days (Anderson et al. 2004; EC 2011; Ostro 2004; WHO 2006b). While these relationships/associations have been identified the exposure-response relationships established are not as strong as those discussed above. Also, the available baseline data does not include information for many of these health effects which means it is not possible to undertake a quantitative assessment.

6.9.3 Approach to the assessment of particulate exposures

In relation to the assessment of exposures to particulate matter there is sufficient evidence to demonstrate that there is an association between exposure to $PM_{2.5}$ (and to a lesser extent PM_{10}) and effects on health that are causal. In addition, the effects related to exposures to $PM_{2.5}$ (or PM_{10}) alone (ie without co-exposures).

The available evidence does not suggest that there is a threshold below which health effects do not occur. Hence there are likely to be health effects associated with background levels of $PM_{2.5}$ and PM_{10}, even where the concentrations are below the current guidelines. Guidelines are currently available for the assessment of $PM_{2.5}$ and PM_{10} in New South Wales (DEC 2005) and Australia (NEPC 2002, 2003). These guidelines are not based on any acceptable level of risk, rather they are based on levels that are desirable in the community to balance background/urban sources with lowering impacts on health and cost savings in the health system.

The air quality goals relate to average or regional exposures by populations from all sources, not to localised 'hot-spot' areas such as locations near industry, busy roads or mining. They are intended to be compared against ambient air monitoring data collected from appropriately sited regional monitoring stations. In some cases, there may be local sources (including busy roadways and industry) that result in background levels of PM_{10} and $PM_{2.5}$ that are close to, equal to, or in exceedance of the air quality goals. Where impacts are being evaluated from a local source it is important to not only consider total impacts associated with the project (undertaken using the current air quality goals) but also evaluate the impact of changes in air quality within the local community.

This assessment has therefore been undertaken to consider both cumulative exposure impacts (see **section 6.9.4**) and incremental exposure impacts associated with changes in $PM_{2.5}$ and PM_{10} concentrations that are associated with the project (see **section 6.9.5**).

6.9.4 Assessment of total exposures

The assessment of cumulative exposures to $PM_{2.5}$ and PM_{10} is based on a comparison of the total concentrations predicted in 2023 and 2033 (ie without the project, with the project and for the cumulative scenario, all of which include background exposures) with the relevant air quality guidelines/standards available from the NEPC and NSW EPA. The current NEPC and NSW EPA air quality goals and guidelines/standards for particulate matter are presented in **Table 6-18**. These guidelines/standards are for cumulative impacts and should also be considered in conjunction with incremental impact calculations presented in **section 6.9.5**.

Table 6-18 Air quality guidelines/standards for particulates

Pollutant	Averaging period	Criteria (µg/m^3)	Reference
PM_{10}	24 hour	50	(NEPC 2016; NSW EPA 2016)
	Annual	25	(NSW EPA 2016)
$PM_{2.5}$	24 hour	25 with goal of 20 by 2025	(NEPC 2016)
	Annual	8 with goal of 7 by 2025	

In relation to the current NEPC guidelines, the following is noted (NEPC 1998, 2010, 2014):

- The guideline was derived through a review of appropriate health studies by a technical review panel of the NEPC where short term exposure-response relationships for PM and mortality and morbidity health endpoints were considered
- Mortality health impacts were identified as the most significant and were the primary basis for the development of the guideline
- On the basis of the available data for key air sheds in Australia, the criteria listed in **Table 6-18** was based on analysis of the number of premature deaths that would be avoided and associated cost savings to the health system (using data from the US). The development of the goal is not based on any acceptable level of risk
- The assessment undertaken considered exposures and issues relevant to urban air environments that are expected to also be managed through the PM guideline. These issues included emissions from vehicles and wood heaters.

Table 6-19 presents a comparison of the NEPC guidelines with those established (following more recent reviews) by the WHO (WHO 2005), the EU and the USEPA (2012). The standards established by the NEPC for $PM_{2.5}$ (and adopted in this assessment) are similar to but slightly more conservative (health protective) than those provided by the WHO, EU and the USEPA. The NEPC and NSW OEH PM_{10} guidelines are also similar to those established by the WHO and EU, however the guidelines are significantly lower than the 24-hour average guideline available from the USEPA.

Table 6-19 Comparison of particulate matter air quality goals

Pollutant	Averaging period	Criteria/guidelines/goals			
		NEPC and NSW OEH	**WHO (2005)**	**EU #**	**USEPA (2012)**
PM_{10}	24 hour	50 µg/m^3	50 µg/m^3	50 µg/m^3 as limit value with 35 exceedances permitted each year	150 µg/m^3 (not to be exceeded more than once per year on average over 3 years)
	Annual	25 µg/m^3	20* µg/m^3	40 µg/m^3 as limit value	NA
$PM_{2.5}$	24 hour	25 µg/m^3 (with goal of 20 by 2025)	25 µg/m^3	NA	35 µg/m^3 (98th percentile, averaged over 3 years)
	Annual	8 µg/m^3 (with goal of 7 by 2025)	10* µg/m^3	25 µg/m^3 as target value from 2010 and limit value from 2015. 20 µg/m^3 as a 3 year average (average exposure indicator) from 2015 with requirements for ongoing percentage reduction and target of 18 µg/m^3 as 3 year average by 2020	12 µg/m^3 (annual mean averaged over 3 years)

Notes:

Current EU Air Quality Standards available from http://ec.europa.eu/environment/air/quality/standards.htm

* The WHO Air Quality guidelines are based on the lowest levels at which total, cardiopulmonary and lung cancer mortality have been shown to increase with more than 95 per cent confidence in response to $PM_{2.5}$ in the ACS study (Pope et al. 2002). The use of a $PM_{2.5}$ guideline is preferred by the WHO (WHO 2005).

The NEPM air quality standards for $PM_{2.5}$ and PM_{10} relate to total concentrations in the air (from all sources including the project). The background air quality data that has been used in **Appendix I** (Technical working paper: Air quality) of the EIS for this project is summarised in **section 6.2** and generally relates to urban air quality in areas located away from major roadways. The background data includes a contribution of PM that is derived from vehicles that utilise the existing road network (but not representative of locations adjacent to main roadways). Hence use of this background data would result in some double counting of the contribution of vehicle emissions to air quality in the local area, as the project has then modelled emissions from surface roads and added these to the background.

Table 6-20 and **Table 6-21** present a summary of the maximum total 24-hour average and annual average concentrations of $PM_{2.5}$ and PM_{10} relevant to the assessment of emissions in 2023 and 2033, for the project and for the cumulative case.

Table 6-20 Review of total PM concentrations – 24-hour average

Location and scenario	Maximum 24 hour average $PM_{2.5}$ concentration (µg/m^3)			Maximum 24 hour average PM_{10} concentration (µg/m^3)		
	Without project	With project	Cumulative	Without project	With project	Cumulative
2023						
Maximum	50.2	48.4	47.1	81.0	82.1	80.9
Maximum residential	40.7	40.9	41.7	70.8	70.9	70.7
Maximum commercial	50.2	44.8	46.4	81.0	80.1	80.7
2033						
Maximum	50.7	48.5	48.5	81.3	86.7	81.8
Maximum residential	40.6	39.1	39.3	70.9	70.9	74.4
Maximum commercial	45.9	43.6	48.5	80.1	77.0	81.8
Guideline	**25** **20 by 2025 (goal)**			**50**		

Table 6-21 Review of total PM concentrations – annual average

Location and scenario	Maximum annual average $PM_{2.5}$ concentration (µg/m^3)			Maximum annual average PM_{10} concentration (µg/m^3)		
	Without project	With project	Cumulative	Without project	With project	Cumulative
2023						
Maximum	13.2	14.1	13.6	25.1	26.5	25.9
Maximum residential	11.8	12.3	12.1	22.8	23.7	23.2
Maximum commercial	12.7	12.7	12.6	24.1	23.8	23.7
2033						
Maximum	13.2	14.2	13.5	25.3	26.1	25.8
Maximum residential	11.7	12.3	12.0	22.6	23.7	23.0
Maximum commercial	12.5	12.1	12.3	23.6	23.4	23.4
Guideline	**8** **7 by 2025 (goal)**			**25**		

The maximum total/cumulative concentrations of $PM_{2.5}$ are above the guidelines for both a 24-hour average and an annual average (including the 2025 goal). This is due in large part to the existing levels of $PM_{2.5}$ in air within the existing urban environment. These elevated background levels would be present in the community regardless of the construction and operation of the project. Concentrations of total $PM_{2.5}$, however, are essentially unchanged within the local community with the operation of the project, as well as the construction and operation of all WestConnex projects.

The maximum cumulative concentrations of PM_{10} presented in the above tables are above the 24-hour average and annual average guidelines. The maximum concentrations in residential and commercial/industrial (workplace) areas are below the annual average guideline. The elevated levels of total PM_{10} is due to the existing levels of PM_{10} in air within the existing urban environment. These elevated background levels would be present in the community regardless of the construction and operation of the project. Concentrations of total PM_{10}, however, are essentially unchanged within the local community with the construction and operation of the project, as well as the operation of all WestConnex projects, the proposed future Western Harbour Tunnel and Beaches Link, the proposed future Sydney Gateway and F6 Extension projects.

To further address potential risks to human health that may be associated with localised changes (or redistribution) in exposures to $PM_{2.5}$ and PM_{10} that relate to the project, an assessment of incremental impacts has been undertaken and are presented in **section 6.9.5**.

6.9.5 Changes in air quality associated with project

Methodology for assessment of $PM_{2.5}$ and PM_{10}

A detailed assessment of potential health effects associated with exposure to changes in air quality as a result of the project has been undertaken. As no threshold has been determined for exposure to $PM_{2.5}$ or PM_{10} the assessment of impacts on health has utilised robust, published, quantitative relationships (exposure-response relationships) that relate a change in $PM_{2.5}$ or PM_{10} concentration with a change in a health indicator. **Annexure A** presents an overview of the methodology adopted for using exposure-response relationships for the assessment of health impacts in a community.

This report has presented an assessment of changes in individual risk associated the predicted changes in air quality, as well as a change in population health impacts (as would be measured by changes in mortality statistics or hospital admissions) related to changes in exposures to particulates in the surrounding community.

For the assessment of changes in particulate matter exposures in the community the assessment has focused on health effects and exposure-response relationships that are robust and relate to $PM_{2.5}$, being the more important particulate fraction size relevant for emissions from combustion sources. Assessment of PM_{10} has also been included.

The specific health effects (or endpoints) evaluated in this assessment have been identified and include the following:

Primary health endpoints:

- Long term exposure to $PM_{2.5}$ and changes in all-cause mortality (equal or greater than 30 years of age)
- Short term exposure and changes to the rate of hospitalisations with cardiovascular and respiratory disease (equal or greater than 65 years of age).

Secondary health endpoints (to supplement the primary assessment):

- Short term exposure to PM_{10} and changes in all-cause mortality (all ages)
- Long term exposure to $PM_{2.5}$ and changes in cardiopulmonary mortality (equal or greater than 30 years of age)
- Short term exposure to $PM_{2.5}$ and changes in cardiovascular and respiratory mortality (all ages)
- Short term exposure to $PM_{2.5}$ and changes in emergency department admissions for asthma in children aged 1–14 years.

Table 6-22 presents a summary of the health endpoints considered in this assessment, the relevant health impact functions (from the referenced published studies) and the associated β coefficient relevant to the calculation of a relative risk (refer to **Annexure A** for details on the calculation of a β coefficient from published studies).

The health impact functions presented in this table are considered to be the most current and robust values, and are appropriate for the quantification of potential health effects for the health endpoints considered in this assessment.

Table 6-22 Adopted health impact functions and exposure-responses relationships

Health endpoint	Exposure period	Age group	Published relative risk [95 confidence interval] per 10 μg/m^3	Adopted β coefficient (as per cent) for 1 μg/m^3 increase in PM	Reference
Primary assessment health endpoints					
$PM_{2.5}$: Mortality, all causes	Long term	≥ 30yrs	1.06 [1.04-1.08]	0.0058 (0.58)	Relationship derived for all follow-up time periods to the year 2000 (for approx. 500,000 participants in the US) with adjustment for seven ecologic (neighbourhood level) covariates (Krewski et al. 2009). This study is an extension (additional follow-up and exposure data) of the work undertaken by Pope (2002), is consistent with the findings from California (1999–2002) (Ostro et al. 2006) and is more conservative than the relationships identified in a more recent Australian and New Zealand study (EPHC 2010).
$PM_{2.5}$: Cardiovascular hospital admissions	Short term	≥ 65yrs	1.008 [1.0059–1.011]	0.0008 (0.08)	Relationship established for all data and all seasons from US data for 1999 to 2005 for lag 0 (exposure on same day) (strongest effect identified) (Bell, M. L. 2012; Bell, Michelle L. et al. 2008)
$PM_{2.5}$: Respiratory hospital admissions	Short term	≥ 65yrs	1.0041 [1.0009–1.0074]	0.00041 (0.041)	Relationship established for all data and all seasons from US data for 1999 to 2005 for lag 2 (exposure 2 days previous) (strongest effect identified) (Bell, M. L. 2012; Bell, Michelle L. et al. 2008)
Secondary assessment health endpoints					
PM_{10}: Mortality, all causes	Short term	All ages*	1.006 [1.004–1.008]	0.0006 (0.06)	Based on analysis of data from European studies from 33 cities and includes panel studies of symptomatic children (asthmatics, chronic respiratory conditions) (Anderson et al. 2004)
$PM_{2.5}$: Mortality, all causes	Short term	All ages*	1.0094 [1.0065–1.0122]	0.00094 (0.094)	Relationship established from study of data from 47 US cities for the years 1999 to 2005 (Zanobetti & Schwartz 2009)

Health endpoint	Exposure period	Age group	Published relative risk [95 confidence interval] per 10 μg/m^3	Adopted β coefficient (as per cent) for 1 μg/m^3 increase in PM	Reference
$PM_{2.5}$: Cardio-pulmonary mortality	Long term	≥ 30yrs	1.14 [1.11–1.17]	0.013 (1.3)	Relationship derived for all follow-up time periods to the year 2000 (for approx. 500,000 participants in the US) with adjustment for seven ecologic (neighbourhood level) covariates (Krewski et al. 2009).
$PM_{2.5}$: Cardiovascular mortality	Short term	All ages*	1.0097 [1.0051–1.0143]	0.00097 (0.097)	Relationship established from study of data from 47 US cities for the years 1999 to 2005 (Zanobetti & Schwartz 2009)
$PM_{2.5}$: Asthma (emergency department admissions)	Short term	1–14 years	–	0.00148 (0.148)	Relationship established from review conducted on Australian children (Sydney) for the period 1997 to 2001 (Jalaludin et al. 2008)
$PM_{2.5}$: Respiratory mortality (including lung cancer)	Short term	All ages*	1.0192 [1.0108–1.0278]	0.0019 (0.19)	Relationship established from study of data from 47 US cities for the years 1999 to 2005 (Zanobetti & Schwartz 2009)

Note: * Relationships established for all ages, including young children and the elderly

The assessment of health impacts for a population associated with exposure to particulate matter has been undertaken utilising the methodology presented by the WHO (Ostro 2004) (also outlined in **Annexure A**) where the exposure-response relationships (see **Table 6-22**) have been directly considered.

A change in relative risk has then been calculated on the basis of the following:

- Estimates of the changes in $PM_{2.5}$ and PM_{10} exposure levels due to the project in 2023 and 2033 (as provided in **Appendix I** (Technical working paper: Air quality) of the EIS) for the scenarios assessed with the project as well as the cumulative impacts from all WestConnex projects at each of the community receptors (see **Figure 4-2)** as well as the maximum off-site residential and workplace receptors from the RWR receptors
- Baseline incidence of the key health endpoints that are relevant to the population exposed (see **Table 4-5**)
- Exposure-response relationships expressed as a percentage change in health endpoint per micrograms per cubic metre change in particulate matter exposure (see **Table 6-22**).

The change in incidence of each health indicator relevant to changes in $PM_{2.5}$ exposures in the local community (for the population exposed) has been calculated on the basis of the following:

- The relative risk has been calculated for a population weighted annual average incremental increase in $PM_{2.5}$ concentrations (using the approach outlined above). The population weighted average change in concentration has been calculated on the basis of the smallest statistical division provided by the Australian Bureau of Statistics within a suburb (ie mesh blocks – which are small blocks that cover an area of about 30 urban residences). For each mesh block in a suburb, the average change in $PM_{2.5}$ concentration has been calculated and multiplied by the population living in the mesh block (data available from the ABS for the 2011 census year). The weighted average has been calculated by summing these calculations for each mesh block in a suburb and dividing by the total population in the suburb (ie in all the mesh block)

- A change in the number of cases associated with the change in $PM_{2.5}$ impact evaluated in the population within the study area has been calculated (refer to **Annexure A** for details on the methodology). The calculation is undertaken utilising the baseline incidence data relevant for the endpoint considered (see **Table 4-5**) and the population (for the relevant age groups) present in the suburb (see **Table 4-3**).

Methodology for assessing exposure to diesel particulate matter

In addition to the above exposure-response relationships, potential exposure to diesel particulate matter (DPM) derived from the project has been evaluated.

Diesel exhaust (DE) is emitted from 'on-road' diesel engines (vehicle engines) and can be formed from the gaseous compounds emitted by diesel engines (secondary particulate matter). After emission from the exhaust pipe, DE undergoes dilution and chemical and physical transformations in the atmosphere, as well as dispersion and transport in the atmosphere. The atmospheric lifetime for some compounds present in DE ranges from hours to days.

Available evidence indicates that there are human health hazards associated with exposure to diesel particulate matter. The hazards include acute exposure-related symptoms, chronic exposure related non-cancer respiratory effects, and lung cancer. The non-cancer health effects associated with exposure to DPM are adequately addressed on the basis of the current $PM_{2.5}$ and PM_{10} guidelines. However, the potential for exposure to DPM to result in an increased risk of lung cancer in the community requires further consideration. **Annexure B** presents the methodology adopted for the assessment of lung cancer risks associated with exposure to DPM. In summary, the following has been assumed/undertaken:

- It has been conservatively assumed that 100 per cent of $PM_{2.5}$ predicted in the local community is derived from diesel vehicles and comprises DPM
- An incremental lifetime risk of lung cancer has been calculated (refer to **Annexure B** for methodology) on the basis of the inhalation toxicity value available from the World Health Organization (WHO 1996).

Acceptability of health impacts

Based on the methodology outlined above, potential health impacts associated with the project have been assessed on the basis of two calculations:

- Calculation of an annual risk for each health endpoint. This is a change in risk that differs from the baseline risk (or incidence) of the effect occurring for any member of the population, where exposed to the change in particulate matter concentration estimated
- Calculation of a change in incidence of the health effect occurring within the population exposed. This calculates the change in the number of cases (mortality or hospitalisations) that may occur for the population assumed to be exposed to the changes in particulate matter concentration estimated.

To determine if the calculated annual risk or change in incidence within a population associated with particulate matter impacts from the project may be considered to be acceptable a number of factors need to be considered. These are discussed further in **Annexure C**.

It is noted that the change in risk and health incidence calculated in this assessment includes negative values (where there is a lower risk and incidence of health effects in the community with the operation of the project) and positive values (where there is an increase in risk and health incidence in the community with the operation of the project).

Any negative values are related to improved health impacts in the community and are considered acceptable. The following discussion relates to the evaluation of positive values.

Risk:

While it is not possible to provide a rigid definition of acceptable risk due to the complex and context-driven nature of the challenge, it is possible to propose some general guidelines as to what might be an acceptable risk for specific development projects.

If a level of less than 10^{-6} (one chance in a million) were retained as a level of increased risk that would be considered as a negligible risk in the community, then the level of risk that could be considered to be tolerable would lie between this level and an upper level that is considered to be unacceptable.

While there is no guidance available on what level of risk is considered to be unacceptable in the community, a level in excess of 10^{-4} for increased risk (one chance in 10,000) has been generally adopted by health authorities as a point where risk is considered to be unacceptable. This level has been adopted in the development of drinking water guidelines (that impact on whole populations) (for exposure to carcinogens as well as for annual risks of disease (Fewtrell & Bartram 2001)) and in the evaluation of exposures from pollutants in air (NSW DEC 2005).

Between an increased risk level considered negligible (less than 10^{-6}) and unacceptable (greater than 10^{-4}) lie risks that may be considered to be tolerable or even acceptable. Tolerable risks are those that can be tolerated (and where the best available, and most appropriate, technology has been implemented to minimise exposure) in order to realise some wider community benefit.

In a societal context, risks are inevitable and any new development would be accompanied by risks which are not amenable or economically feasible to reduce below a certain level. It is not good policy to impose an arbitrary risk level to such developments without consideration of the many factors that should be considered to determine what is ‘tolerable’ or ‘acceptable’.

Hence for this project the calculated risks have been considered to be tolerable when in the range of greater than or equal to 10^{-6} and less than or equal to 10^{-4} of increased risk and where the increased incidence of the health impacts are considered to be insignificant.

Population incidence:

The assessment of changes in incidence of particular health indicators in the community results in the calculation of a change in the number of cases (of mortality, hospital or emergency department admissions) within the population evaluated.

As discussed in **Annexure C**, where changes in air quality associated with this project are well below 10 cases per year they are considered to be within the normal variability of health statistics, and these changes would not be measurable in any health statistics for the area. For evaluating impacts from this project a more conservative tenfold margin of safety has been included to determine what changes in incidence may be considered negligible within the study population.

This means that changes in the population incidence of any health effect evaluated that is less than one case per year are considered negligible.

Calculated risks and population incidence for operation of the project

Review of the changes in particulate matter concentrations predicted in 2023 and 2033 indicates that for a number of receptors in the local community the project results in a decrease in the concentration of $PM_{2.5}$ and PM_{10}. For a number of receptors there is an increase in the concentration of $PM_{2.5}$ and PM_{10}, which relates to the redistribution of emissions on surface roads in the study area, not from emissions from the ventilation facilities (as discussed in **Appendix I** (Technical working paper: Air quality) of the EIS). This is illustrated in **Figure 6-5** that presents a contour plot of the change in annual average $PM_{2.5}$ concentrations associated with the project in the assessment year 2023. For a number of areas, the change is negative (ie a decrease in $PM_{2.5}$ concentrations due to the project) however for some areas adjacent to some roadways (Anzac Bridge or Victoria Road in Drummoyne) or in industrial areas north and north east of Sydney Airport the change is positive (ie an increase in $PM_{2.5}$ concentrations due to the project).

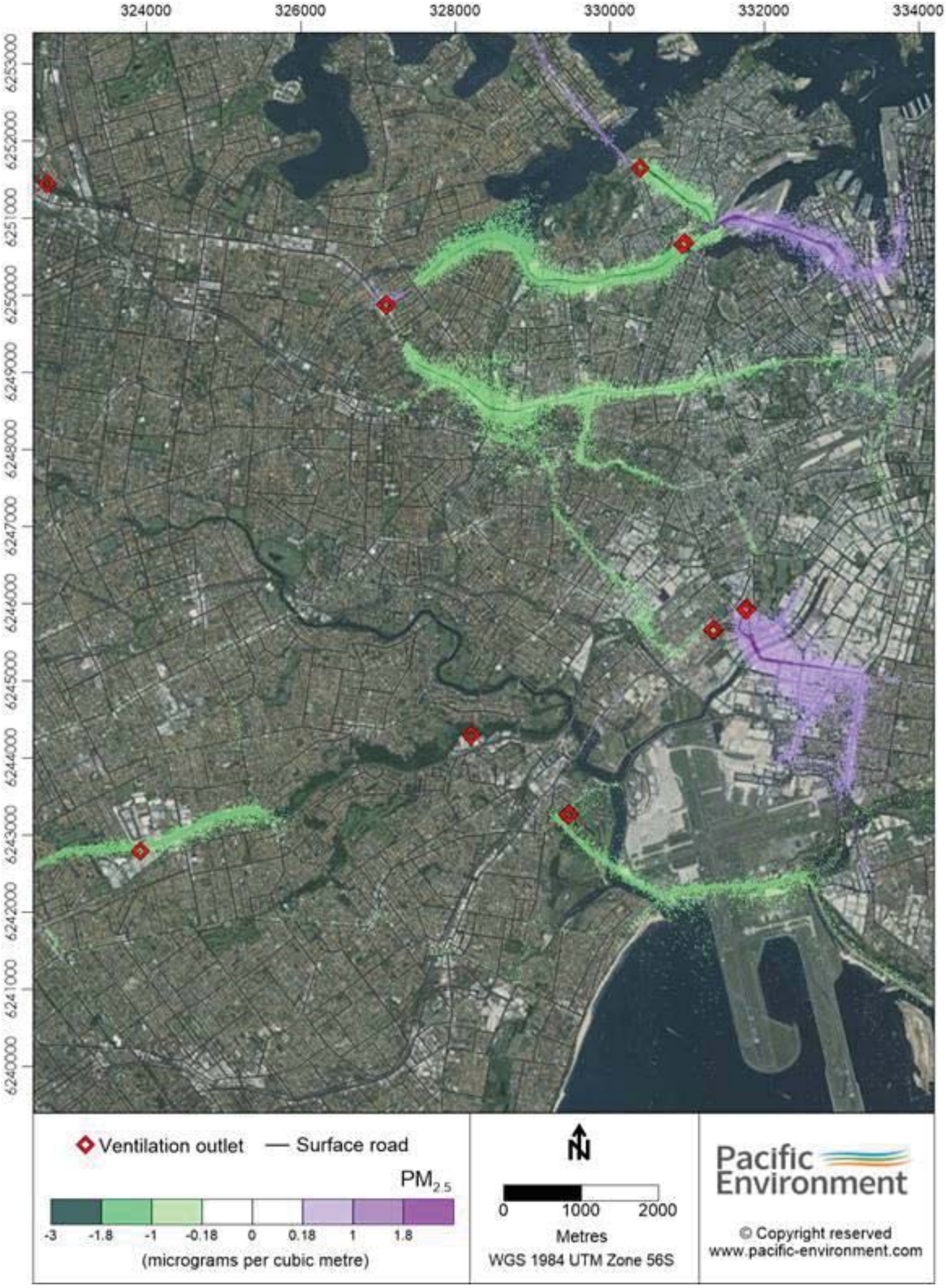


Figure 6-5 Contour plot showing change in annual average $PM_{2.5}$ concentrations associated with the project in 2023

Based on the methodology outlined above, **Table 6-23** and **Table 6-24** present the calculated individual risk associated with changes in $PM_{2.5}$ and PM_{10} concentrations at the maximum impacted residential, childcare, schools, aged care, hospital, commercial/industrial and open space areas as well as the maximum impacted community receptor, for the operational years 2023 and 2033. The change in $PM_{2.5}$ and PM_{10} concentration considered in the risk calculations are also included in the tables.

The calculated change in risk at the maximum receptors represents the worst case impact associated with the project. Risks for all other receptors would be lower than calculated for the maximum receptors. **Figure 6-6** shows the calculated risks for each of the community receptors, associated with the primary health endpoints evaluated in this assessment for the project's operations in 2023 and 2033. All calculated individual risks are presented in **Annexure F**.

Table 6-25 and **Table 6-26** present a summary of the calculated change in incidence of the relevant health effects for the population living in the LGAs within the study area, associated with changes in $PM_{2.5}$ concentrations for 2023 and 2033. All calculations relevant to the LGAs, including calculation for each individual suburb considered in the LGAs, are presented in **Annexure G**.

Table 6-23 Calculated individual risk associated with changes in $PM_{2.5}$ and PM_{10} concentrations – project operations in 2023

Receptor	Change in annual average concentration (µg/m³)		Calculated risks for health endpoints									
			$PM_{2.5}$: Mortality, all causes	$PM_{2.5}$: Cardiovascular hospitalisations	$PM_{2.5}$: Respiratory hospitalisations	PM_{10}: Mortality, all causes	$PM_{2.5}$: Mortality, all causes	$PM_{2.5}$: Mortality, cardiopulmonary	$PM_{2.5}$: Mortality, cardiovascular	$PM_{2.5}$: Mortality, respiratory	$PM_{2.5}$: Asthma emergency department hospitalisations	DPM Lung cancer
	PM_{10}	$PM_{2.5}$	long-term	short-term	short-term	short-term	short-term	long-term	short-term	short-term	short-term	long-term
			≥ 30 yrs	≥ 65 yrs	≥ 65 yrs	all	all	≥ 30 yrs	all	all	1–14 yrs	all
2023 with project												
Maximum residential	0.85	0.51	$3X10^{-5}$	$4X10^{-5}$	$8X10^{-6}$	$3X10^{-6}$	$2X10^{-6}$	$3X10^{-5}$	$7X10^{-7}$	$5X10^{-7}$	$9X10^{-6}$	$2X10^{-5}$
Maximum childcare	0.33	0.43	$3X10^{-5}$	$3X10^{-5}$	$7X10^{-6}$	$1X10^{-6}$	$2X10^{-6}$	$2X10^{-5}$	$6X10^{-7}$	$4X10^{-7}$	$8X10^{-6}$	$1X10^{-5}$
Maximum schools	0.29	0.12	$7X10^{-6}$	$9X10^{-6}$	$2X10^{-6}$	$9X10^{-7}$	$6X10^{-7}$	$6X10^{-6}$	$2X10^{-7}$	$1X10^{-7}$	$2X10^{-6}$	$4X10^{-6}$
Maximum aged care	0.06	0.06	$4X10^{-6}$	$4X10^{-6}$	$1X10^{-6}$	$2X10^{-7}$	$3X10^{-7}$	$3X10^{-6}$	$8X10^{-8}$	$6X10^{-8}$	$1X10^{-6}$	$2X10^{-6}$
Maximum hospital	0.69	0.20	$1X10^{-5}$	$1X10^{-5}$	$3X10^{-6}$	$2X10^{-6}$	$9X10^{-7}$	$1X10^{-5}$	$3X10^{-7}$	$2X10^{-7}$	$4X10^{-6}$	$7X10^{-6}$
Maximum commercial/ industrial	1.70	1.16	$7X10^{-5}$	$9X10^{-5}$	$2X10^{-5}$	$5X10^{-6}$	$5X10^{-6}$	$6X10^{-5}$	$2X10^{-6}$	$1X10^{-6}$	$2X10^{-5}$	$4X10^{-5}$
Maximum open space	1.24	0.78	$5X10^{-5}$	$6X10^{-5}$	$1X10^{-5}$	$4X10^{-6}$	$4X10^{-6}$	$4X10^{-5}$	$1X10^{-6}$	$7X10^{-7}$	$1X10^{-5}$	$3X10^{-5}$
Maximum community receptors	0.19	0.15	$2X10^{-5}$	$3X10^{-5}$	$6X10^{-6}$	$1X10^{-6}$	$2X10^{-6}$	$2X10^{-5}$	$5X10^{-7}$	$3X10^{-7}$	$6X10^{-6}$	$1X10^{-5}$
2023 cumulative												
Maximum residential	1.60	0.62	$4X10^{-5}$	$5X10^{-5}$	$1X10^{-5}$	$3X10^{-6}$	$3X10^{-6}$	$3X10^{-5}$	$8X10^{-7}$	$6X10^{-7}$	$1X10^{-5}$	$2X10^{-5}$
Maximum childcare	0.36	0.26	$2X10^{-5}$	$2X10^{-5}$	$4X10^{-6}$	$1X10^{-6}$	$1X10^{-6}$	$1X10^{-5}$	$3X10^{-7}$	$2X10^{-7}$	$5X10^{-6}$	$9X10^{-6}$
Maximum schools	0.26	0.15	$9X10^{-6}$	$1X10^{-5}$	$2X10^{-6}$	$8X10^{-7}$	$7X10^{-7}$	$8X10^{-6}$	$2X10^{-7}$	$1X10^{-7}$	$3X10^{-6}$	$5X10^{-6}$
Maximum aged care	0.10	0.08	$5X10^{-6}$	$6X10^{-6}$	$1X10^{-6}$	$3X10^{-7}$	$4X10^{-7}$	$4X10^{-6}$	$1X10^{-7}$	$8X10^{-8}$	$1X10^{-6}$	$3X10^{-6}$
Maximum hospital	0.23	0.12	$7X10^{-6}$	$9X10^{-6}$	$2X10^{-6}$	$7X10^{-7}$	$6X10^{-7}$	$6X10^{-6}$	$2X10^{-7}$	$1X10^{-7}$	$2X10^{-6}$	$4X10^{-6}$
Maximum commercial/ industrial	3.36	2.25	$1X10^{-4}$	$2X10^{-4}$	$4X10^{-5}$	$1X10^{-5}$	$1X10^{-5}$	$1X10^{-4}$	$3X10^{-6}$	$2X10^{-6}$	$4X10^{-5}$	$8X10^{-5}$
Maximum open space	1.05	0.54	$3X10^{-5}$	$4X10^{-5}$	$9X10^{-6}$	$3X10^{-6}$	$3X10^{-6}$	$3X10^{-5}$	$7X10^{-7}$	$5X10^{-7}$	$1X10^{-5}$	$2X10^{-5}$
Maximum community receptors	0.14	0.18	$1X10^{-5}$	$1X10^{-5}$	$3X10^{-6}$	$7X10^{-7}$	$9X10^{-7}$	$1X10^{-5}$	$3X10^{-7}$	$2X10^{-7}$	$3X10^{-6}$	$7X10^{-6}$

Negligible risks	**$< 1 \times 10^{-6}$**
Tolerable/acceptable risks	**$\geq 1 \times 10^{-6}$ and $\leq 1 \times 10^{-4}$**
Unacceptable risks	**$> 1 \times 10^{-4}$**

Note: Shaded cell (purple) exceeds the criteria adopted for acceptable risks, refer to the discussion below

Table 6-24 Calculated individual risk associated with changes in $PM_{2.5}$ and PM_{10} concentrations – project operations in 2033

Receptor	Change in annual average concentration (µg/m^3)		Calculated risks for health endpoints									
			$PM_{2.5}$: Mortality, all causes	$PM_{2.5}$: Cardiovascular hospitalisations	$PM_{2.5}$: Respiratory hospitalisations	PM_{10}: Mortality, all causes	$PM_{2.5}$: Mortality, all causes	$PM_{2.5}$: Mortality, cardiopulmonary	$PM_{2.5}$: Mortality, cardiovascular	$PM_{2.5}$: Mortality, respiratory	$PM_{2.5}$: Asthma emergency department hospitalisations	DPM Lung cancer
	PM_{10}	$PM_{2.5}$	long-term	short-term	short-term	short-term	short-term	long-term	short-term	short-term	short-term	long-term
			≥ 30 yrs	≥ 65 yrs	≥ 65 yrs	all	all	≥ 30 yrs	all	all	1–14 yrs	all
2033 with project												
Maximum residential	1.12	0.56	3X10^{-5}	4X10^{-5}	9X10^{-6}	3X10^{-6}	3X10^{-6}	3X10^{-5}	7X10^{-7}	5X10^{-7}	1X10^{-5}	2X10^{-5}
Maximum childcare	0.67	0.39	2X10^{-5}	3X10^{-5}	6X10^{-6}	2X10^{-6}	2X10^{-6}	2X10^{-5}	5X10^{-7}	4X10^{-7}	7X10^{-6}	1X10^{-5}
Maximum schools	0.37	0.15	9X10^{-6}	1X10^{-5}	2X10^{-6}	1X10^{-6}	7X10^{-7}	8X10^{-6}	2X10^{-7}	1X10^{-7}	3X10^{-6}	5X10^{-6}
Maximum aged care	0.11	0.11	7X10^{-6}	8X10^{-6}	2X10^{-6}	3X10^{-7}	5X10^{-7}	6X10^{-6}	1X10^{-7}	1X10^{-7}	2X10^{-6}	4X10^{-6}
Maximum hospital	0.42	0.33	2X10^{-5}	2X10^{-5}	5X10^{-6}	1X10^{-6}	2X10^{-6}	2X10^{-5}	4X10^{-7}	3X10^{-7}	6X10^{-6}	1X10^{-5}
Maximum commercial/ industrial	1.94	1.43	9X10^{-5}	1X10^{-4}	2X10^{-5}	6X10^{-6}	7X10^{-6}	8X10^{-5}	2X10^{-6}	1X10^{-6}	3X10^{-5}	5X10^{-5}
Maximum open space	1.40	0.83	5X10^{-5}	6X10^{-5}	1X10^{-5}	4X10^{-6}	4X10^{-6}	4X10^{-5}	1X10^{-6}	8X10^{-7}	1X10^{-5}	3X10^{-5}
Maximum community receptors	0.23	0.14	3X10^{-5}	4X10^{-5}	9X10^{-6}	2X10^{-6}	3X10^{-6}	3X10^{-5}	7X10^{-7}	5X10^{-7}	1X10^{-5}	1X10^{-5}
2033 cumulative												
Maximum residential	1.26	0.55	3X10^{-5}	4X10^{-5}	9X10^{-6}	3X10^{-6}	3X10^{-6}	3X10^{-5}	7X10^{-7}	5X10^{-7}	1X10^{-5}	2X10^{-5}
Maximum childcare	0.22	0.20	1X10^{-5}	1X10^{-5}	3X10^{-6}	7X10^{-7}	9X10^{-7}	1X10^{-5}	3X10^{-7}	2X10^{-7}	4X10^{-6}	7X10^{-6}
Maximum schools	0.29	0.19	1X10^{-5}	1X10^{-5}	3X10^{-6}	9X10^{-7}	9X10^{-7}	1X10^{-5}	2X10^{-7}	2X10^{-7}	3X10^{-6}	6X10^{-6}
Maximum aged care	0.16	0.06	4X10^{-6}	4X10^{-6}	1X10^{-6}	5X10^{-7}	3X10^{-7}	3X10^{-6}	8X10^{-8}	6X10^{-8}	1X10^{-6}	2X10^{-6}
Maximum hospital	0.52	0.31	2X10^{-5}	2X10^{-5}	5X10^{-6}	2X10^{-6}	1X10^{-6}	2X10^{-5}	4X10^{-7}	3X10^{-7}	6X10^{-6}	1X10^{-5}
Maximum commercial/ industrial	3.74	2.33	1X10^{-4}	2X10^{-4}	4X10^{-5}	1X10^{-5}	1X10^{-5}	1X10^{-4}	3X10^{-6}	2X10^{-6}	4X10^{-5}	8X10^{-5}
Maximum open space	0.92	0.56	3X10^{-5}	4X10^{-5}	9X10^{-6}	3X10^{-6}	3X10^{-6}	3X10^{-5}	7X10^{-7}	5X10^{-7}	1X10^{-5}	2X10^{-5}
Maximum community receptors	0.28	0.15	1X10^{-5}	1X10^{-5}	3X10^{-6}	1X10^{-6}	8X10^{-7}	1X10^{-5}	2X10^{-7}	2X10^{-7}	3X10^{-6}	6X10^{-6}

Negligible risks	**< 1 x 10^{-6}**
Tolerable/acceptable risks	**≥ 1 x 10^{-6} and ≤ 1 x 10^{-4}**
Unacceptable risks	**> 1 x 10^{-4}**

Note: Shaded cell (purple) exceeds the criteria adopted for acceptable risks, refer to the discussion below

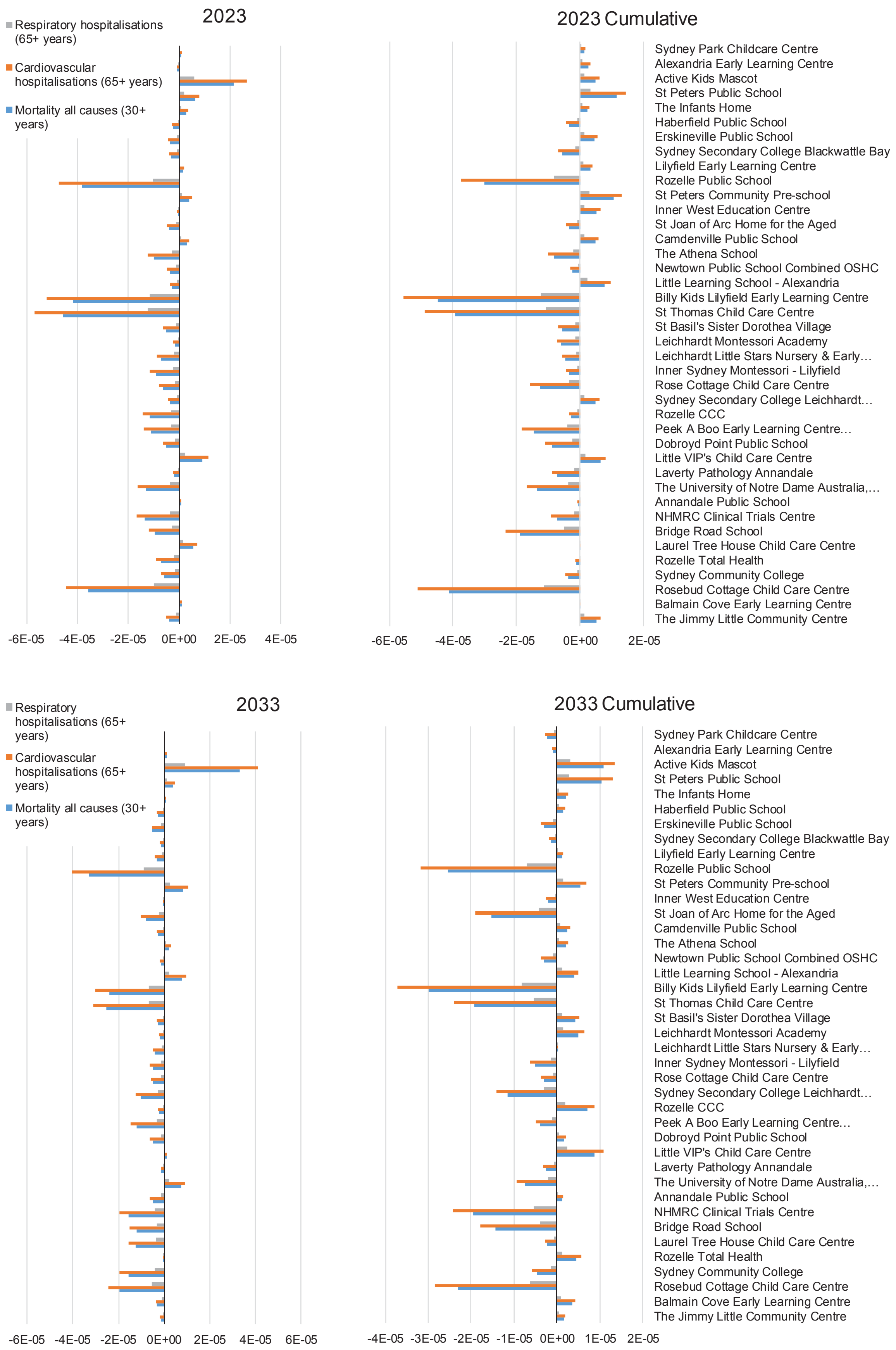


Figure 6-6 Calculated change in individual risk at community receptors from change in $PM_{2.5}$ concentrations (primary health endpoints) – project in 2023 and 2033

Table 6-25 Calculated changes in incidence of health effects in population associated with changes in $PM_{2.5}$ concentrations – project in 2023

LGA/Local statistical area	Change in population incidence – number of cases							
	Primary indicators			Secondary indicators				
	Mortality – All Causes	Hospitalisations – Cardiovascular	Hospitalisations – Respiratory	Mortality – All causes	Mortality – Cardiopulmonary	Mortality – Cardiovascular	Mortality – Respiratory	Morbidity – Asthma ED admissions
	≥ 30 years	≥ 65 years	≥ 65 years	All ages	≥ 30 years	All ages	All ages	1–14 years
With Project								
Canada Bay	-0.000007	-0.0000020	-0.00000045	-0.00000075	-0.0000067	-0.00000022	-0.00000018	-0.00000055
Strathfield*	-0.0012	-0.00032	-0.000070	-0.00014	-0.0010	-0.000043	-0.000031	-0.000083
Burwood	-0.0018	-0.00048	-0.00011	-0.00026	-0.0016	-0.000066	-0.000046	-0.00013
Sydney Inner West	-0.38	-0.072	-0.016	-0.048	-0.34	-0.014	-0.0090	-0.026
Sydney	-0.0045	-0.00074	-0.00016	-0.00061	-0.0041	-0.00017	-0.00012	-0.00014
Botany	0.072	0.021	0.0046	0.0097	0.065	0.0029	0.0019	0.0059
Rockdale	-0.063	-0.019	-0.0041	-0.0086	-0.057	-0.0025	-0.0016	-0.0049
Canterbury-Bankstown	-0.041	-0.011	-0.0025	-0.0055	-0.037	-0.0016	-0.0011	-0.0041
Georges River	-0.015	-0.0046	-0.0010	-0.0018	-0.013	-0.00051	-0.00038	-0.0012
Total for all LGAs	**-0.4**	**-0.09**	**-0.02**	**-0.06**	**-0.4**	**-0.02**	**-0.01**	**-0.03**
Cumulative								
Canada Bay	0.030	0.0081	0.0018	0.0030	0.027	0.00086	0.00074	0.0022
Strathfield*	-0.0036	-0.0010	-0.00022	-0.00042	-0.0032	-0.00013	-0.00010	-0.00026
Burwood	-0.0013	-0.00036	-0.000079	-0.00019	-0.0012	-0.000050	-0.000035	-0.000095
Sydney Inner West	-0.32	-0.061	-0.013	-0.040	-0.29	-0.011	-0.0075	-0.021
Sydney	-0.044	-0.0073	-0.0016	-0.0060	-0.040	-0.0017	-0.0012	-0.0014
Botany	-0.015	-0.0044	-0.0010	-0.0021	-0.014	-0.00061	-0.00039	-0.0013
Rockdale	-0.071	-0.021	-0.0047	-0.0097	-0.064	-0.0028	-0.0018	-0.0055
Canterbury-Bankstown	-0.054	-0.015	-0.0033	-0.0072	-0.049	-0.0021	-0.0015	-0.0054
Georges River	-0.026	-0.0081	-0.0018	-0.0031	-0.023	-0.00090	-0.00067	-0.0021
Total for all LGAs	**-0.5**	**-0.1**	**-0.02**	**-0.07**	**-0.5**	**-0.02**	**-0.01**	**-0.04**

Notes: * Includes suburbs in Auburn LGA

Negative value indicates that there is a decrease in incidence associated with the project

Table 6-26 Calculated changes in incidence of health effects in population associated with changes in $PM_{2.5}$ concentrations – project in 2033

LGA / Local statistical area	Change in population incidence – number of cases							
	Primary Indicators			Secondary Indicators				
	Mortality – All Causes	Hospitalisations – Cardiovascular	Hospitalisations – Respiratory	Mortality – All causes	Mortality – Cardiopulmonary	Mortality – Cardiovascular	Mortality – Respiratory	Morbidity – Asthma ED Admissions
	≥30 years	≥65 years	≥65 years	All ages	≥30 years	All ages	All ages	1–14 years
With Project								
Canada Bay	0.0016	0.00043	0.000094	0.00016	0.0014	0.000046	0.000039	0.00011
Strathfield*	-0.0022	-0.00061	-0.00013	-0.00026	-0.0020	-0.000082	-0.000059	-0.00016
Burwood	-0.00094	-0.00026	-0.000056	-0.00014	-0.00085	-0.000035	-0.000025	-0.000068
Sydney Inner West	-0.34	-0.064	-0.014	-0.043	-0.31	-0.012	-0.0080	-0.023
Sydney	0.021	0.0034	0.00075	0.0028	0.019	0.00080	0.00055	0.00066
Botany	0.084	0.024	0.0054	0.011	0.076	0.0033	0.0022	0.0069
Rockdale	-0.070	-0.021	-0.0046	-0.0095	-0.063	-0.0028	-0.0018	-0.0054
Canterbury-Bankstown	-0.033	-0.0092	-0.0020	-0.0044	-0.030	-0.0013	-0.00090	-0.0033
Georges River	-0.023	-0.0073	-0.0016	-0.0028	-0.021	-0.00082	-0.00060	-0.0019
Total for all LGAs	**-0.4**	**-0.07**	**-0.02**	**-0.05**	**-0.3**	**-0.01**	**-0.009**	**-0.03**
Cumulative								
Canada Bay	0.033	0.0090	0.0020	0.0033	0.030	0.0010	0.00082	0.0024
Strathfield*	-0.00063	-0.00017	-0.000038	-0.000073	-0.00056	-0.000023	-0.000017	-0.000045
Burwood	0.0067	0.0018	0.00040	0.0010	0.0060	0.00025	0.00018	0.00048
Sydney Inner West	-0.24	-0.045	-0.0099	-0.030	-0.21	-0.0085	-0.0056	-0.016
Sydney	-0.042	-0.0068	-0.0015	-0.0056	-0.037	-0.0016	-0.0011	-0.0013
Botany	-0.012	-0.0034	-0.00076	-0.0016	-0.011	-0.00047	-0.00030	-0.0010
Rockdale	-0.080	-0.024	-0.0053	-0.011	-0.072	-0.0032	-0.0021	-0.0063
Canterbury-Bankstown	-0.059	-0.016	-0.0036	-0.0078	-0.053	-0.0023	-0.0016	-0.0058
Georges River	-0.014	-0.0045	-0.0010	-0.0017	-0.013	-0.00050	-0.00037	-0.0012
Total for all LGAs	**-0.4**	**-0.09**	**-0.02**	**-0.05**	**-0.4**	**-0.02**	**-0.01**	**-0.03**

Notes: * Includes suburbs in Auburn LGA

Negative value indicates that there is a decrease in incidence associated with the project

Review of the calculated changes in risk indicates the following in relation to impacts associated with the expected operation of the project in 2023 and 2033, including the cumulative scenario:

- A number of the calculated individual risks as shown in **Figure 6-6** for the community receptors are negative, meaning that the operation of the project would result in lower levels of risk, when compared with the situation where the project is not operating
- The maximum risks calculated for exposures in residential areas are less than $1x10^{-4}$ and considered to be tolerable/acceptable
- The maximum risks calculated for exposures in commercial/industrial areas are between $8x10^{-7}$ and $2x10^{-4}$. The maximum risk level of $2x10^{-4}$ exceeds the adopted criteria for determining unacceptable risks. Impacts that result in exceedance of the adopted risk criteria occur only in the existing industrial location north and northwest of Sydney Airport, between Airport Drive/Alexandria Canal and the Princes Highway. It is noted that the calculation presented relates to exposures that occur at this maximum location for all hours of the day, all of the time. As this area is a workplace, not somewhere people live, the calculated risk is expected to overestimate risks by a factor of about 4.5, hence actual risks in theses industrial areas are expected to be lower and tolerable. Given the proximity of these areas to Sydney Airport (runways and flight paths) it is considered unlikely that they would be rezoned for residential use, hence it is not relevant to evaluate future residential exposures at this location. In addition, it is noted that the calculated risks relate to predicted increases in $PM_{2.5}$, principally related to the proposed future Sydney Gateway project. Emissions to air related to the Sydney Gateway project have been estimated on the basis of provisional information in relation to roadway layout only. The maximum impacts predicted are on roadways/locations that may be within the future roadway alignments. The proposed future Sydney Gateway project would be subject to separate environmental assessment and approval, where more detailed assessment of impacts in this area is expected to be undertaken
- It is noted that the worst case scenario for potential exposure is where a resident works at the maximum impacted workplace and lives at the maximum impacted residential location. Where this may occur, the maximum risk is just less than $1x10^{-4}$, which is considered tolerable/acceptable
- All maximum risks calculated for continuous exposures in childcare centres, schools, aged care homes and open space areas are below $1x10^{-4}$ and considered to be tolerable/ acceptable
- In relation to impacts on the health of the population in the local community, the calculated change in incidence of the health indicators evaluated shows that the increased incidence of the evaluated health effects occurring in the population in the study area ranges from 0.007 to 0.2 cases per year, which would not be measurable and is considered to be negligible.

Review of the calculated impacts in terms of the change in incidence of the relevant health effects for $PM_{2.5}$ in the community, indicates the following:

- The total change in the number of cases relevant to the health effects evaluated, for both 2023 and 2033 is negative, meaning a decrease in incidence as a result of the project. The number of cases, however is very small, less than one for all health effects considered. As a result, these changes would not be measurable within the community
- Most individual LGAs show a total decrease in health incidence. There are a few LGAs (Canada Bay, Botany, Sydney and Burwood) where there is an increase. These increases and decreases are also very small, less than one for all health effects considered. As a result, these changes would not be measurable in the community
- The incidence calculations presented in **Table 6-25** and **Table 6-26** are the totals for each LGA. Within these LGAs are a number of smaller suburbs. The calculated change in incidence relevant to each of these suburbs has also been evaluated, as presented in **Annexure G**. Review of the incidence calculated for the individual suburbs indicates that these predominantly relate to small decreases in health incidence with some suburbs showing and increase. The largest increase in health incidence for any individual suburb is less than 0.1 case. Hence there are no individual suburbs within the LGAs where there is a change incidence that is of significance or would be measurable.

Elevated receptors

The calculations presented in the above relate to inhalation exposures that may occur at ground level (ie within typical low to medium density residential homes and commercial/industrial properties).

Appendix I (Technical working paper: Air quality) of the EIS has conducted a screening assessment of potential issues related to exposures that may occur at elevated receptors, close to ventilation outlets, to identify areas that may need to have more detailed analysis and where future development controls may be required for high-rise buildings. This has been undertaken on the basis of evaluating predicted concentrations of $PM_{2.5}$ at both 10 metres and 30 metres above the ground level, representative of potential exposures that may occur in multi-storey buildings. The assessment undertaken has evaluated impacts at 10 metres and 30 metres across the whole study area, regardless of whether a multi-storey building is present or not. Impacts that are derived from changes in emissions from surface roads are expected to decrease with height above the roadway, however in areas closest to the ventilation outlets there is the potential for increased impacts with height.

The assessment of potential impacts at 10 metres and 30 metres height has focused on the worst case scenario, the year 2033, where cumulative impacts from the WestConnex projects, Sydney Gateway, Western Harbour Tunnel and Beaches Link and F6 Extension are included. The maximum change in $PM_{2.5}$ relevant to this scenario has been evaluated. As the approach adopted in **Appendix I** (Technical working paper: Air quality) of the EIS is a screening level assessment no other pollutants have been evaluated.

Table 6-27 presents the calculated risks associated with the maximum predicted change in $PM_{2.5}$ concentrations at a height of 10 metres and 30 metres above ground level throughout the study area. It is noted that these maximum impacts do not relate to existing multi-storey buildings, rather these are the maximum impacts anywhere in the study area, and have been included to evaluate potential future development. Impacts at existing multi-storey buildings are significantly lower than presented in this table, with changes in $PM_{2.5}$ annual average concentrations predicted to be <0.05 micrograms per cubic metre (refer to **Appendix I** (Technical working paper: Air quality) of the EIS for details).

Table 6-27 Calculated individual risk associated with changes in $PM_{2.5}$ concentrations – cumulative scenario in 2033 for elevated receptors

Health endpoint	Maximum calculated 10 m height	30 m height
Annual average concentration		
$PM_{2.5}$ (µg/m^3)	0.79	5.6
Primary health indicators: $PM_{2.5}$		
Mortality all causes (long term effects, ages 30+)	5 x 10^{-5}	3 x 10^{-4}
Cardiovascular hospitalisations (short term effects, ages 65+)	6 x 10^{-5}	4 x 10^{-4}
Respiratory hospitalisations (short term effects, ages 65+)	1 x 10^{-5}	9 x 10^{-5}
Secondary health indicators: $PM_{2.5}$		
Mortality all causes (short term effects, all ages)	4 x 10^{-6}	3 x 10^{-5}
Mortality, cardiopulmonary (long term effects, ages 30+)	4 x 10^{-5}	3 x 10^{-4}
Mortality, cardiovascular (short term effects, all ages)	1 x 10^{-6}	7 x 10^{-6}
Mortality, respiratory (short term effects, all ages)	7 x 10^{-7}	5 x 10^{-6}
Asthma emergency department hospitalisations (1–14 years)	1 x 10^{-5}	1 x 10^{-4}
Negligible risks	< 1 x 10^{-6}	
Tolerable/acceptable risks	≥ 1 x 10^{-6} and ≤ 1 x 10^{-4}	
Unacceptable risks	> 1 x 10^{-4}	

Note: Shaded cells indicate calculated risks that are considered unacceptable

The calculations presented in **Table 6-27** indicate the following:

- At a height of 10 metres within the study area, the maximum change in $PM_{2.5}$ is lower than at ground level (see **Table 6-23** and **Table 6-24**) and results in risks that are considered to range from negligible to tolerable/acceptable
- At a height of 30 metres within the study area, the maximum change in $PM_{2.5}$ is significantly greater than at ground level and at 10 metres above ground level, and results in risks that are considered to be unacceptable. Further review of the impacts predicted at 30 metres height indicates the following:
  - The impacts identified at 30 metres height are localised close to the ventilation outlets, with the maximum increases more specifically located adjacent to the Campbell Road ventilation facility (noting impacts are lower close to other ventilation outlets)
  - The maximum increase in $PM_{2.5}$ at existing industrial premises was 1.8 micrograms per cubic metres, and the maximum increase at the closest residential area is 1.44 micrograms per cubic metres which are associated with small changes in risk that are considered to be tolerable/acceptable
  - There are currently no multi-storey buildings located close to the St Peters interchange, hence the maximum risks calculated are hypothetical at this stage.

To address the potential health impacts identified, planning controls should be developed in the vicinity of the Campbell Road ventilation facility at St Peters interchange to ensure future developments at heights above 10 metres are not adversely impacted by the ventilation outlets. Development of planning controls would be supported by detailed modelling addressing all relevant pollutants and averaging periods.

6.10 Assessment of regulatory worst-case scenario

A regulatory worst-case scenario has been evaluated in **Appendix I** (Technical working paper: Air quality) of the EIS. This is based on the situation where emissions to air from the tunnel ventilation outlets occur at the maximum discharge limits at all hours of the day. This may occur in the event of a breakdown or accident and may result in a short period of time where emissions from the tunnel ventilation facility are higher than during normal operations. Such situations are not planned and where they occur the duration of the event is not expected to last for longer than a few hours.

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

In relation to impacts on health a worst-case situation results in short-term changes in air quality. Hence health effects identified and evaluated in this assessment that relate to changes in short-term concentrations of $PM_{2.5}$ require further assessment. The assessment of short-term health impacts has utilised the methodology outlined in **Annexure A** with the parameters selected to be relevant to a one-hour or 24-hour exposure period (as relevant to each pollutant). The assessment has considered short-term change in air concentrations associated with maximum emissions from the ventilation outlets from the project tunnels in 2033 for the cumulative scenario.

Risk calculations can be undertaken for the short-term change in air quality associated with each of these scenarios. How often these events occur during any one year may result in some contribution to the total annual individual risk calculated for the expected operation of the project. The frequency of a worst-case traffic scenario occurring is not known, hence for the purpose of this assessment some conservative assumptions have been adopted.

Table 6-28 presents the calculated change in individual risk associated with residential exposure to worst-case emissions of $PM_{2.5}$. The table includes the assumptions adopted for the assessment.

Table 6-28 Maximum calculated risks associated with short-term residential exposure changes in $PM_{2.5}$ concentrations: regulatory worst case 2033 cumulative scenario

Scenario	Maximum change in individual risk for the following short-term health endpoints					
	Cardiovascular hospitalisations (65 years+)	Respiratory hospitalisations (65 years +)	Mortality all causes (all ages)	Mortality cardiovascular (all ages)	Mortality respiratory (all ages)	Asthma ED admissions (1–14 years)
The project						
Maximum annual risk – expected operations	6×10^{-5}	1×10^{-5}	4×10^{-6}	1×10^{-6}	8×10^{-7}	2×10^{-5}
Increase in risk for 1 day of worst-case emissions (24 hours which is highly conservative)	8×10^{-7}	2×10^{-7}	5×10^{-8}	2×10^{-8}	1×10^{-8}	2×10^{-7}
Increase in risk assuming worst-case event occurs 1 day each week (52 days per year)*	4×10^{-5}	9×10^{-6}	3×10^{-6}	8×10^{-7}	5×10^{-7}	1×10^{-5}
Maximum annual risk – expected conditions plus worst-case event**	1×10^{-4}	2×10^{-5}	7×10^{-6}	2×10^{-6}	1×10^{-6}	3×10^{-5}
Negligible risks	$< 1 \times 10^{-6}$					
Tolerable/acceptable risks	$\geq 1 \times 10^{-6}$ and $\leq 1 \times 10^{-4}$					
Unacceptable risks	$> 1 \times 10^{-4}$					

* Assumes that the maximum predicted impact occurs at the same location (receptor) every day the worst-case event occurs. With changes in meteorology in the local area the 24-hour maximum concentration is expected to change in concentration and location over different days. Hence this assumption is conservative

** Assumes the maximum annual average impact and maximum short-term change occur that the same location (receptor)

Review of the maximum calculated changes in risk associated with short-term changes in $PM_{2.5}$ (**Table 6-28**) concentration under the worst-case scenarios evaluated indicates the following:

- The maximum change in short-term risk associated with worst-case scenarios occurring on any one day is negligible
- Where it is conservatively assumed that the worst-case scenario occurs one day each week (and the maximum changes impact occurs at the same receptor location every time), the maximum individual risk increases
- The total maximum individual risk increases to but does not exceed 1×10^{-4} and hence there are no unacceptable risks identified in the community surrounding the project
- The calculated maximum individual risks are in the range 1×10^{-6} to 1×10^{-4} and are considered to range from negligible to tolerable/acceptable.

On the basis of the above, emissions from the ventilation outlets during a worst-case scenario (such as a breakdown or accident) has the potential to increase individual risks, however the maximum individual risks (even where conservative assumptions are adopted) are considered to be tolerable/acceptable.

6.11 Valuing particulate impacts

The SEARs (as outlined in **section 1.3**) requires the assessment of health impacts to also evaluate costs to the community. More specifically, the SEARs have indicated that costs should be evaluated on the basis of the following guidance document:

- Methodology for Valuing the Health Impacts of Changes in Particle Emissions (NSW EPA 2013).

This guideline has developed an approach for use in Australia that is based on the approach developed in the UK. The approach adopted is simplistic, relating health costs in the community to changes in total tonnes of $PM_{2.5}$ emitted. This calculation has generalised the health impacts associated with changes in $PM_{2.5}$ exposures as emitted to air and does not specifically address how people are exposed to these emissions (this is assumed to occur). **Appendix I** (Technical working paper: Air quality) of the EIS has calculated the tonnes of $PM_{2.5}$ relevant to each of the scenarios evaluated for this project. This relates to the total tonnes of $PM_{2.5}$ emitted to air and this shows a small increase in $PM_{2.5}$ with the project in both 2023 and 2033, including the cumulative scenario.

The assessment of potential health effects associated with the change in $PM_{2.5}$ concentrations the community are exposed to, however are different, and as discussed in **section 6.9.5**, **Table 6-25** and **Table 6-26**, the project is associated with a decrease in incidence, or the number of cases, relevant to mortality and hospitalisations (ie a health benefit). These impacts, ie the change in number of cases, ideally should be those that are considered in valuing the health impacts. Where this is considered a reduction in health costs should be calculated. However, that is not the case with the methodology outlined by NSW EPA (2013) which is only based on the change in total tonnes of $PM_{2.5}$ emitted. As a result, the calculations presented are not considered representative of health costs related to the project.

When applying the NSW EPA (2013) methodology, the project area has been assumed to be urban large (noting there are no definitions in the guidance in relation to determining this), where the damage costs listed are $593,617 per tonne of $PM_{2.5}$ in 2011 prices. In today's prices, based on the inflation calculator from the Reserve Bank of Australia[10] the damage cost is $652,066 per tonne of $PM_{2.5}$. Following this approach, the damage costs associated with changes in $PM_{2.5}$ are calculated to be $2,608,264 in 2023 and $4,564,462 in 2033, with the cumulative scenarios result in costs that are $3,260,330 in 2023 and $7,824,792 in 2033. As noted above these costs are not considered to be representative for the project.

[10] http://www.rba.gov.au/calculator/annualDecimal.html

7 Assessment of in-tunnel air quality

7.1 General

The in-tunnel air quality has been evaluated for the following reasons:

- To design and control ventilation systems. Tunnel builders and operators aim to minimise the significant costs involved in providing active ventilation. As a result, systems are designed, built and operated to provide sufficient ventilation to maintain acceptable air quality in the tunnel, but at reasonable cost (NHMRC 2008)
- To manage in-tunnel exposure to air pollution
- To manage external air pollution.

Traditionally, the approach to considering air quality within tunnels was based on managing carbon monoxide levels. However, modern petrol fuelled cars now have low levels of carbon monoxide emissions, and with an increasing proportion of diesel fuelled cars, a number of countries are considering the use of nitrogen dioxide concentrations for tunnel ventilation design.

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. Visibility is reduced by the scattering and absorption of light by PM suspended in the air. 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 micrometres), 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 safe minimum threshold for particles, and so visibility cannot reliably be used as a criterion for health risk (NHMRC 2008). Hence visibility limits within the tunnel have not been further evaluated.

The operational in-tunnel limits for carbon monoxide and nitrogen dioxide in several Sydney road tunnels are shown in **Table 7-1**. 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 7-1 Operational limits in Sydney road tunnels

Tunnel	CO concentration (ppm, rolling average)			NO_2 concentration (ppm)
	3 min	15 min	30 min	15 min
Cross City Tunnel	200	87	50	N/A
Lane Cove Tunnel	–	87	50	N/A
M5 East Tunnel	200	87	50	N/A
NorthConnex WestConnex M4 East WestConnex New M5	200[(a)]	87[(b)]	50[(b)]	0.5[(b)]

Notes:
(a) In-tunnel single point exposure limit
(b) In-tunnel average limit along tunnel length
Sources: NHMRC (2008), Longley (2014c), PIARC (visibility), NSW Government (2015, 2016a, 2016b)

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

For the M4-M5 Link and the associated integrated analysis of all WestConnex tunnels, the 'tunnel average' has been interpreted as a 'route average', being the 'length-weighted average pollutant concentration over a portal-to-portal route through the system'. Tunnel average NO_2 has been assessed for every possible route through the system under a range of travel speeds and capacities with this assessment considering the highest average nitrogen dioxide concentration.

The tunnel ventilation system would be designed and operated so that the in-tunnel air quality limits, consistent with those in the conditions of approval for NorthConnex and other approved WestConnex projects are not exceeded.

Concentrations in the tunnel are expected to vary depending on:

- Time of day: Pollutant concentrations within the tunnels have been estimated to vary by a factor of up to ten times (depending on the particular pollutant and location within the main alignment tunnels) from periods of low traffic to peak traffic
- Location within the main alignment tunnels and ventilation facilities: Concentrations of pollutants would gradually increase from the tunnel entrance to the next offtake to a ventilation outlet. The average exposure for a motorist would be around half of the maximum concentration within the tunnel.

The assessment of potential exposures that may occur in the tunnel has been undertaken with consideration of these factors. In addition, the following has also been considered:

- M4-M5 Link tunnel:
  - The time spent within the tunnel would be limited, taking around five to six minutes to travel the full distance of the M4-M5 Link tunnel (when travelling at 80 kilometres per hour). During peak times the time of travel may be slightly longer depending on the speed of traffic flow in the tunnel. Concentrations are not the same in all parts of the tunnel, with concentrations increasing with distance from the start. Hence the amount of time exposed to the maximum concentration would be much lower (around one minute), with the average exposure through the whole tunnel would be lower than the maximum (at the end of the tunnel or ventilation outlet)
  - The concentration of pollutants within the vehicle itself would be lower, particularly where all windows are closed when inside the tunnel, as most vehicles have filters on the air intake. Where the air conditioning/ventilation in the car is set to recirculation this would limit the contribution of air derived from within the tunnel to the air within the vehicle. Measurements conducted by NSW Health in relation to the M5 East Tunnel (NSW Health 2003) identified that closing car windows and switching the ventilation to recirculation can reduce exposures by about 70–75 per cent for carbon monoxide and nitrogen dioxide, 80 per cent for fine particulates and 50 per cent for volatile organic compounds. Further testing of the reduction in nitrogen dioxide levels inside vehicles using road tunnels was commissioned by Roads and Maritime in 2016 (Pacific Environment Limited (PEL) 2016), where recirculation was found to reduce exposures by around 70 per cent.
- Assessment of cumulative exposures in tunnels:
  - It is expected that users of the M4-M5 Link may also use part of other connecting tunnels for their trip. This may include the M4 East or the New M5, both of which directly connect into the M4-M5 Link tunnel. There are other projects proposed that would also connect with the M4-M5 Link such as the Western Harbour Tunnel and Beaches Link and F6 Extension (via the New M5). This means motorists may be travelling inside a tunnel for a longer distance and time. Given the layout of the WestConnex projects it is unlikely anyone would utilise the full length of the tunnels, from the start of the M4 East to the end of the New M5 (or the other direction), during any one trip. It is more likely that trips may utilise either the M4 East or New M5 and part of, or all of, the M4-M5 Link. Exposures that may occur during longer duration

trips in these connecting tunnels are considered below

- There may be individuals who utilise the network of tunnels in the Sydney area on a frequent basis, throughout the day. This includes taxi drivers, courier drivers and some truck drivers. More frequent exposures in these tunnels are considered below.

The following provides further discussion on the range of concentrations predicted within the tunnel.

7.2 Carbon monoxide

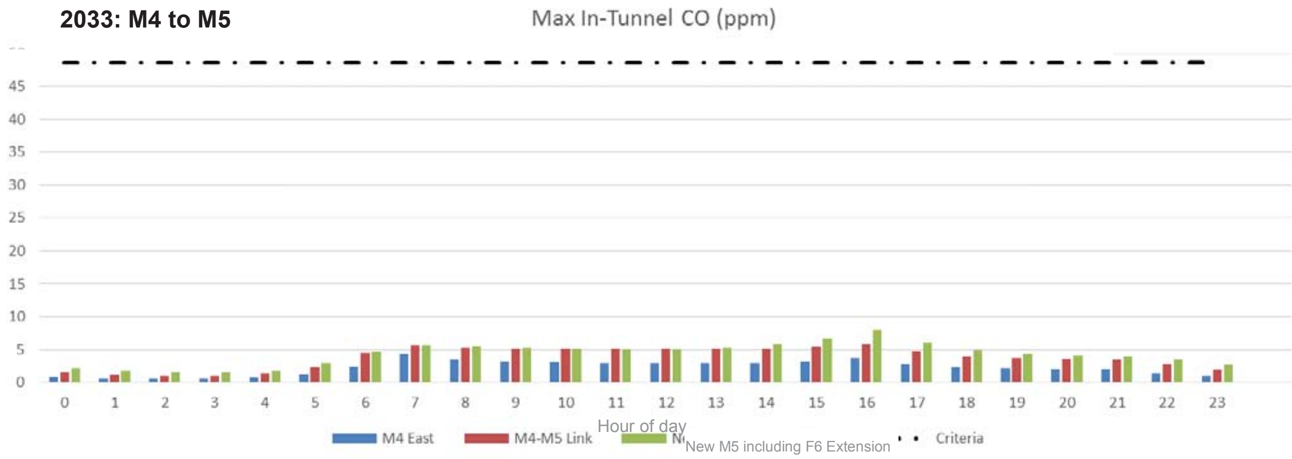
Figure 7-1 presents the maximum one hour concentration of carbon monoxide predicted in the M4 East, M4-M5 Link, New M5 and the proposed future F6 Extension, while travelling in both directions. The figures presented are for the year 2033. The concentrations of carbon monoxide inside the tunnels in 2033 follow the same pattern and are similar in magnitude, with the maximum concentration slightly lower than in 2033.

In relation to the carbon monoxide concentrations predicted within the tunnel, the following is noted:

- The maximum one hour average concentration of carbon monoxide in the tunnels is predicted to be less than 10 ppm in all scenarios. These concentrations are lower than the health based guideline of 25 ppm (one-hour average) established by the WHO (WHO 2010) and 34 ppm established by the USEPA (NHMRC 2008). The concentrations are lower than PIARC in-tunnel limits (Longley 2014)
- The NHMRC (2008) has published measured concentrations of carbon monoxide from a range of tunnels in Sydney and around the world. The measured concentrations come from a number of different studies where the averaging time for the collection of the data varies significantly. This makes it difficult to directly compare the range of reported concentrations with the concentrations predicted in this assessment (ie not comparing data reported over similar averaging/exposure periods). While noting this difficulty in comparing the data, a range of average concentrations of carbon monoxide have been reported from six to 38 ppm (NHMRC 2008). The predicted hourly average concentration in the project tunnel is within the range reported in other tunnels
- The tunnel is designed to meet in-tunnel limits for carbon monoxide. While actual concentrations in the tunnel are expected to be lower than these limits, where the limits are met the following can be noted:
  - The in-tunnel limit for carbon monoxide of 87 ppm as a 15-minute average is equivalent to the health based guideline of 90 ppm (15-minute average) established by the WHO (WHO 2010)
  - The in-tunnel limit for carbon monoxide of 50 ppm as a 30 minute average is the same as the health based guideline of 50 ppm (30 minute average) established by the WHO (WHO 2000a).

On the basis of the above, there are no health issues of concern related to in-tunnel exposures to carbon monoxide. This relates to exposures that may occur in the M4-M5 Link tunnel as well as longer journeys that may include the M4 East or New M5 or other projects where exposures inside the tunnel may be longer, potentially closer to 30 minutes.

2033: M4 to M5



2033: M5 to M4

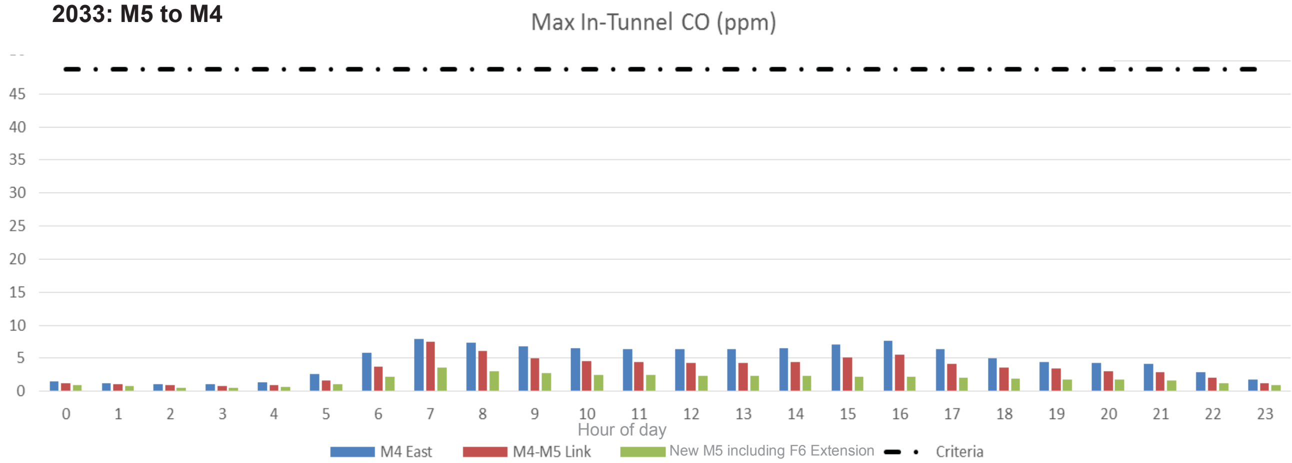


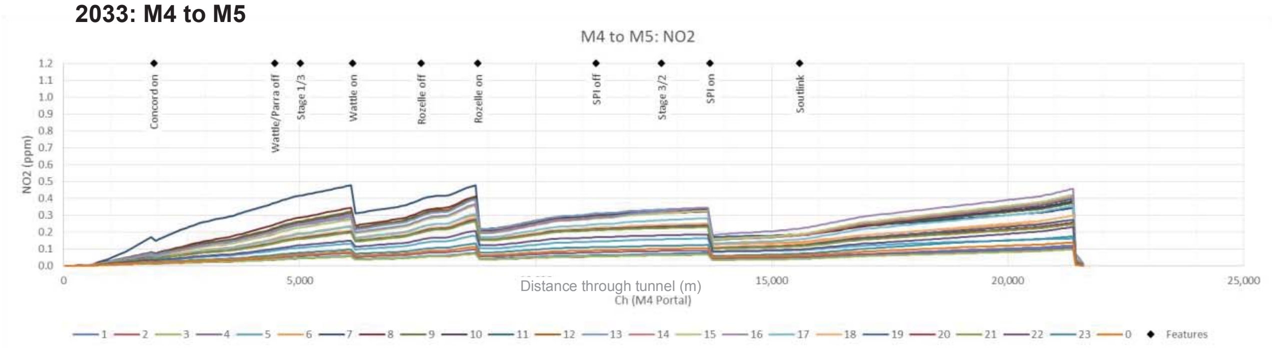
Figure 7-1 Maximum hourly concentration of carbon monoxide in-tunnel (Stacey Agnew 2017)

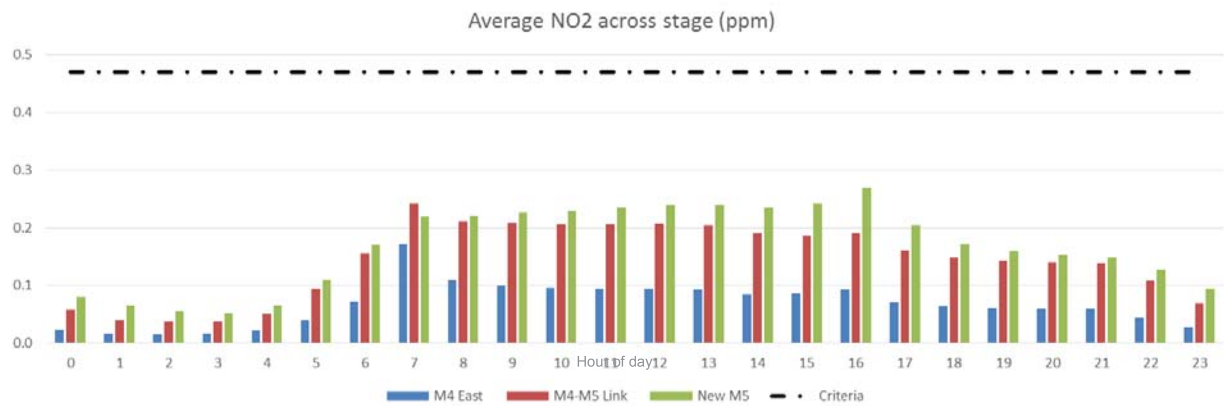
7.3 Nitrogen dioxide

Figure 7-2 presents the concentrations of nitrogen dioxide inside the tunnels, namely M4 East, M4-M5 Link and New M5, during each hour of the day assuming travel through all of these tunnels occurs, in both directions. The average one hour concentration of nitrogen dioxide predicted in these tunnels is also presented. The figures presented are for the year 2033. The concentrations of nitrogen dioxide inside the tunnels in 2033 follow the same pattern and are similar in magnitude, with the maximum concentration slightly lower than in 2033.

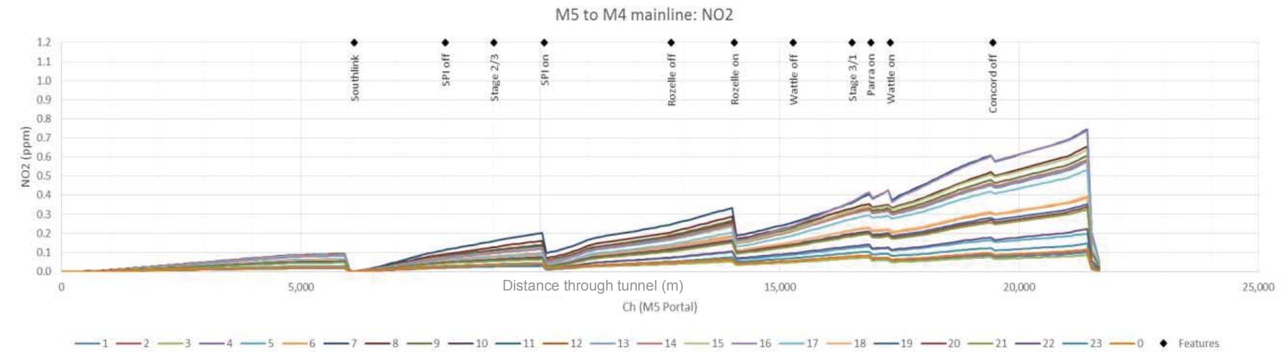
Exposures that may occur within the M4-M5 Link are part of the combined tunnel predictions presented in **Figure 7-2**.

2033: M4 to M5





2033: M5 to M4



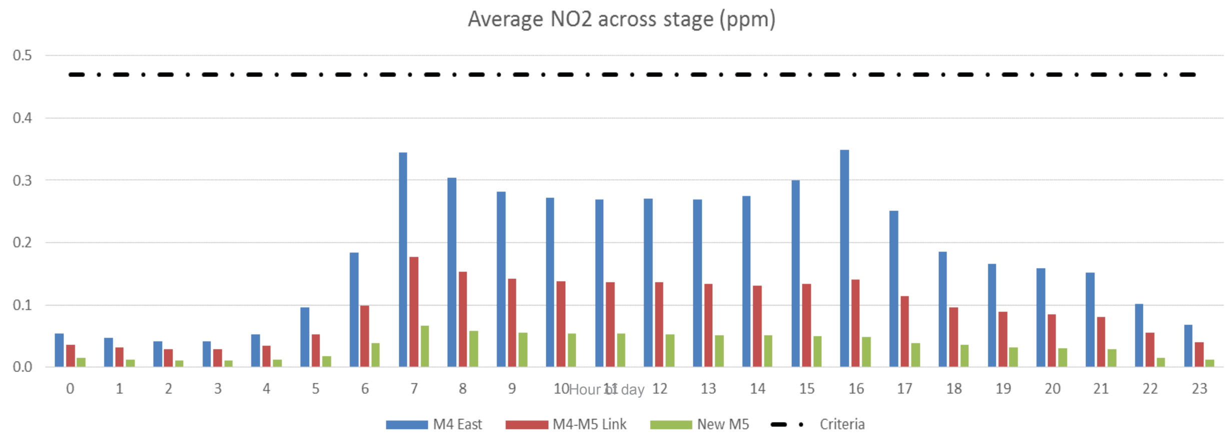


Figure 7-2 Maximum hourly concentration of nitrogen dioxide in-tunnel (Stacey Agnew 2017)

In relation to the nitrogen dioxide concentrations predicted within the M4-M5 Link tunnel, the following is noted:

- The maximum concentrations in the tunnel vary throughout the day, with the maximum concentration predicted at any time of the day less than 0.5 ppm. The average concentration in the tunnel is expected to be (at most) around 0.18 ppm
- The maximum in-tunnel concentrations estimated for travelling at 80 kilometres per hour through the tunnel varies from less than 0.3 ppm when entering the tunnel, depending on the direction of travel to around 0.5 ppm at the Rozelle off-ramp area when travelling from the M4 East. The maximum concentration is equal to the in-tunnel limit of 0.5 ppm (set as a 15-minute average). Actual exposures would only occur in this tunnel for about five to six minutes at an average concentration that ranges up to 0.18 ppm (with windows down). Lower average concentrations of around 0.04 ppm may occur with windows up and ventilation on recirculation
- The NHMRC (2008) has published measured concentrations of nitrogen dioxide from a range of tunnels in Sydney and around the world. The measured concentrations come from a number of different studies where the averaging time for the collection of the data varies significantly. This makes it difficult to directly compare the range of reported concentrations with the concentrations predicted in this assessment (ie not comparing data reported over similar averaging/exposure periods). While noting this difficulty in comparing the data, the NHMRC (2008) have reported a range of average concentrations of nitrogen dioxide in tunnels that range from 0.05 to 0.3 ppm with levels up to 0.4 ppm reported during peak periods. These levels are based on data with averaging times that vary from 30 seconds during travel through a tunnel, six minute averages, to long term data with (unspecified averaging times). At the downstream end of a tunnel (where exposure is very short, ie minutes) levels up to 0.8 ppm have been reported.

In relation to nitrogen dioxide concentrations predicted within the combined tunnels the following is noted:

- The maximum concentrations in any of the tunnels varies depending on the direction and time of travel and location within the tunnels. Where there are major interchanges, air from the tunnels is exhausted to ambient air via the ventilation facilities and fresh air enters the tunnel. This results in a reduction in concentrations at these locations. The concentrations then increase again with further travel through subsequent tunnels. The maximum concentration that may be present inside any of the tunnels, is estimated to be around 0.8 ppm in the M4 East tunnel, prior to exiting the tunnel travelling in a westerly direction
- The average concentration that may be within each tunnel segment, or over a trip that involves travel through connecting tunnels would be lower than the maximums noted above. The average concentration of nitrogen dioxide would vary depending on the time of day and tunnels used. The time spent inside tunnels during these trips would also vary. As noted previously it is highly unlikely that anyone would travel the full length of the WestConnex tunnels (23 kilometres) in any one trip. If the full length of the tunnels was used, travelling at 80 kilometres per hour, the time spent in the tunnels would be about 30 minutes. It is more likely that travel within the WestConnex tunnels would cover about half this distance (for journeys connecting to the city areas), which may result in travel times inside the tunnels ranging from about 15 minutes at 80 kilometres per hour to 30 minutes when the traffic is slower at 40 kilometres per hour.

The concentrations discussed above relate to nitrogen dioxide levels inside the tunnels, not inside the vehicles. A study of nitrogen dioxide concentrations inside vehicles travelling in Sydney and using existing road tunnels was commissioned by Roads and Maritime in 2016 (PEL 2016) to better understand the relationship between nitrogen dioxide outside the vehicle, and inside the vehicle. The study involved a range of vehicles considered representative of the existing vehicle fleet, travelling through existing tunnels in Sydney and simulating travel times between 45 minutes and 60 minutes over a distance of 30 kilometres.

The concentration of nitrogen dioxide that entered a vehicle depended on the concentration outside the vehicle as well as the air exchange rate relevant to the individual vehicle. The air exchange rate depends on the ventilation, whether on recirculation or not, and a range of factors relevant to the vehicle air tightness, or leakiness.

Within existing tunnels utilised in the study, concentrations of nitrogen dioxide were generally less than 0.15 ppm, however during periods of high traffic volume and a high proportion of heavy vehicles, the concentrations inside existing tunnels exceeded 0.5 ppm, with levels up to 0.7 ppm. Inside these tunnels with high external concentrations of nitrogen dioxide, the average concentrations inside the vehicles, when ventilation was on recirculation was less than 0.2 ppm.

The study found that the use of ventilation on recirculation can significantly reduce concentrations of nitrogen dioxide inside vehicles. The ratio of indoor to outdoor concentrations ranged from 0.06 to 0.32. This is consistent with the findings from a NSW Health study on vehicles using the M5 East tunnel, where an indoor to outdoor ratio of 0.25 to 0.3 was determined for nitrogen dioxide where ventilation is set to recirculation. When ventilation was not set to recirculation the concentration of nitrogen dioxide was higher inside the vehicles, and in some cases accumulated inside the vehicle after travelling through short tunnels.

Health effects of short-duration exposures to nitrogen dioxide

A recent review (Jalaludin 2015) has been undertaken to evaluate the available studies in relation to health effects from in-tunnel and short term exposures to nitrogen dioxide. The review evaluated studies associated with exposures that occur for less than 30 minutes as well as those with exposures of more than 60 minutes.

In relation to the available studies (18 studies) that relate to exposures of 30 minutes or less, the review identified the following (Jalaludin 2015):

- There were no effects identified in relation to lung function for individuals exposed to nitrogen dioxide between 0.12 and 0.5 ppm
- The results for inflammatory markers (physiological measures that indicate the respiratory system or other systems in the body are dealing with inflammation) are mixed
- An effect of exposure to nitrogen dioxide and airway responsiveness was identified in individuals with asthma
- There is no clear evidence of a dose-response relationship for exposure and airway responsiveness for nitrogen dioxide levels at or below 0.5 ppm
- The effects observed for airway responsiveness may be transient. There is no clear evidence that repeated exposure to nitrogen dioxide leads to cumulative effects.

In relation to the available studies (14 studies) that relate to exposures of 60 minutes or more, the review identified the following (Jalaludin 2015):

- There were no effects identified in relation to lung function for individuals exposed to nitrogen dioxide between 0.3 and 4 ppm
- The results for inflammatory markers are mixed, however overall, inflammatory markers increased after exposure to nitrogen dioxide
- An effect of exposure to nitrogen dioxide and airway responsiveness was identified
- Insufficient data is available to determine any cardiovascular effects (or otherwise)
- One study indicated the effects were attenuated with repeated exposures.

In relation to the available studies (eight studies) from road tunnels, busy roads and subways, the review identified the following (Jalaludin 2015):

- Exposures to nitrogen dioxide were in the range of less than 0.2 ppm (in seven studies) to 0.5 ppm (in one study)
- There were no effects identified in relation to lung function
- Both upper and lower respiratory symptoms were commonly reported after exposure to road tunnel and subway environments
- The results for inflammatory markers are mixed
- The effects on airway responsiveness were unclear.

When considering the studies conducted in road tunnels, busy roadways and in subways it is important to note that nitrogen dioxide is only part of a complex mixture of air pollution, including $PM_{2.5}$, and determining health effects that may be only related to nitrogen dioxide is difficult.

In addition, there are limitations with the available studies, in particular the small number of healthy and mildly asthmatic subjects, and the lack of subjects who are more sensitive to effects of nitrogen dioxide.

However, overall the available studies indicate that for short-duration exposures to nitrogen dioxide at levels around 0.5 ppm and lower the strongest evidence is for effects on airway responsiveness. These effects are generally seen in asthmatics and the effects are small and transient. However, in some cases the effects were considered clinically relevant, particularly for those with asthma. This is consistent with the findings of the review undertaken by NHMRC (NHMRC 2008), that suggested exposure to elevated concentrations of nitrogen dioxide in a congested tunnel is associated with an increased risk of adverse effects for those with asthma.

For the assessment of short duration exposures to nitrogen dioxide in ambient air, Australia along with a number of other jurisdictions, have established guidelines for one hour average exposures. These guidelines are based on the available short term studies (considered in the review presented by Jalaludin (2015)) suggesting an increased incidence of lower respiratory tract symptoms in children and aggravation of asthma. The guidelines also include an uncertainty factor to protect susceptible people (ie asthmatic children) and as such they are considered to be protective of adverse health effects for all members of the population. These guidelines relate to a one hour averaging period, which is typically longer than the period of exposure expected within the proposed tunnel network during any one trip.

Table 7-2 presents a summary of the available guidelines for the assessment of short duration exposures to nitrogen dioxide within tunnels, and the available ambient air guidelines.

Table 7-2 Summary of nitrogen dioxide guidelines in-tunnel and for short duration exposures

Jurisdiction/Project	Guideline	Averaging period	Nature of guideline (tunnel design or compliance)
In-tunnel			
NSW (ACTAQ 2016)	0.5 ppm tunnel average	15 minutes	Design and compliance
NorthConnex and WestConnex	0.5 ppm tunnel average	15 minutes	Design and compliance
Brisbane City Council/Clem 7 and LegacyWay tunnels	1 ppm tunnel average	NA	Design
PIARC	1 ppm tunnel average	NA	Design
New Zealand	1 ppm	15 minutes	Design
Belgium	0.5 ppm tunnel average	<20 minutes	Design
France	0.4 ppm tunnel average	15 minutes	Design
Norway	0.75 ppm at midpoint in tunnel 1.5 ppm at end of tunnel	15 minutes	Design and compliance
Hong Kong	1 ppm	5 minutes	Design
Short term ambient air guidelines*			
NSW (NEPM and DEC)	0.12 ppm	1 hour	
WHO and EU	0.1 ppm	1 hour	
Canada	0.1 to 0.2 ppm	1 hour	Range in different jurisdictions
UK	0.15 ppm standard 0.1 ppm objective	1 hour	
NZ	0.1 ppm	1 hour	

Jurisdiction/Project	Guideline	Averaging period	Nature of guideline (tunnel design or compliance)
US	0.1 ppm	1 hour average as 98th percentile averaged over 3 years	

* These are regional air guidelines relevant for the assessment of air quality in airsheds, in areas located away from specific sources (including major roadways).

Further consideration of potential exposures within tunnels

The average concentration of nitrogen dioxide has been calculated for all sections of tunnels within the combined (cumulative) tunnel network for different hours of the day, travelling in different directions (Stacey Agnew 2017). These are estimates of the average concentration of nitrogen dioxide inside each of the tunnel segments and for a range of different trips that may take place within the tunnel network. These estimates have been presented for expected traffic conditions (varying by hour of the day and the presence of congested traffic, particularly during peak travel times) as well as an extreme congestion case where traffic travels at an average spend of 20 kilometres per hour. Exposures to nitrogen dioxide within the tunnels during each of these scenarios has been further considered in this assessment.

With windows up and ventilation on recirculation the concentrations that may be present inside vehicles would be lower. The concentrations of nitrogen dioxide inside the vehicle is the point of exposure and what should be considered in relation to the potential for health effects.

In relation to assessing exposures within vehicles using the tunnels, in-vehicle nitrogen dioxide levels have been taken to be equal to the in-tunnel average for the segment travelled multiplied by 0.3, the upper end of the range of ratios for indoor:outdoor nitrogen dioxide levels from the studies undertaken.

For individuals using other modes of transport, the following can be noted:

- Individuals using motorbikes would not have the opportunity to reduce exposure inside the tunnel through the use of ventilation controls. However, the time spent inside tunnels would be less than for other users, particularly in heavy traffic, as motorcyclists can lane filter when traffic is travelling at 35 kilometres per hour and slower. This would limit the amount of time that motorcyclists spend inside the tunnel, even during worst case congested conditions
- Individuals travelling in buses may also be exposed to nitrogen dioxide inside the bus. It is understood that NSW buses have air conditioning and ventilation systems that include recirculation, with new buses[11] allowing a minimum of 10 per cent fresh air at all times to maximum passenger comfort and minimise excess levels of carbon dioxide. Buses may also be leakier than passenger vehicles, resulting in more outdoor air entering the bus. However, the volume of air inside a bus is much greater than in a passenger vehicle and hence air entering from outdoors would be mixed in a larger volume. No data is available for the air exchange rates in Sydney buses. Published data suggests highly variable values in the range of 2.6 to 4.55 air changes per hour for more modern school buses and 16 air exchanges per hour for an older (pre-1998) bus (Knibbs, de Dear & Atkinson 2009). Adopting the nitrogen dioxide model established by Roads and Maritime (PEL 2016), a well ventilated older bus with 16 air exchanges per hour results in an indoor:outdoor ratio for nitrogen dioxide of 0.3, the same as measured for the older/leakier vehicles considered in the RMS study. A lower ratio is calculated for a tighter modern bus. Hence the adjustment of 0.3 to calculate indoor air concentrations of nitrogen dioxide inside passenger vehicles can also be applied to buses.

[11] http://www.transport.nsw.gov.au/sites/default/files/b2b/busreform/bus-specification-double-deck-two-door-city.pdf

Table 7-3 and **Table 7-4** present a summary of the maximum (by time of the day) predicted average concentrations of nitrogen dioxide for various different routes of travel using different parts of the tunnel system (assuming all tunnel projects are completed in 2033), for expected traffic within the tunnel. Average nitrogen dioxide levels in some of the travel routes have also been calculated for the extreme congestion scenario of traffic at 20 kilometres per hour. The tables also present the estimated worst case in-cabin or inside concentration of nitrogen dioxide, where windows are up and ventilation is on recirculation.

Table 7-3 Average nitrogen dioxide levels for different trips using completed tunnel network 2033: M4 to M5 travel direction

Path No.	Travel			Tunnels used for travel along path				Average NO_2 concentration (ppm) – Maximum from travel over all hours of the day				
								Expected traffic		Hour of day for maximum: expected traffic	Extreme congestion	
	Enter at	Exit at	Distance	M4 East	M4-M5 Link	New M5	F6 Extension*	In-tunnel	In-vehicle (recirculation)		In-tunnel	In-vehicle (recirculation)
1A	M4 East	Wattle St	5.4 km	X				0.18	0.055	7am		
1B	M4 East	Parra. Rd	5.5 km	X				0.18	0.054	7am		
1C	M4 East	Anzac Bridge	9.9 km	X	X			0.29	0.088	7am		
1D	M4 East	St Peters	12.4 km	X	X			0.28	0.084	7am		
1E	M4 East	New M5	21.6 km	X	X	X		0.26	0.080	7am	0.44	0.13
1F	M4 East	F6 Extension	19.5 km	X	X	X	X	0.25	0.076	7am		
1G	Concord Rd	Wattle St	4.3 km	X				0.20	0.061	7am		
1H	Concord Rd	Parra. Rd	4.4 km	X				0.20	0.059	7am		
1J	Concord Rd	Anzac Bridge	8.8 km	X	X			0.32	0.095	7am		
1K	Concord Rd	St Peters	11.4 km	X	X			0.30	0.089	7am		
1L	Concord Rd	New M5	20.6 km	X	X	X		0.27	0.082	7am		
1M	Concord Rd	F6 Extension	18.4 km	X	X	X	X	0.26	0.079	7am	0.39	0.12
1N	Wattle St	Anzac Bridge	4.6 km		X			0.31	0.093	7am	0.36	0.11
1P	Wattle St	St Peters	6 km		X			0.25	0.076	7am	0.46	0.14
1Q	Wattle St	New M5	15.2 km		X	X		0.27	0.081	4pm	0.45	0.14
1R	Wattle St	F6 Extension	13 km		X	X	X	0.25	0.074	4pm	0.38	0.11
1S	WHT	St Peters	6 km		X			0.19	0.057	11am to 1pm	0.41	0.12
1T	WHT	New M5	15.2 km		X	X		0.25	0.075	4pm	0.43	0.13
1U	WHT	F6 Extension	13 km		X	X	X	0.23	0.068	4pm	0.34	0.10
1V	St Peters	New M5	9.1 km			X		0.26	0.078	4pm		
1W	St Peters	F6 Extension	6.9 km			X	X	0.22	0.066	4pm		
1X	Iron Cove	Anzac Bridge	1.2 km		X			0.0090	0.0027	7am		
1Y	Iron Cove	St Peters	6.4 km		X			0.18	0.054	10am to 1pm	0.39	0.12
1Z	Iron Cove	New M5	15.6 km		X	X		0.24	0.073	4pm	0.42	0.13
1AA	Iron Cove	F6 Extension	13.4 km		X	X	X	0.22	0.066	4pm	0.33	0.10
1AB	CWL	St Peters	5.1 km		X			0.22	0.066	10am to 1pm	0.47	0.14
1AC	CWL	New M5	14.3 km		X	X		0.27	0.080	4pm	0.45	0.14
1AD	CWL	F6 Extension	12.1 km		X	X	X	0.24	0.073	4pm	0.36	0.11
NO_2 guideline: 15 minute average = 0.5 ppm												
NO_2 guideline: 1 hour average = 0.12 ppm												

Table 7-4 Average nitrogen dioxide levels for different trips using completed tunnel network 2033: M5 to M4 travel direction

Path No.	Travel			Tunnels used for travel along path				Average NO_2 concentration (ppm) – Maximum from travel over all hours of the day				
								Expected traffic		Hour of day for maximum	Extreme congestion	
	Enter at	Exit at	Distance	M4 East	M4-M5 Link	New M5	F6 Extension*	In-tunnel	In-vehicle (recirculation)		In-tunnel	In-vehicle (recirculation)
2A	New M5	St Peters	9.2 km			X		0.06	0.02	7am		
2B	New M5	WHT	14.8 km		X	X		0.12	0.04	7am		
2C	New M5	Wattle St	16.4 km		X	X		0.13	0.04	7am		
2D	New M5	Concord Rd	20.6 km	X	X	X		0.18	0.05	7am		
2E	New M5	M4 East	21.7 km	X	X	X		0.23	0.07	7am	0.46	0.14
2F	F6 Extension	St Peters	7.1 km			X	X	0.05	0.02	7am		
2G	F6 Extension	WHT	12.8 km		X	X	X	0.13	0.04	7am		
2H	F6 Extension	Wattle St	14.3 km		X	X	X	0.14	0.04	7am		
2J	F6 Extension	Concord Rd	18.5 km	X	X	X	X	0.19	0.06	7am		
2K	F6 Extension	M4 East	19.7 km	X	X	X	X	0.24	0.07	7am	0.41	0.12
2L	St Peters	WHT	5.6 km		X			0.19	0.06	7am	0.42	0.13
2M	St Peters	Wattle St	7.1 km		X			0.20	0.06	7am	0.42	0.13
2N	St Peters	Concord Rd	11.3 km	X	X			0.26	0.08	7am		
2P	St Peters	M4 East	12.5 km	X	X			0.34	0.10	7am	0.46	0.14
2Q	Anzac Bridge	Wattle St	4.7 km		X			0.12	0.04	7am	0.29	0.09
2R	Anzac Bridge	Concord Rd	8.9 km	X	X			0.24	0.07	7am	0.29	0.09
2S	Anzac Bridge	M4 East	10 km	X	X			0.34	0.10	7am	0.41	0.12
2T	Parra. Rd onramp	Concord Rd	4.4 km	X				0.31	0.09	7am		
2U	Parra. Rd onramp	M4 East	5.5 km	X				0.47	0.14	7am		
2V	Wattle St	Concord Rd	4.4 km	X				0.27	0.08	4pm		
2X	Wattle St	M4 East	5.6 km	X				0.43	0.13	4pm		
2Y	New M5	Iron Cove	15.6 km		X	X		0.12	0.04	7am	0.46	0.14
2Z	New M5	CWL	14.4 km		X	X		0.11	0.03	7am	0.43	0.13
2AA	F6 Extension	Iron Cove	13.6 km		X	X		0.13	0.04	7am	0.39	0.12
2AB	F6 Extension	CWL	12.3 km		X	X		0.12	0.04	7am	0.35	0.11
2AC	St Peters	Iron Cove	6.4 km		X			0.19	0.06	7am	0.46	0.14
2AD	St Peters	CWL	5.1 km		X			0.18	0.05	7am	0.38	0.11
2AE	Anzac Bridge	Iron Cove	1.3 km		X			0.05	0.01	9am to 2pm	0.16	0.05
2AF	WHT	Wattle St	4.7 km		X			0.12	0.04	7am	0.29	0.09
2AG	WHT	Concord Rd	8.9 km	X	X			0.24	0.07	7am	0.29	0.09
2AH	WHT	M4 East	10 km	X	X			0.34	0.10	7am	0.41	0.12
NO_2 guideline: 15 minute average = 0.5 ppm												
NO_2 guideline: 1 hour average = 0.12 ppm												

The amount of time spent travelling on each route would vary depending on the length of the segment and travel speeds. It is unlikely that travel along any segment, under expected traffic conditions, would take an hour. The longest travel segments may take up to half an hour, hence comparing the in-cabin nitrogen dioxide levels with a one hour average guideline is conservative. For the short travel segments, it is not appropriate to consider the one hour average guideline. For these the 15-minute average guideline would be applicable.

Concentrations of nitrogen dioxide inside vehicle that may use different routes for travel under the expected traffic conditions, including the longest length of combined tunnels connecting the M4 to the M5, are generally well below the 15-minute average and one hour average guidelines. There are two short travel segments (2U and 2X, both less than six kilometres in length) where the average concentration of nitrogen dioxide exceeds the one hour average concentration, however the time spent in these segments would be very short and hence it is not applicable to compare the average concentrations against a one hour average. The concentrations of nitrogen dioxide in these segments is well below the 15-minute average guideline.

Under the extreme congestion scenario, where vehicles are travelling at 20 kilometres per hour, in-tunnel and potential in-vehicle nitrogen dioxide levels are higher. In addition, it is likely that the amount of time spent in the tunnel would be longer, with the longest travel segments potentially taking an hour to cover. The average concentrations of nitrogen dioxide in-vehicle range from 0.09 to 0.14 ppm. These averages sit around the one hour average guideline of 0.12 ppm, with some minor exceedance. It is highly unlikely that the extreme congestion conditions would occur, and that if it does occur, that it would persist for an entire long journey of up to 21.7 kilometres inside the tunnels. Hence the assessment presented is expected to be conservative. On this basis, it is not considered likely that significant adverse health effects would occur as a result of travel that may occur during congested conditions.

In relation to travel by motorcycles, or passengers in vehicles where advice to keep windows up and ventilation on recirculation is not adopted, potential exposures within the tunnels during expected traffic conditions, over the various travel segments varies between 0.009 to 0.47 ppm, with most of the concentrations in the range 0.1 to 0.3 ppm. The concentrations are below the 15-minute average guideline, which would be relevant for travel by motorcycle through most of the travel segments. Travel through longer segments (around 20 kilometres) may take longer, around 20 minutes (or slightly longer). The available health data does not suggest that exposures for a period of 20-30 minutes would be of greater concern than for 15 minutes. As such no significant health effects are expected to occur.

During the extreme congestion scenario, while average nitrogen dioxide concentrations are higher, the time spent inside the tunnels under these conditions would remain short for motorcyclists. As a result, the average nitrogen dioxide levels within the tunnel can be compared against the 15-minute average guideline. It is also noted that the scenario is conservative, particularly for the longer travel segments. All average nitrogen dioxide concentrations in the travel segments are below this guideline and hence no significant adverse health effects are expected for motorcyclists using the tunnels under these conditions.

It is noted that the 15-minute average guideline is not protective of all health effects for all individuals. There is the potential for asthmatic individuals who utilise motorbikes to experience some minor change in respiratory response after using the tunnels, particularly when congested.

During extreme congestion, for passengers in vehicles where advice to keep windows up and ventilation on recirculation is not adopted, the duration of exposure will be longer than assumed for motorcyclists. It is not likely that such exposures would result in adverse health effects, however the potential for asthmatic individuals to experience some minor change in respiratory response after using the tunnels (under extreme congestion conditions) cannot be excluded.

Repeated use of tunnels also requires consideration. The available data on health effects associated with short-duration exposures indicates the effects are transient, ie only relate to the peak exposure that has occurred. Repeated exposures that may occur as a result of morning peak and afternoon peak travel, have not been considered to be additive. Provided the average nitrogen dioxide concentrations that occur during the travel times in the vehicle are below the health based guidelines, which is expected to be the case for the expected traffic conditions, then no significant adverse health effects are expected.

For individuals involved in occupations that may require more regular use of the road network, such as taxi and courier drivers, there is the potential for these individuals to make more frequent and varied trips over different travel segments in any one day. For these drivers, it is important that they keep their window up and ventilation on recirculation to minimise exposures throughout the day.

7.4 Particulate matter

There are no health based guidelines available for the assessment of short-duration exposures to PM within a tunnel. In-tunnel criteria relate to visibility (and safety in using the tunnel). It is expected that the concentration of PM within the tunnel would be higher than ambient air concentrations, and the concentration of PM would increase with increasing distance travelled through the tunnel.

Potential concentrations of PM inside the tunnel are derived from exhaust as well as non-exhaust sources. Non-exhaust sources include tire and break wear and dust from surface road wear and the resuspension of road dust. The modelling of PM and visibility issues within the tunnel has considered both sources. **Table 7-5** presents a summary of the peak concentrations of PM estimated inside the tunnels in 2023, for the expected traffic conditions.

Table 7-5 Predicted peak concentrations of particulate matter in-tunnel: 2023

Scenario/Tunnel segment	Peak PM concentration (mg/m^3)			
	Exhaust		Non-exhaust sources	
	With project	Cumulative	With project	Cumulative
M4-M5				
M4 East	0.05	0.07	0.31	0.39
M4-M5 Link	0.07	0.09	0.42	0.52
New M5 including F6 Extension	0.07	0.08	0.56	0.64
M5-M4				
New M5 including F6 Extension	0.03	0.03	0.36	0.2
M4-M5 Link	0.06	0.07	0.35	0.44
M4 East	0.1	0.12	0.6	0.68

The characteristics of PM derived from exhaust and non-exhaust sources would be different.

The available evidence suggests that non-exhaust particles are generally larger than exhaust particles. It is likely that non-exhaust particles are greater than 10 micrometres in diameter, however this is not well characterised. Where the particles are larger than 10 micrometres in diameter they are of less importance in terms of potential health effects, as these relate to the finer particles that are less than 10 micrometres in diameter, with stronger health effects relevant to exposure to particles less than 2.5 micrometres in diameter. The tunnel design and air quality assessment is based on non-exhaust PM emission factors that relate to PM_{10} and $PM_{2.5}$ from relevant emissions studies. PM from exhaust is expected to be largely fine particulates, ie PM_{10} and $PM_{2.5}$, that are of importance to health.

In relation to the PM concentrations predicted within the tunnel, the following is noted:

- The in-tunnel concentrations for PM are taken to be PM_{10} concentrations where concentrations of $PM_{2.5}$ are likely to comprise a significant portion of the PM_{10} concentration, particularly for exhaust emissions
- PM_{10} concentrations within the tunnels are dominated by non-exhaust sources
- The maximum concentration of PM_{10} in the tunnels evaluated are up to 0.7 milligrams per cubic metre for the project, and 0.8 milligrams per cubic metre for the cumulative scenario. The average concentration in the tunnels would be lower than the peak concentration predicted, potentially up to 50 per cent of that reported as the peak concentration. When windows are up and ventilation is on recirculation the average level of PM_{10} inside a vehicle would be lower, potentially up to 0.08 milligrams per cubic metre

- As a significant proportion of in-tunnel particulate matter is non-exhaust, regular cleaning of tunnel roadways may reduce these levels.

Review of short duration exposure to particles

In relation to assessing potential short-duration exposures to particles, the following should be noted:

- The NHMRC (2008) has published measured concentrations of particulates (as $PM_{2.5}$ and PM_{10}) from a range of tunnels in Sydney and around the world. The measured concentrations come from a number of different studies where the sampling methodology and averaging time for the collection of the data varies significantly. This makes it difficult to directly compare the range of reported concentrations with the concentrations predicted in this assessment (ie not comparing data reported over similar averaging/exposure periods). While noting this difficulty in comparing the data, the range of average concentrations of $PM_{2.5}$ reported typically range from around 0.03 to 0.343 milligrams per cubic metre (AMOG 2012; NHMRC 2008). These levels are based on data with averaging times that vary from one hour averages, peak hour averages, daytime averages to 24 hour averages
- The exposure-response relationships for particulate matter that have been established on the basis of adverse health effects from short term exposures relate to changes in the health effects associated with variability in 24 hour average concentrations of $PM_{2.5}$ in urban air. They do not relate to much shorter variations in $PM_{2.5}$ exposure that may occur within a 24 hour period, where there may be exposures over a few minutes to higher levels of $PM_{2.5}$. No guidelines are currently available for assessing potential health effects that may occur as a result of exposures to particulates that may occur for minutes (or even an hour)
- Recent review (WHO 2013b) of available studies in relation to short duration (less than 24 hour) exposures to particulates indicates the following:
  - Epidemiological and clinical studies have demonstrated that sub-daily exposures to elevated levels of particulate matter can lead to adverse physiological changes in the respiratory and cardiovascular system, in particular exacerbation of existing disease. This is generally consistent with the outcome of studies reviewed and considered by the USEPA (USEPA 2009b)
  - The studies available do not cover a range of exposure concentrations, nor do they adequately address other variables such as co-pollutants (gases) or repeated short-duration exposures
  - The studies have not determined if a one hour exposure would lead to a different response than a similar dose spread over 24 hours, or if an exposure-response can be determined
  - Exposures that occur during the use of various transportation methods (such as in-vehicles) have been found to contribute to and affect 24 hour personal exposures.

The urban epidemiology studies (upon which exposure-response relationships are based and have been used in this assessment) utilise health data for adverse health effects from an urban population, where the urban population would have been exposed to ambient levels of particulate matter (as measured by air monitoring stations) as well as fluctuations that occur throughout the day during various daily activities including in-vehicle exposures (and others such as cooking). These large urban studies have related health effects to regional ambient (urban) air concentrations. They have not measured daily (or longer term) personal exposures to particulate matter, but such fluctuations would occur within the population exposed and would be expected to be accounted for within the health data considered in the epidemiology studies. Specific health effects from the short duration variations in particulate exposures throughout any specific day cannot be determined from these studies. It is therefore important to consider if exposures to $PM_{2.5}$ in the project tunnels would be consistent with other tunnels or in-vehicle exposures (during commuting in an urban environment), where the following can be considered:

- Exposure to particulate matter within vehicles varies with the intensity of the traffic, the age of the vehicle the choice of ventilation used within the vehicle and the type of fuel used (Knibbs, de Dear & Morawska 2010). Levels of $PM_{2.5}$ reported in vehicles in Europe (ETC 2013) vary from 0.022 to 0.085 milligrams per cubic metre for passenger cars and 0.026 to 0.13 milligrams per cubic metre for bus travel

- Levels of $PM_{2.5}$ that have been measured within cars while commuting in Sydney (where tunnel travel was not part of the study) range from 0.009 to 0.045 milligrams per cubic metre (NSW Health 2004)
- Keeping windows closed and switching ventilation to recirculation has been shown to reduce exposures to particulates inside the vehicle by up to 80 per cent (NSW Health 2003). While noting no guidelines are availability for very short duration exposures, this would further reduce exposure to motorists.

7.5 Carbon dioxide issues

To minimise exposures in-vehicle to nitrogen dioxide and particulates the above assessment has relied on Roads and Maritime providing advice to motorists using the proposed tunnels to wind up windows and place ventilation in recirculation. Health issues that may arise from such advice relate to the potential build-up of carbon dioxide inside the vehicle. An assessment of in-cabin levels of carbon dioxide and potential effects on the health and safety of drivers travelling through tunnels over varying distances and times, has been completed by Roads and Maritime in 2017 (enRiskS 2017). Based on this study for vehicles that may include between one and five occupants, travelling through tunnels for up to an hour, the levels of carbon dioxide were not expected to adversely affect driver safety.

Assessment of potential exposures that may occur for periods of time up to two hours, where ventilation is left on recirculation indicates that there may be levels of carbon dioxide inside a vehicle where there are one or more passengers that may affect an already fatigued driver.

It is noted that there is a general lack of guidance or regulations in terms of the design or use of ventilation systems in vehicles in Australia. Hence there is currently no advice to drivers on the suitable use of ventilation in various circumstances, to minimise the potential for effects on already fatigued drivers.

Where Roads and Maritime provides specific advice to drivers entering road tunnels to put ventilation on recirculation, it is recommended that further advice is provided that recirculation should be switched off at some point after using the tunnel network and not left on for an extended period of time.

7.6 Overall assessment

Impacts within the tunnel: while concentrations of pollutants from vehicle emissions are higher within the tunnel (compared with outside the tunnel), and with the completion of a number of tunnel projects (approved or proposed) there is the potential for exposures to occur within a network of tunnels over varying periods of time, depending on the journey. The assessment of potential exposures inside these tunnels, has indicated:

- Where windows are up and ventilation is on recirculation, exposure to nitrogen dioxide inside vehicles is expected to be below the current health based guidelines. In congested conditions inside the tunnels, it is not considered likely that significant adverse health effects would occur. Placing ventilation on recirculation is also expected to minimise exposures to particulates during travel through the tunnels
- For motorcyclists, where there is no opportunity to minimise exposures through the use of ventilation, there is the potential for higher levels of exposure to nitrogen dioxide are particulates. These exposures, under normal conditions, are not expected to result in adverse health effects. When the tunnels are congested it is expected that motorcyclists would spend less time in the tunnels than passenger vehicles and trucks, limiting the duration of exposure and the potential for adverse health effects
- For individuals who regularly use tunnels for commuting or as part of their employment there is the potential for repeated exposures to higher levels of nitrogen dioxide and particulates during the day. While these exposures are not likely to be additive, in terms of potential health effects, it is important that these road users utilise ventilation on recirculation whenever they are using the tunnels
- Where advice is provided to place ventilation on recirculation when using the tunnel or the proposed network of tunnels, it is not expected to result in carbon dioxide levels inside the vehicle

that may adversely affect driver safety. However, where Roads and Maritime provides specific advice to drivers entering road tunnels to put ventilation on recirculation, it is recommended that further advice is provided that recirculation should be switched off at some point after using the tunnel network and not left on for an extended period of time.

8 Assessment of changes in noise and vibration on community health

8.1 General

A detailed assessment of noise and vibration impacts associated with the project is presented in **Appendix J** (Technical working paper: Noise and vibration) of the EIS prepared by SLR Consulting Australia Pty Ltd (SLR 2017).

Appendix J (Technical working paper: Noise and vibration) of the EIS has been reviewed to determine if the predicted impacts have the potential to affect the health of the surrounding community, and if impacts are predicted, if they can be effectively mitigated. The assessment of noise has considered impacts at a number of different receptors (termed noise receivers, or receivers within the Technical Working Paper: Noise and vibration).

For the assessment of noise and vibration impacts the project area has been divided into study areas as follows:

- Haberfield and surrounds
- Darley Road in Leichhardt and surrounds
- Rozelle, Lilyfield, Annandale, Glebe and Pyrmont
- Iron Cove and surrounding areas
- Pyrmont Bridge Road and surrounds
- St Peters and surrounds.

The assessment of noise during construction and operations involved consideration of impacts at 56 Noise catchment areas (NCAs) presented in the figures in **Annexure I**.

8.2 Existing noise environment

8.2.1 General

The study area is an urbanised environment where the existing ambient noise environment is described as variable and is dominated by proximity to major roadways.

To undertake the noise assessment required for the project, the existing background noise quality needed to be assessed as the guidelines that relate to noise impacts from a specific project are based on levels allowable above background.

8.2.2 Ambient noise monitoring

Existing ambient noise was measured at 23 locations (refer to **Annexure I** for locations) between July and November 2016. This involved the use of unattended noise monitors that continuously recorded noise levels over 15-minute sampling periods. Based on the monitoring undertaken rating background level (RBL) has been calculated for use in in the noise assessment. The RBLs calculated relate to specific time periods (namely daytime, evening and night-time) in the *Interim Construction Noise Guideline* (ICNG) (NSW DECC 2009) and *Road Noise Policy* (RNP) (NSW DECCW 2011) guidelines. In addition, attended monitoring was undertaken at a number of locations to supplement this data.

The noise levels at these locations showed a typical diurnal trend with lower noise levels during the night-time than the daytime and evening periods. This is characteristic of urban and suburban areas where the ambient noise environment is primarily influenced by road traffic.

The data is also consistent with observed traffic flows on the adjacent major roads which have a relatively small reduction in traffic volumes during the evening compared to the daytime period, and a more significant reduction in volumes during the night-time.

The measured noise levels were used with consideration of the existing road traffic flows to calibrate the operational noise model and also to establish construction noise management levels (NML) relevant for the project.

8.2.3 Background noise levels

Noise levels that are measured, or modelled, refer to noise levels over a specified period of time and are presented as L_{A1}, L_{A10}, LA_{90}, L_{Amax} and L_{Aeq} levels of the noise environment. The A-weighting is a frequency filter applied to represent how the human ear hears sound. The L_{A1}, L_{A10} and L_{A90} levels are the levels exceeded for one percent, 10 per cent and 90 per cent of the sample period respectively. The L_{Amax} is indicative of maximum noise levels due to individual noise events. The L_{A90} is taken as the assessment or rating background noise level (ABL or RBL). The L_{Aeq} is the equivalent continuous sound energy level relevant to a period of time.

Background noise levels, termed the RBL, were determined for the assessment of construction noise for different periods of the day: daytime (7.00 am to 6.00 pm Monday to Saturday, 8.00 am to 6.00 pm on Sunday), evening (6.00 pm to 10.00 pm) and night-time (10.00 pm to 7.00 am Monday to Saturday and 10.00 pm to 8.00 am on Sunday). The RBLs determined at each of the monitoring locations varied from 45 to 68 decibels (dB(A)) during the daytime, 43 to 67 dB(A) during the evening and 32 to 51 dB(A) during the night-time.

Background noise levels relevant for evaluating operational impacts involved the use of an energy averaged noise level (L_{Aeq}) that relates to exposures over the daytime (15 hours from 7.00 am to 10.00 pm) and night-time (nine hours from 10.00 pm to 7.00 am). During the daytime, $L_{Aeq\ 15\text{-}hour}$ noise levels ranged from 54 to 73 dB(A). During the night-time, $L_{Aeq\ 9\text{-}hour}$ noise levels ranged from 50 to 70 dB(A)).

8.3 Noise assessment criteria

8.3.1 General

Noise issues in NSW are managed by the NSW EPA. The NSW EPA has prepared a number of guidance documents with regard to the types of noise that are considered in relation to construction and operation of the project. The *NSW Industrial Noise Policy* (INP) (NSW EPA 2000), the RNP (NSW DECCW 2011), and the ICNG (NSW DECC 2009) are all relevant to the assessment of noise generated by this project. In all these policies, there is discussion of the need to balance the economic and social benefits of activities that may generate noise with the protection of the community from the adverse effects of noise. The noise assessment criteria adopted relate to levels of noise that can be tolerated or permitted above background before some adverse effect (annoyance, discomfort, sleep disturbance or complaints) occurs.

The *Construction Noise and Vibration Guideline* (Roads and Maritime 2016) (CNVG) outlines Roads and Maritime's approach to assessing and mitigating construction noise. The *Noise Mitigation Guide* (Roads and Maritime 2015) (NMG) applies to the assessment and management of noise during operations. These guidelines are considered in addition to the other relevant policy and guidelines from the NSW EPA.

For the assessment of noise impacts from the project a range of guidelines and criteria have been adopted for the assessment of:

- Construction – including ground-borne noise, vibration and blasting
- Operations – relevant to road noise.

The following sections provide an overview of the guidelines adopted for each of these aspects. In particular, the basis for the guidelines and relevance to the protection of health and wellbeing is noted.

8.3.2 Construction noise criteria

People are usually more tolerant to noise and vibration during the construction phase of projects than during normal operation. This response results from recognition that the construction emissions are of a temporary nature – especially if the most noise-intensive construction impacts occur during the less sensitive daytime period. For these reasons, acceptable noise and vibration levels are normally higher during construction than during operations.

Construction often requires the use of heavy machinery which can generate high noise and vibration levels at nearby buildings and receptors. For some equipment, there is limited opportunity to mitigate the noise and vibration levels in a cost-effective manner and hence the potential impacts should be minimised by using feasible and reasonable management techniques.

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

Appendix J (Technical working paper: Noise and vibration) of the EIS has considered construction noise impacts associated with construction activities for the M4-M5 Link, proposed to occur from 2018 to 2023. There are some areas within the community were construction impacts from a number of road projects are proposed, with these works occurring over a longer period of time, potentially up to eight years. Further discussion on issues related to these longer duration impacts, ie construction fatigue, are further addressed in **section 10.8**.

The ICNG has been adopted for the assessment of noise during construction works (NSW DECC 2009). These guidelines require that noise impacts from the project be predicted at sensitive receptors. These noise levels are then compared with the project specific criteria, referred to as management levels, which are based on an increase above background levels. Where an exceedance occurs, the guidelines require that the proponent must apply all feasible and reasonable work practices to minimise impacts. The management levels are based on levels of noise above background that may result in reactions (or complaints) by the community. The levels are based on some reaction (noise affected) and a strong reaction (highly noise affected).

Levels of noise allowable outside standard work hours, particularly at night, are lower than those permitted during normal work hours. Where construction works are planned to extend over more than two consecutive nights a sleep disturbance assessment is required to be undertaken. Based on the available information on the levels of noise that result in sleep disturbance the following has been adopted:

- A maximum internal noise level below 50–55 dB(A) is considered unlikely to cause awakening
- One or two noise events per night, with a maximum internal noise level of 65–70 dB(A) are not likely to significantly affect health and wellbeing.

The project has considered that a closed window provides up to 10 dB(A) attenuation of noise from outdoors to indoors. The assessment of noise impacts during construction has been undertaken based on 56 noise catchment areas (assumed to have background noise levels consistent with the background noise monitoring location within each catchment area).

The ICNG does not provide direct reference to an appropriate criterion to assess the noise arising from construction traffic on public roads. However, it does refer to the Road Noise Policy which presents a discussion on assessing feasible and reasonable mitigation measures. In assessing feasible and reasonable mitigation measures, an increase of up to 2 dB(A) represents a minor impact that is considered barely perceptible to the average person. Therefore, the noise goal applied to traffic movements on public roads generated during the construction phase of the project is an increase in existing road traffic noise levels of no more than 2 dB(A).

Where construction would be undertaken during the night-time period the potential for sleep disturbance should be assessed. The current approach to identifying potential sleep disturbance impacts is to predict maximum noise levels and assess against a screening criterion 15 dB(A) above the RBL during the night-time period (10.00 pm–7.00 am).

8.3.3 Ground-borne noise criteria

The ICNG provides residential NMLs for ground-borne noise, which are applicable when ground-borne noise levels are higher than the corresponding airborne construction noise levels such as might occur during tunnelling. The ICNG provides ground-borne noise levels at residences for evening and night-time periods only, as the objectives are to protect the amenity and sleep of people when they are at home. The following ground-borne noise levels are applicable for residences:

- Evening 40 dB(A) $L_{Aeq\ (15\ minute)}$
- Night-time 35 dB(A) $L_{Aeq\ (15\ minute)}$.

For commercial properties, an internal ground-borne noise level of 60 dB(A) as $L_{Aeq\ (15\ minute)}$ has been adopted, to identify impacts.

These guidelines are applicable during tunnelling and other construction activities.

8.3.4 Vibration criteria

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

- **Human comfort**: Those in which the occupants or users of the building are inconvenienced or possibly disturbed. These guidelines are of most relevance to the assessment of community health. Intermittent vibration has been evaluated on the basis of the NSW EPA guideline *Assessing Vibration: A Technical Guideline* (NSW DEC 2006), which is based on vibration dose values (VDV). The criteria for VDV are based on the potential for annoyance (based on the level of vibration over the assessment period). Guidelines for continuous and impulsive vibration are dependent on the time of day they occur and the activity taking place that could be affected

- **Building contents**: Those where the building contents may be affected. As people perceive floor vibration well before levels are likely to cause damage to building contents and structures, for most areas controlling vibration to manage human comfort would also address damage to building contents. No separate criteria are adopted to evaluate this aspect

- **Structural damage**: Those in which the integrity of the building or the structure itself may be prejudiced (structural damage). Most commonly specified 'safe' structural vibration limits are designed to minimise the risk of threshold or cosmetic surface cracks, and are set well below the levels that have potential to cause damage to the main structure. The assessment of potential structural damage has been undertaken in accordance with Australian Standard AS2187, British Standard BS 7385 and German Standard DIN 4150:Part 3-1999 (DIN 1999). These guidelines include criteria relevant to addressing blasting activities.

8.3.5 Operational noise criteria

Operational noise impacts have been evaluated on the basis of the RNP, with additional guidance and criteria provided within Roads and Maritime's *Noise Criteria Guideline* (NCG) and NMG. The principles underlying the guidance documents are:

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

The project consists of both new and redeveloped roads or road sections according to the definitions in the guidance documents and so both road types need to be considered in developing project-specific limits.

For residential areas, criteria are established for properties near either freeway/arterial/sub-arterial roads or local roads. These criteria relate to noise levels during the daytime (7.00 am to 10.00 pm) and night-time (10.00 pm to 7.00 am). Night-time noise criteria are aimed at minimising sleep disturbance. Criteria are also available to assessed noise exposures in other types of buildings, including schools, places of worship, open space, childcare, aged care and hospital facilities.

Operational traffic noise from the surrounding road network also required some consideration, with criteria (ie an increase by more than 2 dB(A)) established to determine if such impacts need to be further considered. Guidelines are also available to evaluate maximum noise levels from roadways, such as those from individual vehicles or trucks (eg engine braking). It is noted that there are a range of strategies being implemented across the State to reduce the number of maximum noise events.

The assessment has also evaluated noise from the operation of fixed facilities, namely the jet-fans within the tunnels, ventilation facilities, substations and water treatment plants. Noise from these facilities have been assessed on the basis of criteria in the NSW INP. This policy established criteria for daytime, evening and night-time noises, as well as criteria relevant to the assessment of sleep disturbance.

The current approach to assessing potential sleep disturbance is to apply an initial screening criterion of background (or RBL) plus 15 dB(A) (as described in the Application Notes to the INP), and to undertake further analysis if the screening criterion cannot be achieved. The sleep disturbance screening criterion applies outside bedroom windows during the night-time period. Where the screening criterion cannot be met, additional analysis should consider the level of exceedance as well as factors such as:

- How often high noise events would occur
- The time of day (normally between 10.00 pm and 7.00 am)
- Whether there are times of day when there is a clear change in the noise environment (such as during early morning shoulder periods).

Other guidelines that contain additional advice relating to potential sleep disturbance impacts should also be considered, including the RNP (NSW DECCW 2011). The RNP provides a review of research into sleep disturbance. From the research to date, the RNP concludes that:

- Maximum internal noise levels of 50–55 dB(A) L_{AFmax} are unlikely to awaken people from sleep
- One or two events per night, with maximum internal noise levels of 65 to 70 dB(A) L_{Afmax}, are not likely to affect health and wellbeing significantly.

It is generally accepted that internal noise levels in a dwelling, with the windows open are 10 dB(A) lower than external noise levels. Based on a worst case minimum attenuation, with windows open, of 10 dB(A), the first conclusion above suggests that short term external noises of 60 dB(A) to 65 dB(A) are unlikely to cause awakening reactions. The second conclusion suggests that one or two noise events per night with maximum external noise levels of 75 dB(A) to 80 dB(A) L_{Afmax} are not likely to affect health and wellbeing significantly.

8.4 Overview of noise and vibration assessment

8.4.1 Construction impacts

Construction Noise

The construction noise modelling and assessment has been undertaken in accordance with the applicable NSW legislation and guidelines. Noise mitigation has been recommended in accordance with these guidelines. These guidelines have been developed taking into consideration current international practices, health impacts of noise and to protect vulnerable people.

Noise that may be generated during construction has been modelled based on the type of equipment to be used, where the equipment is to be used in relation to the community receptors, the hours of work, the duration of the activities undertaken and the local terrain.

The assessment has considered a range of standard noise mitigation measures, ie those that would be a standard requirement for a range of construction activities. In some situations, impacts from construction noise and vibration may be unavoidable, particularly where works are undertaken in close proximity to the community. Where this occurs the Roads and Maritime CNVG includes a range of additional mitigation measures to manage these impacts. These measures include actions to notify and provide warning to the community and/or to offer respite or alternate accommodation.

Overall, a worst case assessment has been used in accordance with the ICNG, assuming no additional mitigation measures are implemented. For each area assessed, the noise levels at the most affected receptor have been used to represent the whole noise catchment area.

Noise impacts in excess of the criteria for daytime and night-time noise have been identified at a number of receptors during a range of different construction activities, in all of the key areas evaluated (refer to **Appendix J** (Technical working paper: Noise and vibration) of the EIS for further detail). It is likely that the screening criterion for sleep disturbance would be exceeded for night works adjacent to residential receptors for most works scenarios.

To address the noise impacts identified, mitigation measures have been identified, and evaluated. Specifically, the modelling of noise impacts following the installation of additional measures (such as work hours, use of hoarding, non-tonal reversing beepers and traffic management to minimise reversing) has been undertaken, showing a reduction in noise impacts within the community. However, in most locations a number of properties remain where noise criteria are exceeded, and where further source mitigation measures are required to reduce noise exposures during construction. These measures have been identified and outlined in **Appendix J** (Technical working paper: Noise and vibration) of the EIS.

The assessment has also addressed the impact of consecutive construction works on noise from a number of different infrastructure projects. This is further discussed in **section 10.8**.

Potential noise impacts from movement of construction vehicles

Potential increases in noise for sensitive receptors due to construction traffic has been assessed separately from the assessment of noise from other construction activities. Heavy vehicles involved in construction are expected to travel via existing major roadways with minimal use of local roads. In all areas evaluated, there are no noticeable increases in noise from construction traffic on the proposed routes during the daytime or night-time.

Ground-borne construction noise

Ground-borne noise occurs when works are being undertaken under the ground surface or in some other fashion that results in the vibrations from noise moving through the ground rather than the air. This project involves tunnelling so many of the more significant noise activities would be present at depth (with a large proportion of the main tunnels at depths of 30 to >50 metres), where activities are expected to occur 24 hours per day.

The modelling has addressed the worst case situation when the tunnelling is occurring immediately beneath a sensitive receptor. The tunnelling equipment would move at about 20 to 25 metres per week (on average) so ground-borne noise may be discernible for a relatively short time (up to approximately two weeks). Exceedance of the night-time criteria has been identified for sensitive receptors near key construction areas, specifically Darley Road construction access tunnel (with exceedance up to 4 dB(A)), Pyrmont Bridge Road construction access tunnel (with exceedance up to 15 dB(A)), with worst-case impacts predicted to result in exceedances of up to approximately two weeks.

Impacts have also been identified at a number of residential receptors (383) located above the mainline tunnel alignment. The greatest impacts relate to works in the vicinity of the Rozelle interchange where the tunnel ramps climb to meet City West Link, with exceedance of both daytime and night-time ground-borne noise criteria predicted. Other impacts, where there are exceedances of day and night-time criteria) are in the vicinity of the Iron Cove Link where tunnel ramps climb to meet Victoria Road and St Peters interchange. The duration of these impacts is estimated to be approximately two weeks.

Managing the impacts identified is important. These measures include the validation of predicted impacts and advising the community of noise impacts during specific times.

There are two residential receptors in Haberfield and two residential receptors in Rozelle where ground-borne noise levels are predicted to exceed the night-time NML by 10 dB(A) or more. At these receptors, additional mitigation measures have been identified that include providing individual briefings on impacts and mitigation measures, providing respite periods and alternate accommodation.

Vibration impacts

A range of the equipment to be used in construction have the potential to cause unacceptable levels of vibration. Managing the potential for such vibration to actually cause discomfort or structural damage at sensitive receptor locations is based on ensuring suitable separation distances between the equipment and the receptor locations.

The proposed management of vibration impacts involves validation (by monitoring) of the predicted impacts, advising the community of impacts and offering respite periods to affected residents where human comfort levels are to be exceeded for an extended period of time during any one day.

8.4.2 Operational impacts

Assessment of operational noise impacts has been undertaken by modelling noise associated with the project. The assessment evaluated impacts on the community 600 metres either side of the main project road alignment as well as the community adjacent to a number of collector roads, sub-arterial and arterial roads associated with Victoria Road, City West Link and The Crescent.

The noise modelling has been undertaken to address impacts associated with the project in 2023 and 2033, including a cumulative scenario. The modelling has evaluated noise impacts at the façade of all buildings, including on all floors of multi-storey buildings. An assessment was undertaken to determine how well the model estimated noise impacts based on a current scenario. The modelled and measured results were found to be within acceptable tolerances, which are +/- 2 dB(A).

The assessment of operational noise impacts considered the following:

- Without the project: the noise assessment considered the existing road alignment with existing noise barriers and features within the road corridor evaluated, and traffic volumes predicted without the project
- With the project: the noise assessment considered the proposed design of the project, traffic volumes predicted with the project. The assessment has been initially undertaken with consideration of existing noise barriers and the reference design pavement for all new sections, which is then used to inform options for additional noise mitigation.

The additional noise mitigation measures considered in the assessment include:

- Quieter pavement surfaces
- Noise mounds
- New or increased height noise barriers (where four or more properties are identified that are close together). Such measures are capable of achieving the following:
  - 5 dB(A) reduction at representative receptors for barrier heights of up to five metres
  - 10 dB(A) reduction at representative receptors for barrier heights above five metres and up to eight metres.

There are some properties where the requirements for barriers cannot be met, in which case other measures are considered.

- At-property treatment of individual receptors or homes, where residual impacts remain after all feasible and reasonable measures have been exhausted. Such measures depend on the age and condition of the property. In general, architectural treatments should aim to reduce noise levels in habitable rooms by 10 dB(A) and the assessment has identified different levels of treatment for properties that require a noise reduction of less than or equal to 10 dB(A) and those requiring reductions of more than 10 dB(A).

The noise modelling also identified that a significant number of already noise impacted receptors (approximately 60 per cent) will have decreased noise levels with the project. This is due to the predicted decrease in traffic volumes on parts of the surface road network as a result of the project.

Without mitigation, a significant number of receptors have been identified in most NCAs where exceedances of the daytime and night-time noise criteria are predicted. The change in noise levels are predicted up to 2 dB(A) at most receptors, with more significant increases up to >12 dB(A) at a smaller number of receptors to the south of Victoria Road adjacent to the Iron Cove Link. Less than 1 per cent of the receivers are predicted to experience an increase of more than 2.0 dbA due to the project.

This redistribution of noise, associated with the operation of the project in 2033 (worst-case year) is illustrated in **Figure 8-1**.

Additional mitigation measures have been identified for receptors where increased noise levels are greater than 2 dB(A), greater than 5 dB(A) above the criteria or where acute noise impacts are predicted. Where multistorey buildings are present, the impacts identified primarily relate to the first two floors (64 per cent), with lower impacts on level three (15 per cent), floor four (nine per cent), floor five (four per cent) and higher (eight per cent). Further assessment of the implementation of barriers for noise mitigation resulted in the identification of a number of buildings (200 buildings) (and floors in multi-story buildings) where at-property noise treatments will be required.

Where cumulative noise impacts are considered (from the operation of all WestConnex projects plus the proposed future Western Harbour Tunnel and Beaches Link, Sydney Gateway and F6 Extension projects), the number of noise receptors requiring additional noise mitigation decreases slightly. This is due to the further redistribution of traffic on surface roads.

Maximum noise levels have been predicted to increase in NCA33 and NCA36, specifically to the south of Victoria Road adjacent to the Iron Cove Link tunnel portals; and NCA24, specifically receptors to the west of Victoria Road near Lilyfield Road.

Noise emissions from fixed facilities in the Iron Cove area are predicted to exceed the criteria by up to 12 dBA at the most-affected receivers in NCA33, adjacent to the substation. The impacts identified may be managed/mitigated through equipment and location selection, pavement selection, noise mounds and barriers, silencers, acoustic lined ductwork and acoustic louvres.

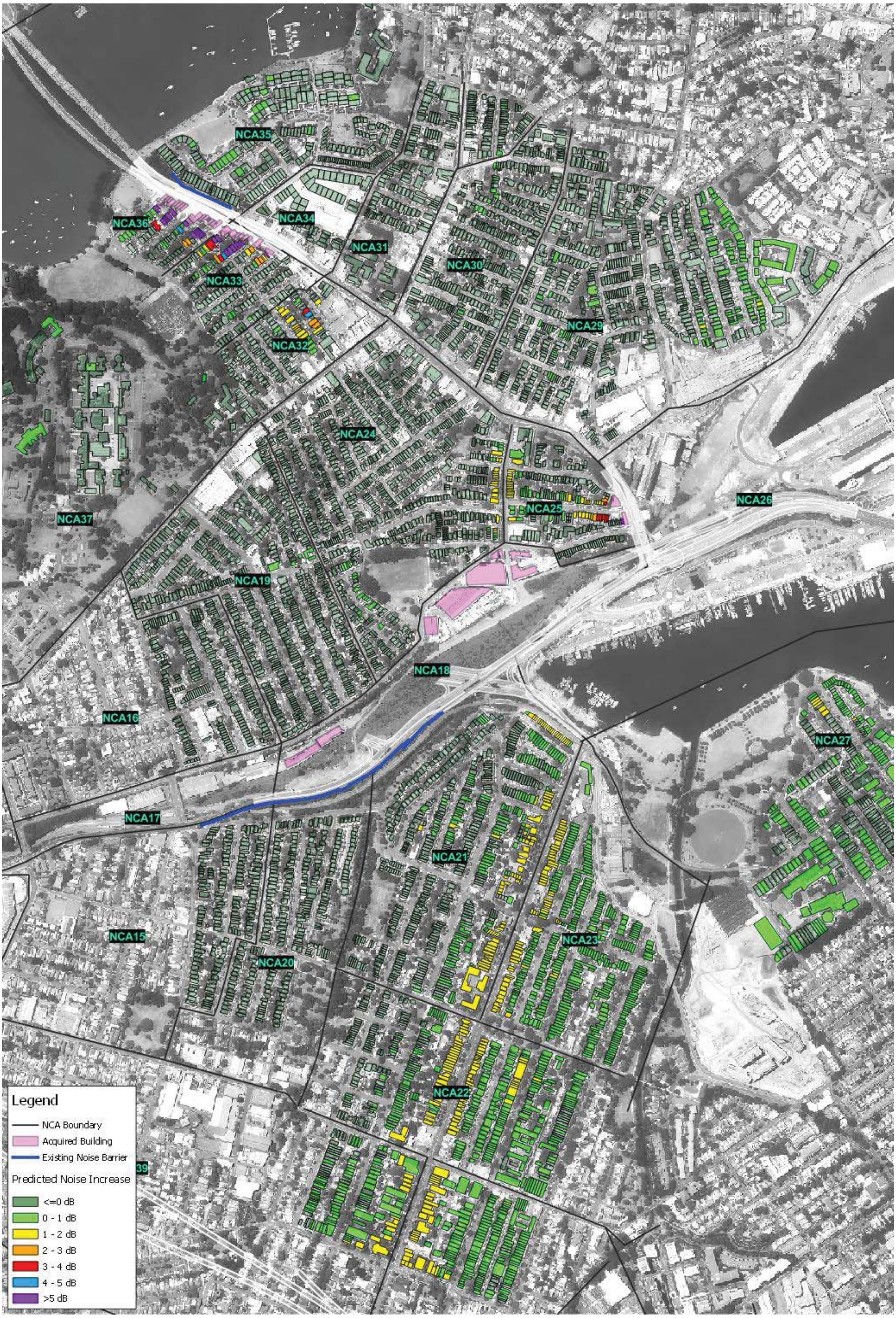


Figure 8-1 Predicted change in noise levels with project without mitigation (daytime – 2033)

8.5 Health outcomes relevant to noise

8.5.1 General

Environmental noise has been identified (I-INCE 2011; WHO 2011) as a growing concern in urban areas because it has negative effects on quality of life and wellbeing and it has the potential for causing harmful physiological health effects. With increasingly urbanised societies impacts of noise on communities have the potential to increase over time.

Deciding on the most effective noise management options in a specific situation is not just a matter of defining noise control actions to achieve the lowest noise levels or meeting arbitrarily chosen criteria for exposure to noise. The goal should be designed to achieve the best available compromise between the benefits to society of reduced exposure to community noise versus the costs and technical feasibility of achieving the desired exposure levels given the project. On the one hand, there are the rights of the community to enjoy an acceptably quiet and healthy environment. On the other hand there are the needs of the society for new or upgraded facilities, industries, roads and recreation opportunities, all of which typically produce more community noise (I-INCE 2011; WHO 2011).

Sound is a natural phenomenon that only becomes noise when it has some undesirable effect on people or animals. Unlike chemical pollution, noise energy does not accumulate either in the body or in the environment but it can have both short term and long term adverse effects on people. These health effects include (WHO 1999, 2011):

- Sleep disturbance (sleep fragmentation that can affect psychomotor performance, memory consolidation, creativity, risk-taking behaviour and risk of accidents)
- Annoyance
- Hearing impairment
- Interference with speech and other daily activities
- Children's school performance (through effects on memory and concentration)
- Cardiovascular health.

Other effects for which evidence of health impacts exists, but for which the evidence is weaker, include:

- Effects on mental health (usually in the form of exacerbation of existing issues for vulnerable populations rather than direct effects)
- Tinnitis (which can also result in sleep disturbance, anxiety, depression, communication and listening problems, frustration, irritability, inability to work, reduced efficiency and a restricted participation in social life)
- Cognitive impairment in children (including deficits in long term memory and reading comprehension)
- Some evidence of indirect effects such as impacts on the immune system.

Within a community the severity of the health effects of exposure to noise and the number of people who may be affected are schematically illustrated in **Figure 8-2**.

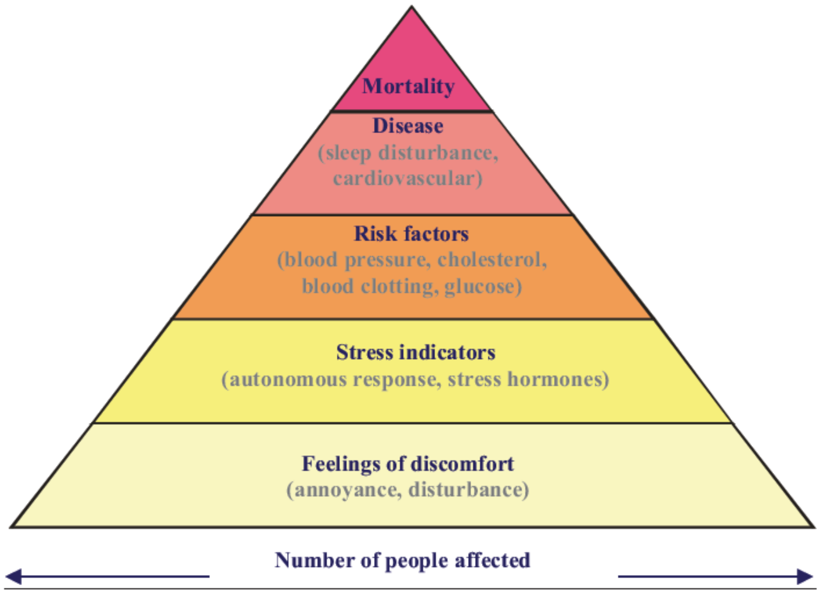


Figure 8-2 Schematic of severity of health effects of exposure to noise and the number of people affected (WHO 2011)

Often, annoyance is the major consideration because it reflects the community's dislike of noise and their concerns about the full range of potential negative effects, and it affects the greatest number of people in the population (I-INCE 2011; WHO 2011).

There are many possible reasons for noise annoyance in different situations. Noise can interfere with speech communication or other desired activities. Noise can contribute to sleep disturbance, which can obviously be very annoying and has the potential to lead to long term health effects. Sometimes noise is just perceived as being inappropriate in a particular setting without there being any objectively measurable effect at all. In this respect, the context in which sound becomes noise can be more important than the sound level itself (I-INCE 2011; WHO 2011).

Different individuals have different sensitivities to types of noise and this reflects differences in expectations and attitudes more than it reflects any differences in underlying auditory physiology. A noise level that is perceived as reasonable by one person in one context (eg in their kitchen when preparing a meal) may be considered completely unacceptable by that same person in another context (eg in their bedroom when they are trying to sleep). In this case the annoyance relates, in part, to the intrusion from the noise. Similarly, a noise level considered to be completely unacceptable by one person, may be of little consequence to another even if they are in the same room. In this case, the annoyance depends almost entirely on the personal preferences, lifestyles and attitudes of the listeners concerned (I-INCE 2011; WHO 2011).

Perceptible vibration (eg from construction activities) also has the potential to cause annoyance or sleep disturbance and so adverse health outcomes in the same way as airborne noise. However, the health evidence available relates to occupational exposures or the use of vibration in medical treatments. No data is available to evaluate health effects associated with community exposures to perceptible vibrations (I-INCE 2011; WHO 2011).

It is against this background that regulators in various communities have established sound level criteria above which noise is deemed to be unacceptable and below which it is deemed to be acceptable. Any assessment of noise impacts needs to consider the relevant criteria established for a new or existing (or upgraded) facility or activity. Where there are impacts in excess of these guidelines, an assessment of noise mitigation is required to be undertaken.

8.5.2 Health impacts from traffic noise

Road traffic noise is caused by the combination of rolling noise (noise from tyres on the roadway) and propulsion noise (from engine, exhaust and transmission).

A number of large international studies are available that have specifically evaluated health impacts associated with exposure to road traffic noise. Where exposure to road traffic noise is associated with, or can be shown to be causal, adverse health effects an exposure-response relationship is often established. The main health effects that have been studied in these types of investigations in relation to road traffic noise are annoyance, sleep disturbance, cardiovascular disease, stroke and memory/concentration (cognitive) effects. These are further discussed below.

Cardiovascular effects

There is substantial evidence that hypertension and more importantly blood pressure measurements are an independent risk for cardiovascular disease. Cardiovascular diseases are the class of diseases that involve the heart or blood vessels, both arteries and veins. These diseases can be separated by end target organ and health outcomes. Strokes reflecting cerebrovascular events and ischaemic heart disease (IHD) or coronary heart disease (CHD) are the most common representation of cardiovascular disease.

A link between noise and hypertension is relatively well established in the relevant literature. Whilst there is no consensus on the precise causal link between the two, there are a number of credible hypotheses. A leading hypothesis is that exposure to noise could lead to triggering of the nervous system (autonomic) and endocrine system which may lead to increases in blood pressure, changes in heart rate, and the release of stress hormones. Depending on the level of exposure to excess noise, the duration of the exposure and certain attributes of the person exposed, this can cause an imbalance in the person's normal state (including blood pressure and heart rate), which may make a person hypertensive (consistently increased blood pressure) which can then lead to other cardiovascular diseases (DEFRA 2014). This hypothesis is illustrated in **Figure 8-3**.

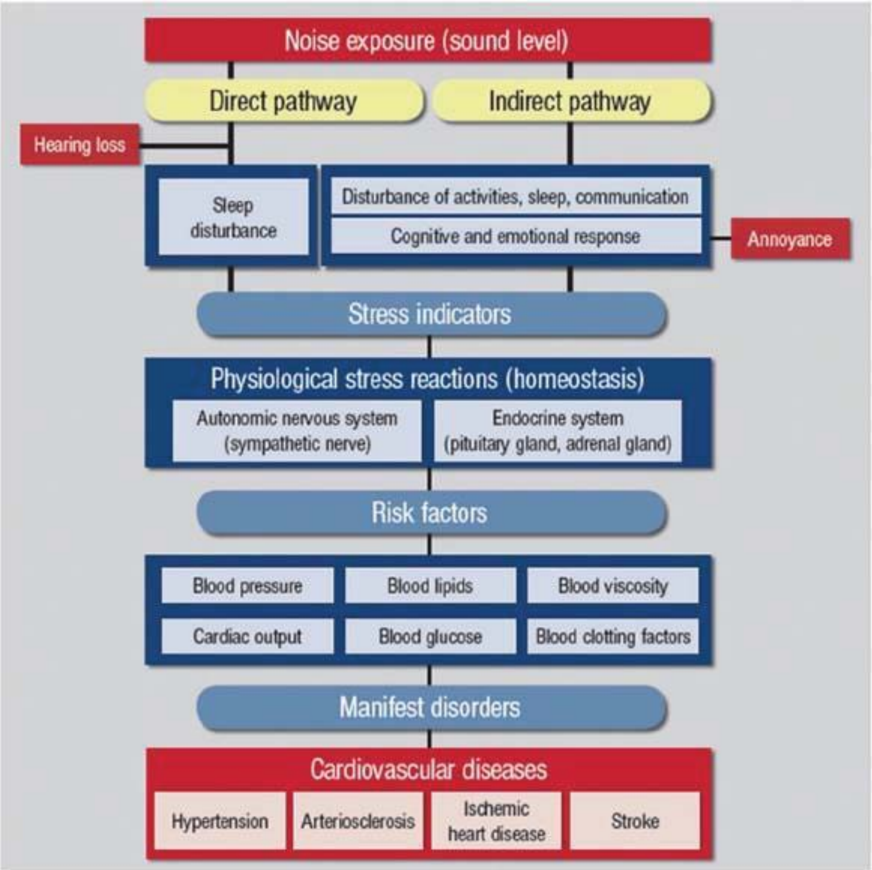


Figure 8-3 Noise reaction model/hypothesis (Babisch 2014)

The available studies regarding road traffic noise and cardiovascular disease risk largely involve meta-analysis (ie statistical analysis that combines the results of multiple scientific studies). A number of studies have been published by Babisch (Babisch 2002, 2006, 2008, 2014; van Kempen & Babisch 2012) have provided the basis for a number of exposure-response relationships adopted for the assessment of cardiovascular health effects associated with road traffic noise.

In relation to hypertension the most relevant recent study (van Kempen & Babisch 2012) involved analysis of 27 studies between 1970 and 2010, where a relationship between road traffic noise and hypertension was determined. This relates to the incidence of hypertension in the population and has been adopted by the European Commission for the assessment of health impacts of road noise in Europe (EEA 2014).

Relationships have also been established between road traffic noise (as L_{den})[12] and ischemic heart disease (Babisch 2014; Vienneau et al. 2015). The study by Babisch (2014) involved analysis of 14 studies related to road traffic noise. The study by Vienneau et al (2015) involved analysis of 10 studies related to both air and road transport. The study by Babisch (2014) was more directly relevant to road traffic noise and has been adopted in this assessment.

Meta-analysis involves more detailed statistical analysis of large numbers of individual epidemiological studies. In relation to the risk of stroke from exposure to noise, there are limited meta-analysis type studies available and the studies available combine the risks from noise from road and air transport. A more specific study that just investigated the link between road traffic noise and cardiovascular disease/mortality has been undertaken in London (Halonen et al. 2015). This was a large epidemiological study that identified statistically significant associations between road traffic noise (as modelled to residential dwellings) and hospital admissions for stroke and all-cause mortality. The relationships identified related to exposure to day and evening noise as $L_{Aeq,16h}$. The study corrected for confounders[13] such as $PM_{2.5}$ and NO_2 exposures and has been considered suitable for use in this assessment. The relative risk identified for hospital admissions for stroke is equivalent to that identified from a meta-analysis of air and road noise (Houthuijs et al. 2014).

The relationships determined in the above studies relate to noise exposures in excess of a threshold. The threshold for where these effects are of significance are generally equal to or above the noise criteria adopted for the assessment of operational noise impacts. It is noted, however that in areas already affected by noise at levels above these thresholds, the guidelines relate to an increase in noise attributed to the project, with a guideline of 2 dB(A) adopted. An increase in noise by 2 dB would not be associated with unacceptable cardiovascular risks (where the above exposure-response relationships were considered).

Annoyance and sleep disturbance

Changes in annoyance and sleep disturbance associated with noise are considered to be pathways for the key health indicators listed above. However, these issues are of importance to the local community and so it is relevant to evaluate the changes in levels of annoyance and sleep disturbance as a result of noise from the operation of the project within the community.

Annoyance

Annoyance is a feeling of displeasure associated with any agent or condition known or believed by an individual or group to adversely affect them. Annoyance following exposure to prolonged high levels of environmental noise may also result in a variety of other negative emotions, for example feelings of anger, depression, helplessness, anxiety and exhaustion (EEA 2014).

Annoyance levels can be reliably measured by means of an International Organisation for Standardization/Technical Standard (ISO/TS) 15666:2003 defined questionnaire, which has enabled

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[12] L_{den} = average noise level across day, evening and night (ie 24 hour period)

[13] Confounders are variables (not the ones being studied) that can affect the same health measures/outcomes, and make it appear that an observed exposure is associated with an outcome. These variables can distort the presence of, and magnitude of a relationship that is established between an exposure and an effect/outcome. Good studies try to correct for confounders, however not all of these are known and the way in which the correction is applied can vary.

the identification of relationships between annoyance and noise sources. The European Commission (EC 2002) conducted a review of the available data and provided recommendations on relationships that define the percentage of persons annoyed (%A) and the percentage of persons highly annoyed (%HA) to total levels of noise reported as L_{DEN} (ie average noise levels during the day, evening and night). These relationships were established for exposure to aircraft noise, road traffic noise and rail traffic noise, and have been adopted by the UK and European Environment Agency (DEFRA 2014; EEA 2010, 2014). The recommended relationships between noise exposure and annoyance are based on the data from a large set of field studies in which data on noise exposure and noise annoyance (as reported by individuals) were collected.

The available noise guidelines have been developed to address noise annoyance within the community. Hence the increase in noise permitted as a result of the project is small. In many cases the change in noise exposure is reduced as a result of the project. However where noise level changes of 2 dB(A) occur, this has the potential to result in an increase in individuals highly annoyed by noise by 2 per cent, which is well below the level of annoyance of 5 per cent considered to be of concern (or likely to be perceived) by residents (Schomer 2005).

Sleep disturbance

It is relatively well established that night time noise exposure can have an impact on sleep (WHO 2009, 2011). Noise can cause difficulty in falling asleep, awakening and alterations to the depth of sleep, especially a reduction in the proportion of healthy rapid eye movement sleep. Other primary physiological effects induced by noise during sleep can include increased blood pressure, increased heart rate, vasoconstriction, changes in respiration and increased body movements (WHO 2011). Exposure to night-time noise also may induce secondary effects, or so-called after effects. These are effects that can be measured the day following exposure, while the individual is awake, and include increased fatigue, depression and reduced performance.

Studies are available that have evaluated awakening by noise, increased mortality (i.e. increase in body movements during sleep), self-reported chronic sleep disturbances and medication use (EC 2004). The most easily measurable outcome indicator is self-reported sleep disturbance, where there are a number of epidemiological studies available. From these studies the WHO (2009, 2011) identified an exposure-response relationship that relates to the percentage of persons sleep disturbed and highly sleep disturbed to total levels of noise reported as L_{night} (ie average noise levels during night, which is an eight-hour time period, as measured outdoors). The relationship adopted relates to the assessment of road-traffic noise, with other relationships for air and rail traffic noise. These relationships have been adopted by the WHO (2009, 2011), UK and European Environment Agency (DEFRA 2014; EEA 2010, 2014).

The available noise guidelines include criteria to address sleep disturbance that are based on the above studies and relationships. Hence compliance with these guidelines will address health impacts associated with sleep disturbance in the community.

Cognitive effects

There is evidence for effects of noise on cognitive performance in children such as lower reading performance (WHO 2011). A major study was undertaken in the EU – RANCH – and this study was reviewed in WHO (2011). The study found an exposure-response relationship between noise and cognitive performance in children for aircraft noise but the relationship between performance and noise for road traffic was much less clear (Stansfeld et al. 2005a; Stansfeld et al. 2005b; WHO 2011). The same study showed that road traffic alone did not show an association between road traffic noise and adverse changes in children’s cognitive functions studied (reading comprehension, episodic memory, working memory, prospective memory or sustained attention), nor with sustained attention, self-reported health, or mental health.

Individual road noise events

It is noted that noise impacts can also occur because of individual noise events, such as engine braking or loud exhausts. The noise measures adopted above for the assessment of the health effects of noise relate to an average/equivalent sound level over different time periods, which, when measured, would include individual noise events. This is the preferred approach for evaluating annoyance and other health effects related to noise (NSW DECCW 2011). Individual noise events are of most significance in relation to the assessment of sleep disturbance. The available research indicates that one or two individual noise events per night, with a maximum indoor noise level of 65 to 70 dB(A) are not likely to affect health and wellbeing (NSW DECCW 2011). Criteria have been adopted to address maximum noise events, however it is noted that it is not possible to model all individual noise events as these relate to individual vehicles or trucks and individual driving behaviour that cannot be predicted.

8.6 Assessment of noise impacts from project

In relation to this project, potential noise impacts have been assessed against Australian (more specifically NSW) criteria that have been established on the basis of the relationship between noise and health impacts. The criteria developed for use in the assessment for control of noise come from policy documents developed by the NSW Government including the INP, the NSW Interim Construction Noise Policy, and the RNP (NSW DECC 2009; NSW DECCW 2011; NSW EPA 2000). All of these policies are based on the health effects of noise outlined in the reviews published by the following organisations:

- World Health Organization – *Guidelines on Community Noise – Health effects of noise* (WHO 1999)
- World Health Organization – *Night Noise Guidelines for Europe* (WHO 2009)
- International Institute of Noise Control Engineering – *Guidelines for Community Noise Impact Assessment and Mitigation* (I-INCE 2011)
- Environmental Health Council of Australia – The health effects of environmental noise – other than hearing loss (enHealth 2004).

Various attempts have been made to assess the effect (measured by average reported annoyance, sleep disturbance or a similar type of effect) from community noise (measured by long term average sound levels) to develop exposure-response relationships. As individual reactions to noise are so varied, these studies need large sample sizes to obtain reasonable correlation between the noise exposure and the response. Any dose-response relationship determined from large studies over a range of communities and cultures will not necessarily represent the reaction of individuals or small communities. These exposure-response relationships are of value for macro-scale (ie whole urban environment scale) strategic assessment purposes where individual differences are not important; however, they are not as useful when considering potential impacts on a small population located close to a specific project/activity. Hence these macro-scale relationships cannot be easily applied (in any meaningful way) in this assessment.

For a number of the noise guidelines (including the RNP), the criteria have been established on the basis of noise annoyance, which is considered to be the more sensitive effect and an effect that precedes the physiological effects. As a result, these guidelines are designed to be protective of all adverse health effects. Other guidelines are based on specific sensitive health effects such as sleep disturbance for the assessment of night-time noise.

As guidelines/criteria that are based on the protection of health are available to assess construction and operational noise impacts associated with this project, the assessment of potential health impacts has focused on whether the guidelines/criteria established can be met. Where the guidelines cannot be met then there is the potential for the above adverse health effects to occur in the community adjacent to the project.

In most cases, when developing management limits for the project, it has been assumed that there is a 10 dB(A) difference between noise inside and outside of a building with windows open. This assumption is sourced from the RNP. Further consideration of this assumption raises a number of issues including:

- Internal noise levels are defined in the RNP as those measured in the centre of a habitable room so if activities (like sleeping or concentrating) happen at the edge of a room they may be more impacted by noise than might be expected
- The RNP refers to windows being open sufficient to provide adequate ventilation as discussed in the Building Code of Australia. The Building Code of Australia does not require that residential buildings have significant levels of ventilation and, as a result, opening a window sufficient to provide the minimum ventilation required is unlikely to mean that the window is completely open or even that more than one window in a room is opened. Sufficient ventilation may result from the existing drafts in a building (with no windows open) or the opening of two windows only for the entire building. Assuming that the 10 dB(A) change in noise applies for all situations where windows are open is not appropriate
- Consequently, the use of this assumption in setting noise management limits for this project may need to be reviewed when designing property specific noise mitigation measures (to be undertaken in consultation with the property owner).

For over 60 per cent of the receptors evaluated, noise levels will be reduced as a consequence of the project, resulting in associated health benefits. However, the worst case assessment also predicts that noise criteria and vibration criteria will be exceeded at a number of properties adjacent to the project during construction and operation without mitigation measures.

The worst-case levels estimated are sufficiently high for some receptors during some works that health impacts are likely to occur. These properties are located south of Victoria Road adjacent to the Iron Cove Link tunnel portals, and to the west of Victoria Road near Lilyfield Road. These are primarily related to the new road alignment being closer to residential homes, and the removal of buildings closest to the road (that previously were a barrier to noise from the roadway). A number of properties have also been identified where cumulative noise impacts exceed the relevant guidelines.

Loss of use of outdoor areas, disturbance of sleep, reduced capacity for concentration, interference with speech and other activities are all likely with potential for effects on cardiovascular health if the elevated noise at a particular location occurs for extended periods. Annoyance and increased stress levels will also occur.

Consequently, the management and mitigation of noise and vibration during the construction phase of the project will be essential. Mitigation measures considered during operation principally involve the use of low noise pavement, noise mounds and noise barriers. Where these measures cannot be installed or do not provide sufficient mitigation, in-property treatments have been considered for 205 buildings.

The detailed design for the mitigation measures will be outlined in the Construction Noise and Vibration Management Plan (CNVMP) as discussed in **Appendix J** (Technical working paper: Noise and vibration) of the EIS. The aim of the mitigation measures should be to reduce noise and vibration to levels that comply with the management goals established in this assessment. If it is not possible to achieve compliance with these goals, health impacts for the affected community are likely.

While these mitigation measures are required to ensure that the environment where people spend most of the day (ie indoors) is not associated with adverse health impacts from excessive noise, it does assume that residents take up in-property treatment measures and where they do, they keep external windows and doors shut and have minimal use of outdoor areas.

In urban areas particularly where existing levels of noise are dominated by road traffic noise, access to outdoor green space areas that are not (perceived to be) impacted by noise (eg where there is a quiet side of a specific property or there is access to a quiet green space areas close to the residential home) have been found to significantly improve wellbeing and lower levels of stress (Gidlöf-Gunnarsson & Öhrström 2007). Impacts on the use and enjoyment of outdoor areas due to increased noise may result in increased levels of stress at individual properties.

Where specific residents/properties do not take up the recommended in-property treatments to mitigate noise indoors there is the potential for noise levels at these properties to exceed the relevant guidelines/criteria. In these situations, there is the potential for adverse health effects, particularly annoyance and sleep disturbance, to occur.

Community consultation will be an important part of the process in addressing noise impacts for the project as there are a number of individual homes where in-property treatment will be required to enable the noise criteria to be met, and minimise the potential for adverse health effects associated with the project. However, such treatments may have other effects (as discussed above) which will also need to be managed/considered.

9 Public safety and contamination

9.1 General

This section provides a review of the potential risks posed to public safety, associated with the project. This section also presents a review of health impacts associated with the presence and management of contamination (in soil or water) relevant to the project.

This section only addresses risks to the community, ie risks that only have the potential to adversely affect the community. Issues relevant to workplace health and safety during construction (including contamination remediation) and operation have not been further discussed or addressed.

Evaluation of public safety has considered the hazard and risk assessment, presented in **Chapter 25** (Hazard and risk) of the EIS. This assessment was undertaken in accordance with the State Environmental Planning Policy No.33 (The Policy) Hazardous and Offensive Developments, that identified and addresses risks during construction and operation. Pedestrian safety aspects are addressed in detail in the Traffic and Transport assessment. Issues from these assessments specifically relevant to public health and safety have been further detailed in this section.

Health impacts associated with contamination have been assessed on the basis of **Appendix R** (Technical working paper: Contamination) of the EIS.

Health impacts associated with subsidence have been assessed on the basis of **Chapter 12** of the EIS (Land use and property).

9.2 Public safety

9.2.1 Construction

A range of potential hazards have been identified that have the potential to affect public safety during construction. These are outlined in **Table 9-1**, along with discussion on the risks that may be posed by these hazards. Not all the hazards identified in the Hazard and Risk assessment have been included in the table, only those where there is the potential for risks to public safety.

Table 9-1 Overview of public safety hazards and risks: Construction

Hazard: Public safety	Risk to public safety	Management measures
Storage and handling of dangerous goods on construction sites that may impact on the off-site community	Low The storages during construction are low. In the event of an incident, there would not be an off-site risk.	All materials will be stored in accordance with the Australian Dangerous Goods Code that includes the use of bunding, ventilation of areas where gases are stored, locating stores of these materials away from sensitive areas, maintaining a register and inventory.
Transport of dangerous goods and hazardous substances on public roads within the community	Low The quantities and frequency of transport for these chemicals is low. All transport will be using trucks that are suitable to transport these materials, with procedures in place to manage any leaks or spills during an accident.	All materials are to be transported in accordance with the Storage and Handling of Dangerous Goods Code of Practice (WorkCover NSW 2005), *Dangerous Goods (Road and Rail Transport) Act 2008* (NSW), Dangerous Goods (Road and Rail Transport) Regulation 2014 (NSW) and relevant Australian Standards.
Tunnel collapse, that may affect community areas overlying the tunnel	Low	All tunnelling to be undertaken under a permit to tunnel system that requires detailed consideration of ground support performance, geotechnical and

Hazard: Public safety	Risk to public safety	Management measures
		groundwater conditions for each tunnel section.
Potential acid sulfate soil, that may result in acidification and the mobilisation of metals, adversely impacting groundwater that can then migrate off-site	Low	Standard construction and mitigation measures would be applied to mitigate the potential risks associated with the disturbance of acid sulfate soils.
Contamination, specifically the presence of hazardous materials such as asbestos and works in areas where contamination is present in soil, which may result in contaminants migrating off-site and affecting the community	Low	Removal of asbestos is required to be undertaken in accordance with procedures detailed in the Asbestos Management Plan as part of the Construction Environmental Management Plan (CEMP) for the project, which reflect national legislation and guidance.
Flooding issues that extend outside the construction areas into the community	Low as flooding risks to off-site areas evaluated have been considered to be minor.	Design to minimise the potential for off-site flooding impacts.
Damage to underground utilities, affecting roadways and services provided to the community	Low	A Utilities Management Strategy (refer to **Appendix F** of the EIS) has been prepared for the project that identifies management options, including relocation or adjustment of the utilities. This includes consultation with utilities and service infrastructure providers to mitigate the risk of unplanned or unexpected disturbance of utilities.
Bushfire or fire risks that may spread off-site and affect neighbouring properties	Low	The project is in a highly urbanised area that is not in or near a bushfire prone area. Management of construction facilities and activities involving flammable materials and ignition sources will be undertaken to minimise fire risks. High risk construction activities, such as welding and metal work, would be subject to a risk assessment on total fire ban days, and restricted or ceased as appropriate.
Aviation risks, specifically works that may affect the safety of aircraft using Sydney Airport	Low	Construction activities would be carried out to ensure that equipment such as cranes and materials do not intrude into the obstacle limitation surface (OLS) or procedures for air navigation systems operations (PANS-OPS) for the airport. The Civil Aviation and Safety Authority (CASA) and Department of Infrastructure and Regional Development (DIRD) are being consulted to ensure construction works are undertaken in line with the *Airports (Protection of Airspace) Regulations 1996* (Commonwealth) and the *Airports Act 1996* (Commonwealth), in a manner that satisfies the requirements of CASA. This includes compliance with CASA requirements for lighting

Hazard: Public safety	Risk to public safety	Management measures
Traffic and trucks on surface roads and the potential for changes in public safety	Low Changes to the surface road network may require temporary traffic detours. Construction road traffic volumes are low compared with existing traffic volumes, which is not expected to significantly impact on road safety.	Heavy vehicle movements will involve the use of major roads including Parramatta Road, City West Link, Victoria Road, Pyrmont Bridge Road and Princes Highway. All traffic detours would be undertaken in accordance with approvals by Roads and Maritime, local councils and the Transport for NSW Transport Management Centre. Property access will be maintained, or alternate access provided. A Construction Traffic Management and Access Plan (CTAMP)will be prepared to manage these impacts.
Pedestrian and cycle safety	Low Construction and surface road works may require temporary detours for pedestrians and cyclists.	Alternate safe pedestrian and cycle access is to be provided where it is practical and safe to do so. This will be addressed in the CTAMP.
Subsidence	Low Tunnel induced ground movement that may result in ground settlement is considered to be low along most of the tunnel alignment. In some areas, where shallow tunnelling or multiple tunnels are proposed close to each other, higher levels of settlement are predicted. In these areas, potential settlement impacts require further assessment and potential management.	Further assessment of potential settlement impacts, including modelling would be required during the detailed design. Where ground movement in excess of settlement criteria are predicted a range of design, construction and ground improvement measures (as outlined in **Chapter 12** (Land use and property) of the EIS) would be considered to reduce impacts. In addition, a range of management measures would be implemented (as detailed in **Chapter 12** (Land use and property) of the EIS). This includes the preparation and implementation of a Settlement Monitoring Plan, preparation of building condition surveys, repair of cracking or property damage deemed to have occurred from the construction of the project, and preparation of agreements with utility owners and infrastructure owners identifying acceptable levels of settlement, monitoring requirements and measures to be implemented where levels are exceeded.

On the basis of the above there are no issues related to construction that have the potential to result in significant safety risks to the community.

9.2.2 Operation

A range of potential hazards have been identified that have the potential to affect public safety during the operation of the project, principally in relation to traffic accidents. These are outlined in **Table 9-2**, along with discussion on the risks that may be posed by these hazards. Not all the hazards identified in the Hazard and Risk assessment have been included in the table, only those where there is the potential for risks to public safety.

Table 9-2 Overview of public safety hazards and risks: Operation

Hazard: Public safety	Risk to public safety	Management measures
Storage, handling and transport of dangerous goods required for maintenance of the project, that may impact on the off-site community	Low The storages are minor, with limited and infrequent transport of these materials required.	All materials will be stored and transported in accordance with the relevant legislation and codes.
Transport of dangerous goods and hazardous substances in project tunnels	Low The transport of these materials will be prohibited within the tunnels (as per Road Rules 2014, 300-2 NSW rule: carriage of dangerous goods in prohibited areas).	Signage will be provided near tunnel entry portals advising of the restrictions to ensure compliance.
Traffic accidents in project tunnels	Low to moderate All use of public roadways carries an inherent risk of vehicle collision. The project has been designed to minimise these risks for travel within the tunnels. The project also provides fire and life safety requirements.	Measures include: • Use of height detection systems prior to tunnel entry portals • Tunnel barrier gates to prevent access if the tunnel is closed • CCTV throughout the tunnel • Adjustable speed signs • Provision of breakdown bays and emergency phones, provision of pedestrian cross-passages to enable safe evacuation from the tunnel • Automated fire detection • Longitudinal ventilation to push smoke in the direction of traffic flow away from the fire source towards a ventilation facility or portal • Water deluge system that can be activated manually or automatically. An Incident Response Plan will be developed and implemented in the event of an accident or incident.
Traffic accidents on surface roads (including pedestrian and cycle safety)	Moderate, however the risk is considered to be reduced with the project	The design of the project has been developed to inherently minimise the likelihood of incidents and crashes. The project will involve a reduction in traffic on some roadways, which has the potential to reduce crash rates, improve pedestrian and cyclist safety.
EMF from new substations at Darley Road (MOC1), Rozelle West (MOC2), Rozelle East (MOC3), Iron Cove Link (MOC4) and	Low	The detailed design of project substations would ensure that the exposure limits for the general public in the Draft Radiation Standard – Exposure Limits for Magnetic Fields (Australian Radiation Protection and

Hazard: Public safety	Risk to public safety	Management measures
Campbell Road (MOC5) and Haberfield		Nuclear Safety Agency December 2006) would not be exceeded at the boundary of the substation sites.
Bushfire risks	Low	The project is in a highly urbanised area that is not in or near a bushfire prone area. Operational infrastructure is largely invulnerable to bushfires as it is not combustible.
Aviation risks, specifically works that may affect the safety of aircraft using Sydney Airport	Low	The project design has considered airspace protection and associated risk and hazards. This includes the design of lighting and the ventilation facilities to ensure they meet the safety requirements set by DIRD and CASA.
Subsidence	Low The potential for soil consolidation in areas above the tunnel alignment over time is low.	None identified for the operational phase.

On the basis of the above there are no issues related to the operation of the project that have the potential to result in significant safety risks to the community.

9.3 Contamination

Contamination risk issues to the community are more relevant to the construction phase of the project because exposure to contaminated soil or groundwater would most likely occur during the excavation and construction phase, if not appropriately managed. The interaction with contamination and the community during the operations phase is primarily related to spills and accidents associated with the completed motorway. **Appendix R** (Technical working paper: Contamination) of the EIS has considered the location of the construction activities in relation to known areas of contamination in soil and groundwater, as well as issues associated with the impact of construction on the environment, where the community may be exposed.

9.3.1 Construction

In relation to construction works, the following hazards have been identified, and ranked as posing a low, medium or high risk[14]) that require management:

- Low level risk:
  - Presence of hazardous materials, specifically lead paint and asbestos in buildings to be demolished, Rozelle civil and tunnel site at Rozelle, Victoria Road civil site at Rozelle, Iron Cove civil site at Rozelle and Pyrmont Bridge Road tunnel site at Annandale
  - Presence of soil and/or groundwater contamination as a result of historical uses, relevant to the Wattle Street civil and tunnel site (C1a) at Haberfield, Haberfield civil and tunnel site (C2a) and Haberfield civil site (C2b) at Haberfield, Northcote Street civil site (C3a) at Haberfield, Darley Road civil and tunnel site (C4) at Leichhardt, Victoria Road civil site (C7) at Rozelle
- Medium level risk:
  - Presence of soil and/or groundwater contamination as a result of historical uses, relevant to the Parramatta Road East civil and tunnel site (C1b) at Haberfield, Parramatta Road West

[14] The level of risk depends on the likelihood of contamination being present, including the concentrations that may be present, and the likelihood that the community or an environment may be exposed to the contamination, as a result of the project.

civil site (C3b) at Ashfield, Iron Cove Link civil site (C8) at Rozelle, Pyrmont Bridge Road tunnel site (C9) at Annandale

- High level risk
  - Presence of soil and groundwater contamination as a result of historical uses, relevant to the Rozelle civil and tunnel site (C5) at Rozelle, The Crescent civil site (C6) at Annandale, Campbell Road civil and tunnel site (C10) at St Peters (also noted to be potentially affected by landfill gas).

During tunnelling works, groundwater would be extracted and would be collected, treated and discharged in accordance with the adopted site guidelines. The surface water receiving bodies in the vicinity of the project that have the potential to be impacted if groundwater disposal is not effectively addressed include Cooks River (including Alexandria Canal) and Sydney Harbour/Parramatta River (including Hawthorne Canal, Rozelle Bay and Iron Cove).

Locations where shallow tunnelling works are proposed may also encounter contaminated groundwater derived from a range of former and current businesses/industries overlying the tunnelling activities. This is specifically relevant on Parramatta Road in Annandale, Victoria Road at Rozelle, St Peters and the Rozelle Rail Yards. This may result in the ingress of contaminated groundwater that would require the temporary construction of water treatment plants to treat and manage this water to comply with the NSW Water Quality Objectives.

Meeting these guidelines would require contaminant levels to be sufficiently low that they do not affect the health of the community using these waterways for recreation.

Appendix R (Technical working paper: Contamination) of the EIS outlines the measures required to be adopted during construction to manage soil and water contamination. These are to be outlined in detail in the Construction Environmental Management Plan (CEMP). For sites where remediation is required a remedial action plan (RAP) would be required. In some cases, where limited information is currently available on contamination a detailed site investigation (DSI) is required. A DSI and RAP, and all remediation works are required to be undertaken in accordance with guidance from the NSW EPA, including obtaining approved by an independent NSW EPA accredited site auditor. This process is required to ensure assessment and remedial works adequately address and prevent risks to human health, including the surrounding community.

9.3.2 Operation

During operation, groundwater seepage would be required to be extracted from the tunnels, treated and discharged to the receiving water bodies. The groundwater quality may be impacted along parts of the tunnel alignment due to overlying contamination sources.

Tunnel drainage infrastructure will be designed to accommodate a combination of water ingress events including groundwater ingress, stormwater ingress at portals, tunnel wash-down water, fire suppressant deluge or fire main rupture and spillage of flammable and other hazardous materials. Separate sumps will be provided at tunnel low points, one to collect groundwater ingress and one to collect the other potential water sources. Tunnel drainage streams from the mainline works would be pumped to an operational water treatment plant at Darley Road, Leichhardt with treated flows ultimately discharged to Hawthorne Canal.

Tunnel drainage for Rozelle and the Iron Cove Link tunnels would be pumped to an operational water treatment plant at Rozelle interchange, with treated flows ultimately discharged to Rozelle Bay. Tunnel drainage from approximately one kilometre of the northbound and 600 metres southbound tunnel would be captured by the New M5 drainage system and conveyed to the New M5 operational water treatment plant at Arncliffe which ultimately drains to the Cooks River.

The tunnel operational water treatment facilities would be designed such that effluent will be of suitable quality for discharge to the receiving environment. The level of treatment would consider the characteristics of the discharge and receiving waterbody, any operational constraints or practicalities and associated environmental impacts and be developed in accordance with ANZECC (2000) and with consideration to the relevant NSW Water Quality Objectives.

Treated flows from the Rozelle water treatment plant would be discharged to a constructed wetland within the Rozelle Rail Yards. This would provide some ‘polishing’ of the effluent, helping to remove residual dissolved constituents such as nitrogen and phosphorus not removed by the operation water treatment plant. The wetland at Rozelle interchange would also be used to treat a portion of stormwater runoff. Opportunities to incorporate other forms of nutrient removal will be investigated during detailed design for the treatment plant at Darley Road, as required.

Meeting the NSW Water Quality Objectives would require contaminant levels to be sufficiently low that they do not affect the health of the community using these waterways for recreation.

Appendix R (Technical working paper: Contamination) of the EIS outlines the measures required to be adopted during operation of the project. This includes assessment of the suitability of land to be redeveloped following construction, for uses such as open space/recreational (or other uses as relevant). These works are required to be undertaken in accordance with guidance from the NSW EPA, including obtaining approved by an independent NSW EPA accredited site auditor. This process is required to ensure assessment and remedial works adequately address and prevent risks to human health, including the surrounding community.

The potential impacts to health for storages of chemicals and products associated with the operation of the project have been assessed in **section 9.3.2**.

10 Assessment of changes in social aspects on community health

10.1 General

The World Health Organization defines health as ‘a (dynamic) state of complete physical, mental and social wellbeing and not merely the absence of disease or infirmity’. Hence the assessment of health should include both the traditional/medical definition that focuses on illness and disease as well as the broader social definition that includes the general health and wellbeing of a population.

The assessment of changes in air quality and noise on the health of the local community (presented in **sections 6**, **7** and 8) addressed key aspects that have the potential to directly affect health.

This section has more specifically evaluated changes in the community that have the potential to indirectly affect the health and wellbeing of the community. This section also provides a review of whether there are any impacts that are likely to be more significant in any section of the community, and if these areas may result in inequitable impacts on the health of the population. This may affect population groups that may be advantaged or disadvantaged based on age, gender, socioeconomic status, geographic location, cultural background, aboriginality, current health status or existing disability. The evaluation presented in this section provides a qualitative evaluation of potential health impacts on the community.

Within an urban environment there are a wide range of complex factors (acting and interacting at different scales) that can affect health and wellbeing. This is conceptualised in **Figure 10-1** (presented by the International Council for Science and similar to that defined by the WHO) (ICSU 2011), that also presents a summary of the outcomes of this assessment. The broad range of factors identified may result in either positive or negative impacts on health and wellbeing. It is noted that no single element or determinant acts in isolation. Health and wellbeing in the urban environment depends on the sum of the total interactions between many factors. It is within this complex model that changes associated with the M4-M5 Link project, as well as the other WestConnex projects, have been evaluated in relation to impacts on health and wellbeing.

Appendix P (Technical working paper: Social and economic) of the EIS undertaken by HillPDA (2017) provides details in relation to many of the social impacts associated with the project. Aspects that are specifically relevant to potential impacts on the health and wellbeing of the community, either positive or negative, have been further highlighted in this section.

10.2 Changes in traffic

The study area includes the local road network around the Wattle Street and St Peters interchanges (also relevant to the M4 East and New M5 projects) as well as the Rozelle interchange and Iron Cove Link.

The Wattle Street interchange and surrounding area is currently heavily influenced by Parramatta Road, which is classified as an arterial road. Alternative east-west arterial roads within the project area include Frederick Street/Wattle Street/Dobroyd Parade/City West Link, Queens Road/Gipps Street/Patterson Street and the Hume Highway.

The Rozelle interchange and surrounding area includes the Rozelle Rail Yards site. Key roads in the vicinity of this area includes: City West Link, Victoria Road and the Western Distributor/Anzac Bridge, all of which are major arterial roads; Lilyfield Road, Catherine Street, The Crescent/Minogue Crescent/Ross Street, and Johnston Street all of which are collector roads.

The St Peters interchange and surrounding area includes links with the M5 East Motorway corridor that provides the main passenger, commercial and freight connection between southwest Sydney and the Sydney CBD, Sydney Airport and Port Botany. It is the main east-west freight, commercial and passenger vehicle corridor in southern Sydney, and is of local and regional transport importance in terms of its function. It also connects to the Sydney orbital network and interstate transport routes. The corridor forms part of the AusLink National Land Transport Network (National Road Network) and the Sydney orbital network. The major arterial road network in the study area is subject to high levels of congestion particularly during peak periods, as outlined **Appendix H** (Technical working paper: Traffic and transport) of the EIS.

Construction

A number of changes to local roads are proposed during the construction phase of works. While it is expected that access to all properties on the local roads would be maintained during the construction works, some permanent and temporary closures or reduced capacity of some local roads may affect the movement of local traffic through the area. In relation to traffic changes in the project area during construction, most of the issues that are relevant to community health relate to public safety, which is addressed in **section 9**.

In addition to safety risks to the public, construction works are expected to result in some increases in travel times for motorists, bus travel, pedestrians and cyclists. These changes have the potential to result in increased levels of stress and anxiety in the local community (as discussed below). These impacts, however, are expected to occur during the period of construction only.

A CTAMP would be prepared for the project, detailing temporary road closures and including traffic control procedures, signage requirements, construction traffic management requirements of the relevant Roads and Maritime manuals and procedures and Australian Standards.

Operations

Once the project is complete, it is expected to result in reductions in vehicle delays in a number of areas. There are some roads, however, where traffic volumes would increase, including Anzac Bridge and Victoria Road at Drummoyne.

Traffic congestion and long commuting times can contribute to increased levels of stress and fatigue, more aggressive behaviour and increased traffic and accident risks on residential and local roads as drivers try to avoid congested areas (Hansson et al. 2011). Increased travel times reduce the available time to spend on heathy behaviours such as exercise, or engage in social interactions with family and friends. Long commute times are also associated with sleep disturbance, low self-rated health and absence from work (Hansson et al. 2011). Reducing travel times and road congestion is expected to reduce these health impacts.

Public transport

Access to public transport is important, particularly for people who cannot or are unable to drive (such as the elderly and those with disabilities). Lack of good access to public transport for these individuals can result in increased feelings of isolation, helplessness and dependence.

During construction of the project, public transport in the project corridor and surrounding areas may be temporarily affected. The construction of the M4-M5 Link would not directly affect heavy rail or light rail services however passenger access to stations may be affected by temporary traffic changes and congestion arising from the presence of construction works. Most impacts related to the project relate to bus travel, where construction activities would result in the relocation of some bus stops and increased travel times.

From a public transport network perspective, the project, once complete, is expected to generally facilitate faster and more reliable morning and evening outbound bus journeys. Some inbound morning and evening bus journey times are forecast to increase however due to traffic congestion along the Western Distributor and Anzac Bridge combined with increased bus travel demands to Bathurst Street and the Sydney Harbour Bridge.

Pedestrian and cycle access

Walking and cycling have many health benefits including maintaining a healthy weight and improved mental status (Hansson et al. 2011; Lindström 2008; Wen & Rissel 2008; WHO 2000d).

There is currently a network of cycle paths in the area, comprising a mixture of separated cycleways and on road paths in areas of low to medium traffic. The current cycling network is predominantly oriented to recreational trips rather than commuter trips with dedicated cycleways concentrated within recreational spaces and along the foreshore.

As identified in **Appendix N** (Technical working paper: Active transport strategy) of the EIS, significant and highly valued active transport networks include the Bay Run, Glebe Foreshore, Anzac Bridge cycleway and the northern part of the GreenWay (the active transport connection between Cooks River and Iron Cove). The shared path along Whites Creek to Buruwan Park is also used by cyclists and pedestrians. Shared pedestrian and cycle paths also run both sides of Victoria Road with important overpasses provided at the city end of Victoria Road and across City West Link to provide connection to the water.

During construction, temporary alterations and diversions to pedestrian and cyclist networks have the potential to affect commuter departure times, travel durations, movement patterns and accessibility. Construction and operation of the project would result in changes to pedestrian and cycle access, including temporary and permanent closures or diversions of some pathways and pedestrian bridges. While the opportunity to walk or cycle in the project area would be maintained, the alterations and changes to amenity may detract from the experience of an environment and potentially deter people from enjoying an active lifestyle or feeling connected with their community. Hence it is important that the diversions and detours are safe, and perceived by the community to be a safe alternative.

Once completed, the M4-M5 Link project includes a range of changes to the active transport network in the area of the Rozelle Rail Yards (including links from Anzac Bridge to The Bays Precinct and Victoria Road, and through the Rozelle Rail Yards), Johnstons Street Link, Victoria Road – Iron Cove Link, Whites Creek Link and Johnston Creek Valley Link. Some of the proposed active transport improvements are to be completed in combination with other projects proposed in these areas.

Improvements in the active transport network, including improvements in transport connections, will have a positive benefit on community health. Where active transport opportunities are improved and offer safe alternatives to driving and public transport, they can encourage more active recreation and commuting activities.

Impacts on health and emergency services

The existing arterial roads and the local road network are currently used by emergency services to travel to and from call-outs. Construction of the project may require temporary traffic diversions, road occupation, temporary road closures and alternative property access arrangements.

The CTAMP for the project would be developed in consultation with relevant emergency services, ensuring that procedures are in place to maintain safe, priority access for emergency vehicles through construction zones. Additionally, local emergency services would be periodically updated on the staging and progress of construction works.

The project, during construction and operation, would not impact access to health or emergency services.

10.3 Property acquisitions

The project has been designed to minimise the need for surface property acquisition and impacts on other social infrastructure. This has been done through the following:

- Locating road infrastructure in tunnels
- Where possible, using areas within the footprint of the M4 East and New M5 projects
- Where possible, using government owned land, including land already owned by Roads and Maritime.

Notwithstanding, the project does require a number of property acquisitions as well as other temporary and permanent impacts on land use.

The acquisition and relocation of households and businesses due to property acquisition can disrupt social networks and affect health and wellbeing due to raised levels of stress and anxiety. This includes increased levels of stress and anxiety during the process of negotiating reasonable compensation. The purchase of and moving into a house can be one of the most significant events in a person's life. Both a house and a workplace are central to daily routine with the location of these premises influencing how a person may travel to/from work or study, the social infrastructure and businesses they visit and the people they interact with.

Impacts associated with property acquisition would be managed through a property acquisition support service that would provide the following:

- Affected households would have access to a counselling service that would assist people through the property acquisition process and, where necessary, provide referrals to more specialised experts
- An independent service would be provided to vulnerable households (eg elderly, those suffering an illness) to assist with relocation. Assistance could include finding a suitable house for relocation (purchase or rent), arranging removalists, disconnecting services and attending appointments with solicitors or other representatives
- A community relations support toll-free telephone line is to be established to respond to any community concerns or requests for translation services
- A property acquisition factsheet that outlines the process and provides further information for concerned residents is to be prepared and made available online and in hard copy at project information centres.

All acquisition required for the project would be undertaken in accordance with the *Land Acquisition (Just Terms Compensation) Act 1991* (NSW), the *Land Acquisition Information Guide* (NSW Government 2014) and the land acquisition reforms announced by the NSW Government in 2016 (NSW Government, 2016), which can be viewed online at:

https://www.finance.nsw.gov.au/sites/default/files/NSW_Government_Response.pdf. Relocation and some other categories of expenses would be claimable under this Act.

10.4 Green space

Green space within urban areas includes green corridors (paths, rivers and canals), grassland, parks and gardens, outdoor sporting facilities, playing fields and children play areas. Epidemiological studies have been undertaken that show a positive relationship between green space and health and wellbeing (de Vries et al. 2003; Health Scotland 2008; Kendal et al. 2016; Maas et al. 2006; Mitchell & Popham 2007). The outcomes of these international studies from the literature did depend on the quality of the available green space. They showed that green space areas in low socio-economic areas often had poor facilities, higher levels of graffiti, vacant/boarded up buildings and lower levels of safety. These studies showed that such spaces had few health benefits.

The health benefits of green space in urban areas include the following (Health Scotland 2008; Kendal et al. 2016; Lee & Maheswaran 2011):

- Green space areas that include large trees and shrubs can protect people from environmental exposures associated with flooding, air pollution, noise and extreme temperature (by regulating microclimates and reducing the urban heat island effect)
- Reduced morbidity
- Improved opportunities for physical activity and exercise. The benefits depend on a range of factors including the distance, ease of access, size of green space, location in relation to connectivity to residential or workplace areas, attractiveness, available facilities (particularly where used by specific sporting clubs) and multi-use (ie including children play areas, garden, seating, sporting facilities that can be used by a wide range of the community for different purposes)
- Improved mental health and feelings of wellbeing, particularly lower stress levels
- Improve opportunities for social interactions.

Green space areas in urban areas may also present some hazards, such as attracting antisocial behaviours (particularly in isolated areas), providing areas for drug or sexual activity and unintentional injuries from sports or use of playground equipment. It has also been found that individuals from ethnic or minority groups and those with disabilities are less frequent users of use green spaces areas.

There are a number of existing sporting/recreational facilities and parks in the project area, that include sporting fields, parks and reserves, playgrounds. The project has been designed to minimise impacts on existing recreational facilities. This is of particular note for the Glebe Foreshore and the Bay Run.

Table 10-1 provides a summary of the open space areas impacted by construction and operation.

Table 10-1 Impacts to green space during construction and operation

Construction impacts to open space	Operational impacts to open space
Haberfield and Ashfield (C1a, C2a, C3a, or C1b, C2b, C3b)	
None	None Delivery of new open space in accordance with the M4 East Urban Design and Landscape Plan
Darley Road civil and tunnel site (C4)	
None	None
Rozelle civil and tunnel site (C5), The Crescent civil site (C6) and Victoria Road civil site (C7)	
Construction in Buruwan Park between The Crescent and the Rozelle Bay light rail stop. Buruwan Park would be inaccessible during construction. Access to the light rail would be maintained.	Buruwan Park would be occupied by permanent operational infrastructure (including the new alignment of The Crescent). This park will no longer exist when construction of the project is complete. However, the project will deliver new open space within the Rozelle Rail Yards in accordance with the Urban Design and Landscape Plan to be prepared for the project. This will be a positive impact, and of benefit to the community.
Iron Cove Link civil site (C8)	
Temporary occupation of a section of King George Park immediately south of Iron Cove Bridge approach during construction. Realignment of the Bay Run at the connection to Victoria Road.	Permanent occupation of a section of King George Park immediately south of Iron Cove Bridge approach for the widened westbound Victoria Road carriageway and road embankment. However, the project will deliver new open space at this location in accordance with the Urban Design and Landscape Plan to be prepared for the project. This will be a positive impact, and of benefit to the community.
Manning Street bioretention facility	
Temporary occupation of a portion of the existing informal car park between Manning Street and King George Park during construction. No impacts to the adjacent King George Park during construction.	Permanent occupation for a bioretention facility and upgraded and improved car park. The bioretention facility would not impact the adjacent open space areas of King George Park during operation.
Pyrmont Bridge Road tunnel site (C9)	
None	None
Campbell Road civil and tunnel site (C10)	
None	None Delivery of new open space in accordance with the New M5 Urban Design and Landscape Plan.

During construction, the project would require the removal of some established vegetation across the project footprint, as well as permanent changes in access to Buruwan Park at Rozelle, and a section of King George Park south of Iron Cove Bridge.

Following completion of the construction works it is proposed that the Rozelle Rail Yards would be developed as open space, including a constructed wetland and pedestrian and cyclist infrastructure. A bioretention facility would be located within King George Park located south of Manning Street at Rozelle. Open space areas created at these locations would be developed and implemented in accordance with the Urban Design and Landscape Plan for the project. These additional or improved open space areas would provide the community in Rozelle with increased opportunity for active recreational activities and increased green space, potentially improving health. In the area around Wattle Street and Campbell Road, the project will include new open space areas in line with the M4 East and New M5 Urban Design Landscape Plans.

10.5 Changes in community access and connectivity

Roads and freeways can divide residential communities hindering social contact. The presence of busy roads inhibits residents from socialising and children from playing, or accessing nearby recreational areas. Heavy traffic also affects child development (WHO 2000d). Children learn how to make responsible decisions, how to behave in different situations and develop a relationship with their environment and community through independent mobility. Where children have the opportunity to be able to play in local streets or safely access local parks they have been found to have twice as many social contacts as those where such activities are prevented by heavy traffic or unsafe conditions.

Social connectedness and relationships are important aspects of feeling safe and secure. Streets with heavy traffic have been associated with fewer neighbourhood social support networks and have been linked to adverse health outcomes (WHO 2000d). Any temporary and permanent changes to the access to social infrastructure, community resources or to other desirable locations (such as employment, study, friends and family) and safety to movement may affect community networks and in turn trigger community severance.

Community severance effects often occur during major transportation projects (during construction and operation) due to detours in the local road network, changes to active and public transport routes, and connector roads receiving an increase or decrease in traffic movements. The changes to the road networks particularly along City West Link, Victoria Road, The Crescent, Lilyfield Road and Darley Road may contribute to feelings of community severance and disconnection. However, it is noted that these are existing major road corridors, where community severance and disconnection may already be of significance. The project is not introducing new major roadways that would change existing conditions.

Construction of the project would include the removal of two pedestrian bridges across Victoria Road and City West Link which are popular for both recreational and commuter pedestrian and cyclist traffic. The removal of these bridges, despite the temporary alternatives, may reduce community cohesion and sense of access to place. These connections provide important access to Rozelle Bay and through to the Glebe Foreshore walkways. The civil site at The Crescent would also reduce the connection for pedestrian and cyclists to the Glebe Foreshore walkways for residents of both the Rozelle area and Annandale. This reduced connectivity may deter people from participating in community activities or active transport, potentially reducing the connection to an environment and feeling of community cohesion.

Once construction is completed, parts of the Rozelle Rail Yards would be redeveloped as public open space. This would provide significantly improved community access and transport linkages through this area.

10.6 Visual changes

Visual amenity can be described as the pleasantness of the view or outlook of an identified receptor or group of receptors (eg residences, recreational users). Visual amenity is an important part of an area's identity and offers a wide variety of benefits to the community in terms of quality of life, wellbeing and economic activity. For some individuals, changes in visual amenity can increase levels of stress and anxiety. These impacts, however, are typically of short duration as most people adapt to changes in the visual landscape, particularly within an already urbanised area. As a result, most changes in visual impacts are not expected to have a significant impact on the health of the community.

During construction, visual amenity throughout the project area has the potential to be affected by factors such as the removal of established vegetation, the installation of construction hoardings and/or the visual appearance of construction sites. In some areas, the acoustic sheds and hoardings required to manage noise impacts during construction are large and may cause overshadowing. Further factors may include the alteration of view corridors to heritage, open space, water bodies or the city skyline.

The operational project would include changes to local visual amenity due to the presence of new and amended infrastructure (including ventilation facilities, water treatment plants, substations, bridges and drainage channels), landscaping and urban design features.

10.7 Equity

The health effects associated with impacts related to transport projects are not equally distributed across the community. Groups at higher risk, or more sensitive to impacts, include:

- Elderly
- Individuals with pre-existing health problems
- Infants and young children
- Individuals with disabilities
- Individuals who live in areas of higher levels of air or noise pollution.

Often the impacts can accumulate in the same areas, which may already have poorer socio-economic and health status, most commonly due to the affordability of housing in areas that are closer to main roads, industry or rail infrastructure. Disadvantaged urban areas are commonly characterised by high traffic volumes, higher levels of air and noise pollution, feelings of insecurity and lower levels of social interactions and physical activity in the community.

To further evaluate potential equity issues associated with the project, the location of impacts identified in relation to air quality, noise and traffic were reviewed individually and in combination, in conjunction with available information on the location of sensitive community groups.

It is noted that in many urban areas housing prices are lower on main roadways. The median house prices in the study area are variable, however in most areas they are consistent with the Sydney average. Some public housing is located in the study area; however, these properties are mixed in with privately owned property such that there are no specific areas with higher populations of public housing tenants. Hence there are no social equity issues identified in relation to the change in air quality in the local community.

There are no areas identified in the local community where the combined impact from changes in noise and air quality would be different from the conclusions presented for the individual assessment of air quality and noise impacts.

A number of existing industrial premises located in the area to the north and northwest of Sydney Airport, between Airport Drive/Alexandria Canal and the Princes Highway that experience the greatest increase in particulates and nitrogen dioxide, associated with the project. These areas are industrial, where the incremental risks are considered to be acceptable/tolerable (see **section 6**). There are no community facilities (including childcare or aged care facilities) located in these areas, and it is not expected that the area would be rezoned in the future for residential or community use given the proximity to Sydney Airport (including flight paths).

Suburbs in the study area that, based on the 2011 Census Data, are slightly more disadvantaged (in relation to the Socio-Economic Index for Areas (SEIFA)) include Glebe, Eveleigh and Marrickville, as well as populations in the Canterbury area. There are no project related air quality or noise impacts (including during cumulative scenarios) that are of significance in these areas. Impacts on human health in these areas would be lower than predicted for the maximum impacted individuals.

Residents and community facilities located adjacent to a number of key surface roads, particularly City West Link, Parramatta Road, Princes Highway, part of Victoria Road in Rozelle, Southern Cross Drive and the M5 would benefit from reduced traffic volumes, potentially improved traffic and pedestrian safety, and improvements (albeit small and not measurable) in air quality and noise.

In relation to broader equity aspects the M4-M5 Link, along with other approved WestConnex projects (M4 East and New M5) are aimed at improving access to the area from outer lying areas in the west and southwest. The SEIFA for populations in the outer west and southwest are lower, indicating they are more disadvantaged, than populations in the study area. Improving access and travel times for these more disadvantaged populations provides the potential for health benefits such as those that are derived from improved employment opportunities, decreased travel times (and potentially more time available for other active, family or community activities) and reduced levels of stress and anxiety.

10.8 Construction fatigue

Construction fatigue relates to receptors that experience construction impacts from a variety of projects over an extended period of time with few or no breaks between construction periods. Construction fatigue typically relates to traffic and access disruptions, noise and vibration, air quality, visual amenity and social impacts from projects that have overlapping construction phases or are back to back.

The assessment of construction fatigue in this report includes the following projects that may overlap with the timing of the construction of the M4-M5 Link project, or have been recently completed, comprising:

- WestConnex M4 East
- WestConnex New M5
- Western Harbour Tunnel and Beaches Link project
- CBD and South East Light Rail (specifically the Rozelle maintenance depot)
- Site management works at the Rozelle Rail Yards
- Sydney Metro City and Southwest (specifically the Marrickville dive site).

The area is also subject to ongoing urban development, with many of the LGAs in the study area projected to have significant population growth (see **section 4.4**). Construction impacts on the community occur from all these different projects and can result in construction impacts that are no longer considered to be transient and/or short-term.

In relation to the M4-M5 Link project there are some areas where construction impacts will occur at the same time and consecutively with other projects. The areas of greatest impact are in Haberfield, Rozelle and St Peters.

Appendix I (Technical working paper: Air quality) of the EIS has not specifically addressed impacts to air from longer duration construction activities. The approach adopted evaluates risk on the basis of the type and scale of activity and potential for dust to be generated, and the location of sensitive receptors in the vicinity of these works. Hence the dust management measures identified to minimise dust impacts and health risks during construction would be need to be applied through the duration of the works, consistent with standard construction management practices. Such measures would need to then be applied across all construction projects, for major infrastructure and other construction activities (including building works) to minimise impacts in the long-term and would be subject to the requirements of approvals for those projects.

Appendix J (Technical working paper: Noise and vibration) of the EIS has included an assessment of noise impacts that may occur where there are construction activities from a number of road or other infrastructure projects that occur consecutively (one after another) and result in exposure to construction noise impacts for a longer period of time. For the key areas, where construction fatigue may be of concern, the following was identified:

- Haberfield: construction activities associated with the M4 East project as well as the M4-M5 Link within the construction ancillary facilities in Haberfield would result in surrounding communities being exposed to construction noise for longer periods of time. Areas potentially affected (depending on which construction ancillary facilities are utilised during the construction of the M4-M5 Link project) are located:
  - Adjacent to the Northcote Street civil site
  - Adjacent to the Wattle Street civil and tunnel site
  - Adjacent to the Haberfield civil and tunnel site

    In these areas, additional mitigation measures are identified, specifically an increase in the height of hoarding around the construction sites and at-receptor noise mitigation (where required), to address these longer duration noise impacts.
- Rozelle: construction activities associated with the M4 East project, M4-M5 Link and other infrastructure projects, namely the CBD and South East Light Rail Rozelle maintenance depot would result in construction noise for longer periods of time. Areas affected are located:
  - Adjoining Lilyfield Road between Justin Street and Ryan Street
  - Adjoining Brenan Street between Starling Street and White Street

    In these areas additional mitigation measures were identified, specifically an increase in the height of hoarding around the construction sites, an upgrading of the acoustic shed performance and at-receptor noise mitigation (where required), to address these longer duration noise impacts. Under this scenario there are a number (345 receptors) that may be impacted by vibration at levels that exceed the human comfort criteria. These impacts will require monitoring and management
- St Peters: construction activities associated with the New M5 and the M4-M5 Link would result in exposure to construction noise for longer periods of time. Areas affected are:
  - Adjoining Campbell Road

    In these areas, additional mitigation measures are recommended that include optimising the design of acoustic sheds, noise barriers/hoarding and management measures and at-receptor noise mitigation (where required), to address these longer duration noise impacts.

There are other impacts associated with construction that affect the health and wellbeing of the community. This includes:

- Traffic and transport:
  - Congestion on surface roads from the movement of construction vehicles including heavy vehicles (for spoil haulage) and light vehicles (such as worker access to construction ancillary facility sites)
  - Temporary access disruption to private properties including residences and businesses
  - Partial and/or complete closure of roads, active transport links (ie pedestrian and cyclist paths, including provision of alternate links), and potential loss of street parking
  - Changes to the location of bus stops and access to light rail stations
- Visual amenity
  - Views of temporary noise barriers and construction hoarding, plant and equipment
  - Alteration of views through removal of buildings and landscaping.

Where these impacts occur for extended periods of time, there is the potential that increased levels of stress and anxiety may also continue for extended periods of time. Health effects associated with stress and anxiety are further discussed in **section 10.10**.

To assist in managing construction fatigue, the project is expected to involve an Acoustic Advisor, a Utilities Coordination Group and have a complaints procedure in place during construction, as follows:

- The Acoustic advisor is an independent technical specialist whose role will be to review data collected and provide advice and recommendations to ensure noise and vibration impacts are avoided or minimised within the community. This may involve changes in work practices or the implementation of additional noise management/mitigation measures. This role will be undertaken for the duration of construction
- The Utilities Coordination Group, formed of representatives from all concurrent projects and asset providers, will review the concurrent activities to manage and minimise impacts to utilities (relocation, adjustment or protection), where possible
- A Complaints Management System will be in place for the duration of construction. This system includes the recording of complaints and how the complaint was addressed (within a Complaints Register). A Community Complaints Commissioner, who is an independent specialist, will oversee the system and will follow-up on any complaint where the public is not satisfied with the response.

10.9 Economic aspects

The construction expenditure of the project would be of significant benefit to the economy. This expenditure would inject economic stimulus benefits into the local, regional and state economies. Ongoing or improved economic vitality of significant health benefit to the community. Employment opportunities would grow in the region through the potential increase in business customers and through the increase in demand for construction workers. The increase in demand for labour may increase wages in the region, particularly for construction workers, who would be in high demand.

It is noted that the acquisition and relocation of some businesses can result in impacts on local economies. In addition, changes to access during construction may also adversely impact on some local businesses. To minimise these impacts the project would include development of a Business Management Strategy.

Freight and commercial vehicle movements are an important component of the economy. Numerous industries are dependent upon efficient transport to service operational requirements. Transport for NSW estimated that freight and logistics contributed $58 billion to NSW State Gross Product (GSP) in 2011, this represented 13.8 per cent of NSW GSP at the time.

An objective of the M4-M5 Link project is to encourage heavy and commercial vehicle movements into the tunnel, increasing efficiencies and reducing *'freight costs through increased travel speeds and reliability and reducing the distances travelled by freight vehicles'.*

The transport modelling undertaken for the project highlighted that there could be potentially substantial benefits for freight and commercial vehicle movements during the operation of the M4-M5 Link. The subsequent effects of the operation of the M4-M5 Link on business productivity include:

- Reduced cost of commercial and freight movements
- Increased productivity from reduced congestion and travel times for commercial and freight movements
- Increased economic output as a result of increased efficiency in freight and commercial vehicle movements.

The modelling determined that a significant number of freight vehicles diverted from surface roads into the M4-M5 Link, with an expectation of travel time savings. This in turn would improve travel times on existing major arterial surface roads such as Victoria Road, Parramatta Road and The Princes Highway for commuters and commercial vehicles. These benefits are difficult to quantify.

10.9.1 Road tolling

Funding of WestConnex, as proposed in the WestConnex Updated Strategic Business Case, assumes a distance based toll would be implemented on operation of each component project. Distance based tolling means that motorists would only pay tolls for the sections of the motorway they use. The proceeds of the toll on each component project once operational would be applied to fund the construction of other components of the WestConnex program of works. Tolls for the entire WestConnex Motorway would be capped at a maximum amount of $8.60 (2017 dollars) for cars and light commercial vehicles. Cars and light commercial vehicles would pay around one third of the toll for heavy commercial vehicles. Tolls will escalate up to a maximum of four per cent or the consumer price index (CPI) per year (whichever is greater) until 2040. After that, CPI will apply.

The socio-economic impacts associated with a new toll road are diverse and far ranging, with the level of the effect being related to which road users are targeted and the amount charged.

The implementation of road tolls can have direct impacts on travel times, reduced emissions and traffic accidents, as well as other less direct impacts on social inequality, company movements, and effects on the regional/national economy which are more difficult to quantify and are generally documented qualitatively.

One impact is the potential to increase congestion volumes on surrounding roads as a result of toll avoidance. The use of a toll road can also increase the cost of living and can exacerbate social inequality. Specifically, the impact of roads tolls on households can be assessed as a function of household income, urban spatial structure, and available mobility choices. Depending on the travel routes of individuals, and the individual economic situation, there may be a proportion of the population that avoid the use of tollways due to affordability.

The magnitude of tolls proposed for the M4-M5 Link project, including consideration of toll avoidance, has been factored into the traffic modelling, and subsequent air quality and noise modelling, and hence impacts on the health of the community have been considered.

10.10 Stress and anxiety issues

A number of changes within the community (see **sections 10.2** to **10.9)** have the potential to affect levels of stress and anxiety. Some changes may result in a lowering of feelings of stress and anxiety, and there are others that may result in higher levels within the community. In addition, construction fatigue (as discussed in **section 10.8**) from the combined WestConnex projects, other infrastructure projects and ongoing urban developments associated with urban growth, may result in elevated levels of stress and anxiety for extended periods of time.

Chronic and persistent negative stress, or distress, can lead to many adverse health problems including physical illness and mental, emotional and social problems. Response to stress will vary between individuals with genetic inheritance and personal/environmental experiences of importance (Schneiderman, Ironson & Siegel 2005).

An acute stressful event results in changes to the nervous, cardiovascular, endocrine and immune systems, more commonly known as the “fight or flight” response (Schneiderman, Ironson & Siegel 2005). Unless there is an accident or other significant event, such acute stress events are not expected to be associated with construction or operation of the M4-M5 Link project.

For shorter-term events, stress causes the immune system to release hormones that trigger the production of white blood cells, that fight infection and other disease-fighting elements. This response is important for fighting injuries and acute illness. However, this activity within the body is not beneficial if it occurs for a long period of time. Hormones released during extended or chronic stress can inhibit the production of cytokines (the messengers that allow cells to talk together to fight infection) lowering the body’s ability to fight infections. This makes some individuals more susceptible to infections, and may also experience more severe infections. It can also trigger a flare up of pre-existing autoimmune diseases (which are a range of diseases where the immune system gets confused and starts attacking healthy cells) (Mills, Reiss & Dombeck 2008; Schneiderman, Ironson & Siegel 2005).

Other physiological effects associated with chronic stress include (Brosschot, Gerin & Thayer 2006; McEwen, Bruce S. 2008; McEwen, B. S. & Stellar 1993; Mills, Reiss & Dombeck 2008; Moreno-Villanueva & Bürkle 2015):

- Digestive disorders, with hormones released in response to stress causing a number of people to experience stomach ache or diarrhoea, with appetite also affected in some individuals (resulting in under-eating or over-eating)
- Chronic activation of stress hormones can raise an individual’s heart rate, cause chest pain and/or heart palpitations and increase blood pressure and blood lipid (fat) levels. Sustained high

levels of cholesterol and other fatty substances can lead to atherosclerosis and other cardiovascular disease and sometimes a heart attack (Pimple et al. 2015; Seldenrijk et al. 2015)

- Cortisol levels, release at higher levels with stress, play a role in the accumulation of abdominal fat, which has been linked to a range of other health conditions
- Stress can cause muscles to contract or tighten, cause tension aches and pains (Ortego et al. 2016).

Some individuals respond to elevated levels of stress by taking up or continuing unhealthy stress coping strategies such as smoking, drinking or overeating, all of which are associated with significant health risks. Chronic levels of stress have also been found to cause or exacerbate existing mental health issues, including mood disorders such as depression and anxiety, cognitive problems, personality changes and problem behaviours. It can also affect individuals with pre-existing bipolar disorders.

By-products of stress hormones can act as sedatives (chemical substances which cause us to become calm or fatigued). When such hormone by-products occur in large amounts (which will happen under conditions of chronic stress), they may contribute to a sustained feeling of low energy or depression. Habitual patterns of thought which influence appraisal and increase the likelihood that a person will experience stress as negative (such as low self-efficacy, or a conviction that you are incapable of managing stress) can also increase the likelihood that a person will become depressed. It is normal to experience a range of moods, both high and low, in everyday life. While some "down in the dumps" feelings are a part of life, sometimes, people fall into depressing feelings that persist and start interfering with their ability to complete daily activities, hold a job, and enjoy successful interpersonal relationships (Mills, Reiss & Dombeck 2008; Schneiderman, Ironson & Siegel 2005).

Some people who are stressed may show relatively mild outward signs of anxiety, such as fidgeting, biting their fingernails, tapping their feet, etc. In other people, chronic activation of stress hormones can contribute to severe feelings of anxiety (eg racing heartbeat, nausea, sweaty palms, etc.), feelings of helplessness and a sense of impending doom. Thought patterns that lead to stress (and depression, as described above) can also leave people vulnerable to intense anxiety feelings (Mills, Reiss & Dombeck 2008).

Anxiety or dread feelings that persist for an extended period of time; which cause people to worry excessively about upcoming situations (or potential situations); which lead to avoidance; and cause people to have difficulty coping with everyday situations may be symptoms of one or more anxiety disorders (Mills, Reiss & Dombeck 2008).

More generally, it must be noted that urbanisation, or increased urbanisation, regardless of specific projects has been found to affect levels of stress and mental health (Srivastava 2009). These impacts are greater where there is urbanisation without improvements in infrastructure to improve equitable access to employment and social areas/communities (Srivastava 2009).

The role of either acute or long-term environmental stress on the health of any community, in general and for specific project(s), including the WestConnex projects, cannot be quantified. There are a wide range of complex factors that influence health and wellbeing, specifically mental health. It is not possible to determine any specific outcomes that may occur as a result of a specific project, or number of projects. However, it is noted that within any urban environment there will be a wide range of stressors present from infrastructure projects as well as other urban developments that may or may not contribute to the health effects outlined above.

It is noted that the M4-M5 Link project along with the other approved WestConnex projects aim to improve infrastructure, connections and access within the urban environment. Hence on a broader scale, the longer-term projects, while requiring long-term management to minimise construction impacts, may assist in reducing stress and associated physiological and mental health impacts within the urban environment.

10.11 Overall assessment

Within an urban environment there are a wide range of complex factors (acting and interacting at different scales) that can affect health and wellbeing. This is conceptualised in **Figure 10-1** (presented by the International Council for Science and similar to that defined by the WHO) (ICSU

2011). The factors identified may result in either positive or negative impacts on health and wellbeing. It is noted that no single element or determinant acts in isolation. Health and wellbeing in the urban environment depends on the sum of the total interactions between many factors.

Potential impacts related to this project are summarised on the figure, showing both positive and negative impacts. The figure illustrates the complexity of making definitive conclusions in relation to health impacts in the community. However, it is noted that where negative impacts have been identified, impacts to the community are minimised through the implementation of appropriate mitigation or management measures.

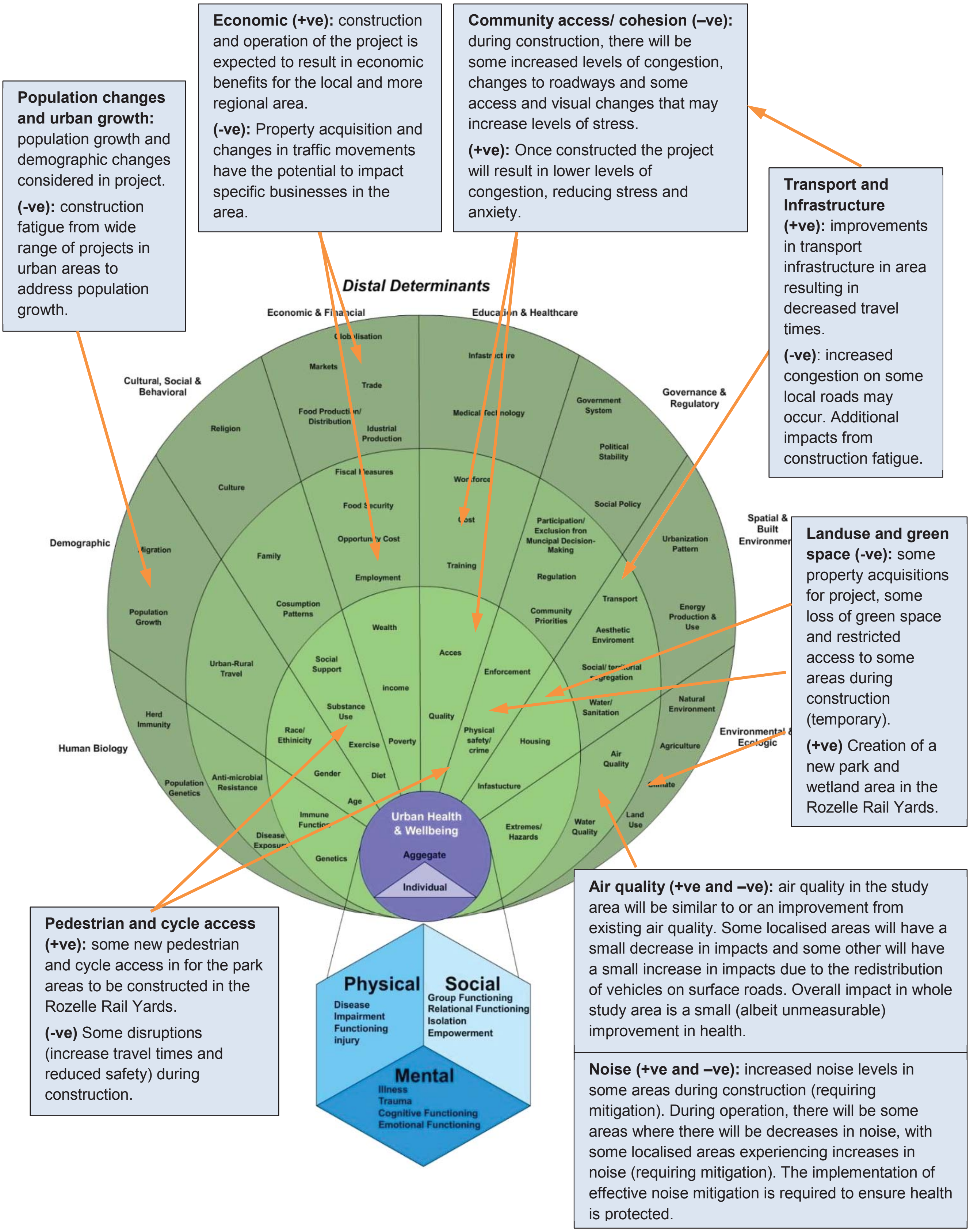

Figure 10-1 Conceptual framework for determinants of health and wellbeing in the urban environment and potential impacts from project (ICSU 2011)

11 Uncertainties

11.1 General

Any assessment of health risk or health impact incorporates data and information that is associated with some level of uncertainty. In most cases, where there is uncertainty in any of the key data or inputs into an assessment of health risk or health impact, a conservative approach is adopted. This approach is adopted to ensure that the assessment presents an overestimation of potential health impacts, rather than an underestimation. It is therefore important to provide some additional information on the key areas of uncertainty for the HHRA to support the conclusions presented.

11.2 Population health data

There are limitations in the use of this data for the quantification of impact and risk. This data is derived from statistics recorded by hospitals and doctors, reported by postcode of residence, and are dependent on the correct categorisation of health problems upon presentation at the hospital. There may be some individuals who may not seek medical assistance particularly with less serious conditions and hence there is expected to be some level of under-reporting of effects commonly considered in relation to morbidity. Quantitatively, the baseline data considered in this assessment is only a general indicator (not a precise measure) of the incidence of these health endpoints.

11.3 Exposure concentrations

The concentration of various pollutants in air (ie exposure concentrations) and noise levels relevant to different locations in the community have been calculated on the basis of a range of input assumptions and modelling. Details of these are presented within the relevant technical reports.

11.3.1 Traffic modelling

Assessment of impacts of the project on air and noise has relied on the modelling of traffic changes (refer to **Appendix H** (Technical working paper: Traffic and transport) of the EIS). The traffic modelling has considered increased activity at Sydney Airport and Port Botany as well as population growth projections over the Sydney metropolitan area.

11.3.2 Air quality

An assessment on the scale of 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 emissions and concentrations, and there are clearly limits to how accurately any impacts in future years can be predicted. Conservatism is built into predictions to ensure that a margin of safety is applied (ie to minimise the risk that any potential impacts are underestimated).

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 quite 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.

A number of conservative assumptions and approaches have been adopted in the assessment of air quality impacts, which include:

- Emissions model adopted overestimate emissions and concentrations within the tunnels (by a factor of 1.7 to 3.3)
- Assessment of total concentrations at receptor locations has adopted a contemporaneous approach. For the assessment of impacts it is assumed that the background concentration estimated occurs at the same time as the maximum predicted air quality impact from the project. It is unlikely that this would occur, and as a result the predicted maximum total concentration will be an overestimate. It is noted that it is not possible to know the true total (background plus project) concentration at any location.

A comparison of modelled and measured air concentrations was undertaken to evaluate the performance of the modelling approach adopted (as presented in **Annexure J** of **Appendix I** (Technical working paper: Air quality) of the EIS). For the assessment of total 1-hour average NOx, the modelled/predicted concentrations using the contemporaneous approach was found to significantly overestimate the total concentration. For the assessment of annual average NOx the modelled/predicted concentrations were found to be higher than measured, but the level of overestimation was less than for the 1-hour average data. The modelling of particulate matter was found to overestimate concentrations (with the level of overestimation less than observed for NOx).

When looking at different times of the day, the modelling was found to slightly overpredict impacts during peak hour, under predict impacts during the middle of the day. In addition, the modelling was found to overpredict concentrations on weekends as it has been assumed that the weekday pattern of use for the project is the same on weekends. This will result in an overestimation of annual average concentrations in the study area.

Overall, the approach adopted for modelling changes in air quality is considered to have provided conservative estimates of exposure concentrations throughout the study area.

11.3.3 Noise assessment

The noise impact assessment incorporates information on traffic volumes and composition from the traffic model and other information on the design of the M4-M5 Link project. The modelling also incorporates measured background noise levels and a range of inputs and assumptions in relation to noise generated from the project. The model used in the assessment was validated based on existing information and traffic information and found to predict noise impacts within acceptable levels of variability, namely the difference between measured and modelled noise levels is ± two dB(A).

11.4 Approach to the assessment of risk for particulates

11.4.1 General

The available scientific information provides a sufficient basis for determining that exposure to particulate matter (particularly $PM_{2.5}$ and smaller) is associated with adverse health effects in a population. The data is insufficient to provide a thorough understanding of all of the potential toxic properties of particulates to which humans may be exposed. Over time it is expected that many of the current uncertainties would be refined with the collection of additional data, however some uncertainty would be inherent in any estimate. The influence of the uncertainties may be either positive or negative.

Overall, however, the epidemiological and toxicological data on which the assessment presented in this technical working paper are based on current and robust information for the assessment of risks to human health associated with the potential exposure to particulate matter from combustion sources.

11.4.2 Exposure-response functions

The choice of exposure-response functions for the quantification of potential health impacts is important. For mortality health endpoints, many of the exposure-mortality functions have been replicated throughout the world. While many of these have shown consistent outcomes, the calculated relative risk estimates for these studies do vary. This is illustrated by **Figure 11-1**, **Figure 11-2** and **Figure 11-3** that show the variability in the relative risk estimates calculated in published studies for the US (and Canadian) population that are relevant to the primary health endpoints considered in this assessment (USEPA 2012). A similar variability is observed where additional studies from Europe, Asia and Australia/New Zealand are considered.

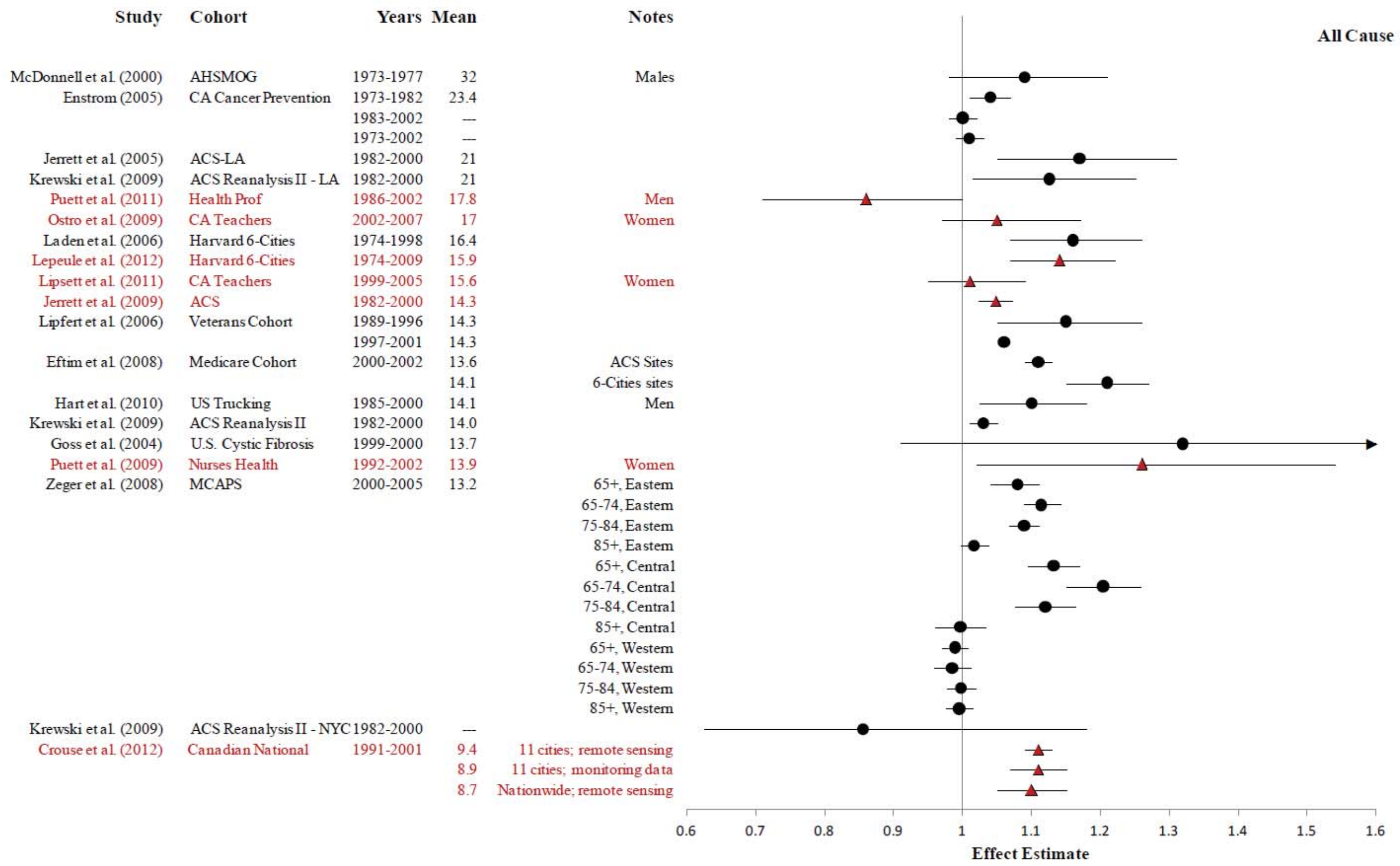

Figure 11-1 All-cause mortality relative risk estimates for long term exposure to $PM_{2.5}$ (USEPA 2012, note studies in red are those completed since 2009)

Study	Location	Age	Lag	Mean	98th
Metzger et al. (2004)	Atlanta, GA	All	0-2	17.8	---
Tolbert et al. (2007)	Atlanta, GA	All	0-2	17.1	---
Zanobetti et al. (2009)*	26 U.S. Communities	65+	0-1	15.3	---
Ito et al. (2011)	New York, NY	40+	0	14.4	---
Bell et al. (2008)	202 U.S. Counties	65+	0	12.9	34.2
Slaughter et al. (2005)	Spokane, WA	All	1	10.8	29.6
Kloog et al. (2012)	New England	65+	0-1	9.6	---
Kim et al. (2012)	Denver, CO	All	0-2 DL	8.0	---
Burnett et al. (1999)	Toronto, CAN	All	0-1	18.0	---
Ito (2003)	Detroit, MI	65+	1	18.0	---
Metzger et al. (2004)	Atlanta, GA	All	0-3	17.8	---
Dominici et al. (2006)	204 U.S. Counties	65+	0-2 DL	13.3	34.8
Pope et al. (2006)	Utah Valley, UT	All	0	10.1-11.3	---
Zanobetti et al. (2009)*	26 U.S. Communities	65+	0-1	15.3	---
Sullivan et al. (2005)	King County, WA	21-98	24 h	12.8	---
Peters et al. (2001)	Boston, MA	61.6a	24 h	12.1	28.2
Zanobetti & Schwartz (2005)	Boston, MA	65+	0	11.1**	---
Stieb et al. (2009)*	7 Canadian cities	All	0	6.7-9.8	---
Burnett et al. (1999)	Toronto, CAN	All	0-2	18.0	---
Ito (2003)	Detroit, MI	65+	1	18.0	---
Metzger et al. (2004)*	Atlanta, GA	All	0-2	17.8	---
Symons et al. (2006)	Baltimore, MD	All	2	16.0	---
Zanobetti et al. (2009)*	26 U.S. Communities	65+	0-1	15.3	---
Dominici et al. (2006)	204 U.S. Counties	65+	0	13.3	34.8
Haley et al. (2009)	New York State	All	0-2	11.1-15.5	---
Pope et al. (2008)	Utah	All	0-13 DL	10.8	44.5
Stieb et al. (2009)*	7 Canadian cities	All	0	6.7-9.8	---
Metzger et al. (2004)*	Atlanta, GA	All	0-2	17.8	---
Dominici et al. (2006)	204 U.S. Counties	65+	0	13.3	34.8
Kloog et al. (2012)	New England	65+	0-1	9.6	---
Szyszkowicz et al. (2012)*	Edmonton, CAN	All	0-3	8.5	---

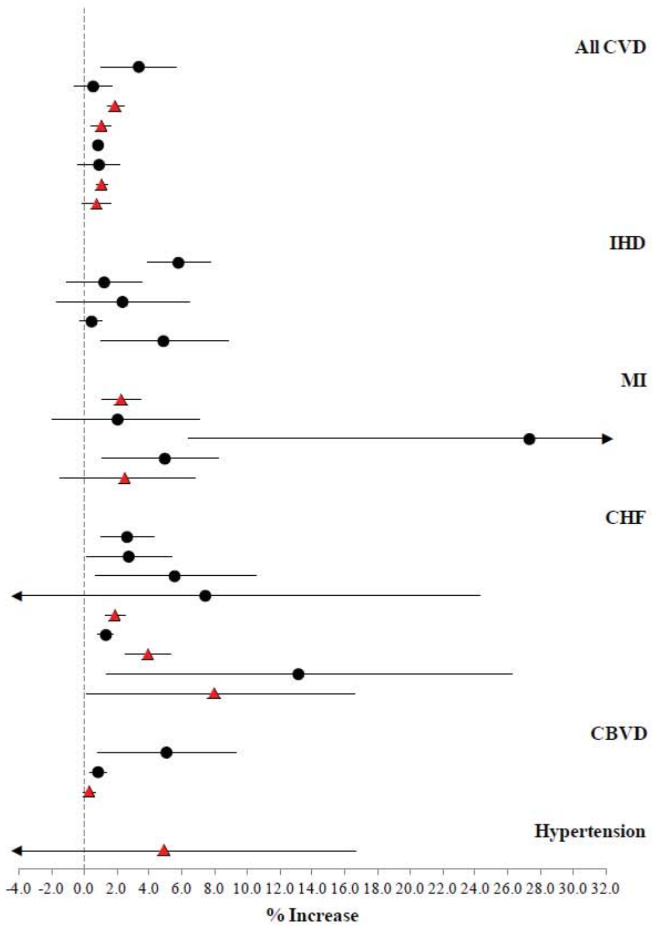

Figure 11-2 Per cent increase in cardiovascular-related hospital admissions for a 10 microgram per cubic metre increase in short term (24 hour average) exposure to $PM_{2.5}$ (USEPA 2012, note studies in red are those completed since 2009)

(Note: CVD = cardiovascular disease; IHD = ischemic heart disease ; MI = myocardial infarction; CHF = congestive heart failure; CBVD = cerebrovascular disease)

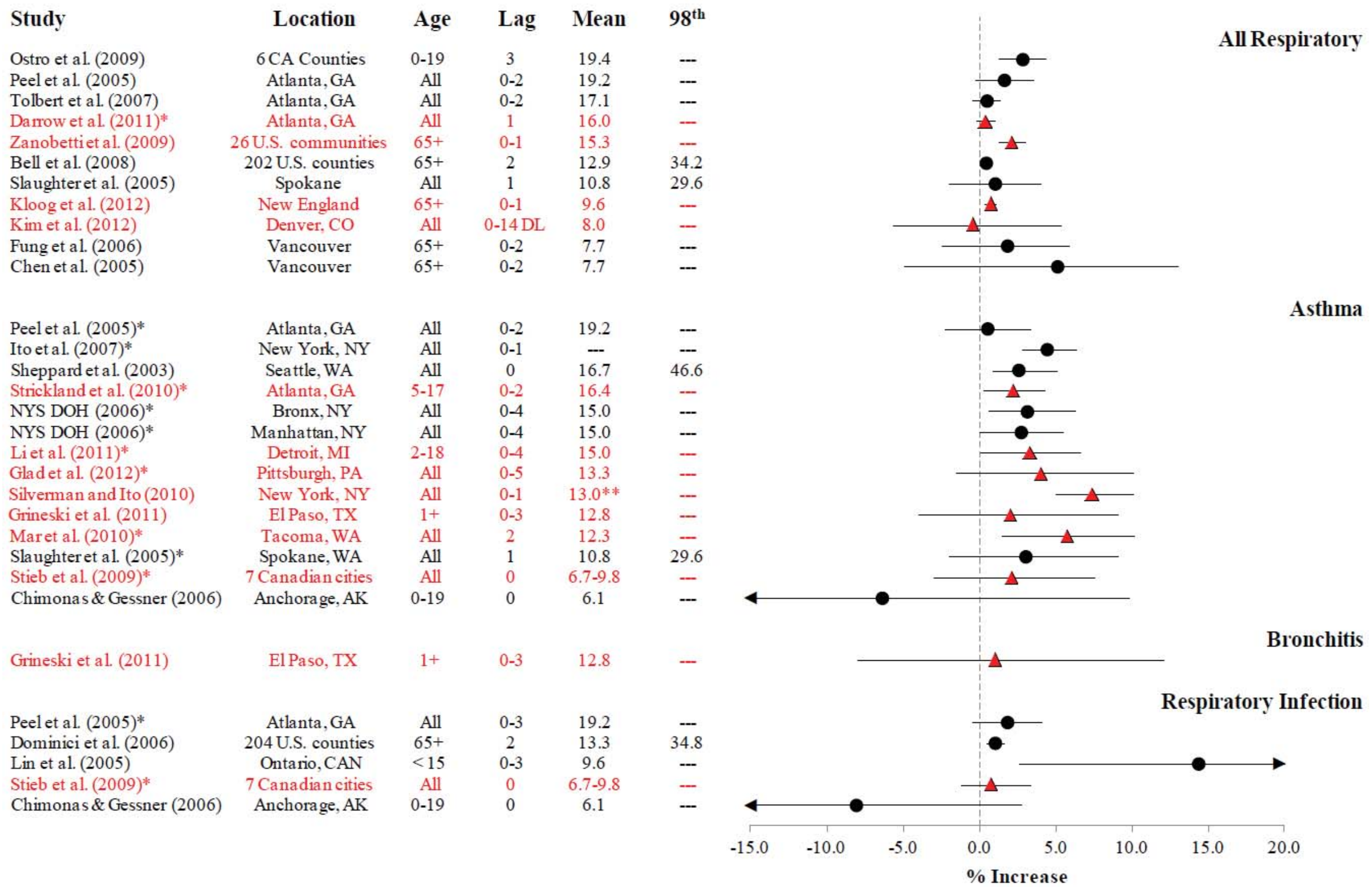

Figure 11-3 Per cent increase in respiratory-related hospital admissions for a 10 micrograms per cubic metre increase in short term (24 hour average) exposure to $PM_{2.5}$ (USEPA 2012, note studies in red are those completed since 2009)

These figures illustrate the variability inherent in the studies used to estimate exposure-response functions. The variability is expected to reflect the local and regional variability in the characteristics of particulate matter to which the population is exposed.

Based on the available data, and the detailed reviews undertaken by organisations such as the USEPA (USEPA 2010, 2012) and WHO (WHO 2003, 2006a, 2006b) and discussions with NSW Health, the adopted exposure-response estimates are considered to be current, robust and relevant to the characterisation of impacts from $PM_{2.5}$.

11.4.3 Shape of exposure-response function

The shape of the exposure-response function and whether there is a threshold for some of the effects endpoints remains an uncertainty. Reviews of the currently available data (that includes studies that show effects at low concentrations) have not shown evidence of a threshold. However, as these conclusions are based on epidemiological studies, discerning the characteristics of the particulates responsible for these effects and the observed shape of the dose-response relationship is complex. For example, it is not possible to determine if the observed no threshold response is relevant to exposure to particulates from all sources, or whether it relates to particulates from combustion sources only.

Most studies have demonstrated that there is a linear relationship between relative risk and ambient concentration however for long term exposure-related mortality a log-linear relationship is more plausible and should be considered where there is the potential for exposure to very high concentrations of pollution. In this assessment, the impact considered is a localised impact with low level incremental increases in concentration. At low levels, the assumption of a linear relationship is considered appropriate.

11.5 Diesel particulate matter evaluation

The assessment of exposure to diesel particulate matter has assumed that 100 per cent of the $PM_{2.5}$ associated with the project is derived from diesel sources. This is a conservative assumption.

The health hazard conclusions associated with exposure to diesel particulate matter are based on studies that are dominated by exhaust emissions from diesel engines built prior to the mid-1990s. With current engine use including some new and many older engines (engines typically stay in service for a long time), the health hazard conclusions, in general, are likely to be applicable to engines currently in use.

However as new and cleaner diesel engines, together with different diesel fuels, replace a substantial number of existing engines; the general applicability of the health hazard conclusions may require further evaluation. The NEPC (NEPC 2009) has established a program to reduce diesel emissions from the Australian heavy vehicle fleet. This is expected to lower the potential for all diesel emissions over time.

11.6 Co-pollutants

For the assessment of nitrogen dioxide, particulates and noise, the exposure-response relationships used in this assessment are based on large epidemiology studies where exposures have occurred in urban areas. These exposures do not relate to only one pollutant or exposure (noise) but a mix of these, and others including occupational and smoking. While many of the studies have endeavoured to correct for other pollutants and exposures, no study can fully correct for these and there would always be some level of influence from other exposures on the relationships adopted.

In relation to air quality, many of the pollutants evaluated come from a common source (eg fuel combustion) so the use of only particulate matter (or nitrogen dioxide) as an index for the mix of pollutants that is in urban air at the time of exposure is reasonable but conservative.

In relation to the assessment of cardiovascular effects from road traffic noise, these effects are also associated with (and occur together with) increased exposures to vehicle emissions, specifically particulate exposures.

For this reason, it is important the health risks and incidence evaluations presented for exposure to nitrogen dioxide, particulates and noise should not be added together as these effects are not necessarily additive as the relationships already include co-exposures to all these aspects (and others).

11.7 Selected health outcomes

The assessment of risk has utilised exposure-response functions and relative risk values that relate to the more significant health endpoints where the most significant and robust positive associations have been identified. The approach does not include all possible subsets of effects that have been considered in various published studies. However, the assessment undertaken has considered the health endpoints/outcomes that incorporate many of the subsets, and has utilised the most current and robust relationships.

11.8 Changing population size and demographics

The assessment presented has utilised information on the size of the population and distribution of the population in relevant ages from the ABS Census data from 2011. No data was available from the ABS Census in 2016 at the time this report was prepared. As discussed in **section 4** the population in the study area is projected to increase significantly by 2035. In addition, many of the LGAs are expecting a significant increase in the proportion of the population aged 65 years and over.

The increase in population size and distribution does not affect the calculation of an individual risk. The key aspect that does affect this calculation is the baseline incidence of the health effects within the population. Based on statistics from NSW Health the baseline incidence of the health effects evaluated in this assessment have been relatively stable or decreasing over time (with improvements in health care). Hence changes in the population over time are not expected to result in any increase in the calculated individual risk.

For the calculation of the change in incidence in the community the size and distribution of the population is important. However, as the project is associated with an overall improvement (ie decrease in incidence) in the health endpoints evaluated, and increase in population would not change this outcome.

It is noted that population growth has been included in the forecast of traffic volumes predicted for the project and hence these changes have, by default, be incorporated into all subsequent impact assessment, including assessments associated with changes in air quality, noise and vibration and human health.

11.9 Application of exposure-response functions to small populations

The exposure-response functions have been developed on the basis of epidemiological studies from large urban populations where associations have been determined between health effects (health endpoints) and changes in ambient (regional) particulate levels. Typically, these exposure-response functions are applied to large populations for the purpose of establishing/reviewing air guidelines or reviewing potential impacts of regional air quality issues on large populations. When applied to small populations (less than larger urban centres such as the whole of Greater Sydney) the uncertainty increases.

In addition, it is noted that the exposure-response functions relate changes in health endpoints with changes in regional air quality measurements. They do not relate to specific local sources (which occur within a regional airshed), or daily variability in exposure that may occur as a result of various different activities that may occur in any one day.

12 Conclusions

An assessment of health impacts associated with the M4-M5 Link project has been undertaken. This assessment has specifically addressed changes in community exposures to air pollution and noise, as well as impacts on health associated with social changes associated with the project.

Based on the assessment undertaken and presented in this report the following has been concluded:

In relation to air quality:

- Impacts associated with construction activities require management to ensure impacts to community health are minimised. Measures required to be implemented to minimise dust impacts are to be detailed in a Construction Air Quality Management Plan, as detailed in **Appendix I** (Technical working paper: Air quality) of the EIS
- Impacts in the community outside the tunnel: the project is expected to result in a decrease in total pollutant levels in the community. The project is expected to result in a redistribution of impacts associated with vehicle emissions, specifically in relation to emissions derived from vehicles using surface roads. For much of the community this would result in no change or a small improvement (ie decreased concentrations and health impacts), however for some areas located near key surface roads a small increase in pollutant concentration may occur. Potential health impacts associated with changes in air quality (specifically nitrogen dioxide and particulates) within the local community have been assessed and are considered to be acceptable
- For the project, future development of land (including re-zonings) in the vicinity of the Campbell Road ventilation facility at St Peters interchange require planning controls to be developed to ensure future developments at heights 30 metres or higher are not adversely impacted by the ventilation outlets. Development of planning controls would be supported by detailed modelling addressing all relevant pollutants and averaging periods
- Impacts within the tunnel: while concentrations of pollutants from vehicle emissions are higher within the tunnel (compared with outside the tunnel), and with the completion of a number of tunnel projects (approved or proposed) there is the potential for exposures to occur within a network of tunnels over varying periods of time, depending on the journey. The assessment of potential exposures inside these tunnels, has indicated:
  - Where windows are up and ventilation is on recirculation, exposure to nitrogen dioxide inside vehicles is expected to be below the current health based guidelines. In congested conditions inside the tunnels, it is not considered likely that significant adverse health effects would occur. Placing ventilation on recirculation is also expected to minimise exposures to particulates during travel through the tunnels
  - For motorcyclists, where there is no opportunity to minimise exposures through the use of ventilation, there is the potential for higher levels of exposure to nitrogen dioxide. These exposures, under normal conditions, are not expected to result in adverse health effects. When the tunnels are congested it is expected that motorcyclists would spend less time in the tunnels than passenger vehicles and trucks, limiting the duration of exposure and the potential for adverse health effects

In relation to noise and vibration, potential impacts during construction and operation have been considered:

- Construction: without implementation of mitigation measures there is the potential for noise and vibration impacts associated with a range of construction activities to result in adverse health effects in the community. Hence it is important that management and/or mitigation measures are implemented throughout the construction period to minimise the potential for adverse health effects. These management and mitigation measures (including the requirement for noise monitoring) are to be outlined in detail within the Construction Noise and Vibration Management Plan. Additional management measures have been identified to specifically address and minimise noise impacts from multiple projects that may impact on and result in construction fatigue issues in the community

- Operation: during the operation of the project a number of properties have been identified where road noise has the potential to be elevated and adversely affect health. For these properties mitigation measures are required to protect the health of occupants. These mitigation measures may include noise barriers and/or at property architectural treatments. The recommended mitigation measures would ensure that the levels of road traffic noise experienced by residents would be reduced as low as feasible and reasonable

Changes in the urban environment associated with the project have the potential to result in a range of impacts on health and wellbeing of the community. The potential for changes to result in impacts on health and wellbeing is complex. Changes that may occur have the potential to result in both positive and negative impacts. Positive impacts include economic benefits, changes in traffic levels in some areas and increased public open space in the Rozelle Rail Yards. Negative impacts may occur as a result of traffic changes during construction, property acquisitions, visual changes, noise impacts and changes in access/cohesion of local areas. These may result in increased levels of stress and anxiety. In many cases the impacts identified are either short term (associated with construction only) and/or mitigation/management measures have been identified to minimise the impacts on the community.

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Annexure A – Approach to risk assessment using exposure-response relationships

Mortality and morbidity health endpoints

A quantitative assessment of risk for these endpoints uses a mathematical relationship between an exposure concentration (ie concentration in air) and a response (namely a health effect). This relationship is termed an exposure-response relationship and is relevant to the range of health effects (or endpoints) identified as relevant (to the nature of the emissions assessed) and robust (as identified in the main document). An exposure-response relationship can have a threshold, where there is a safe level of exposure, below which there are no adverse effects; or the relationship can have no threshold (and is regarded as linear) where there is some potential for adverse effects at any level of exposure.

In relation to the health effects associated with exposure to nitrogen dioxide and particulate matter, no threshold has been identified. Non-threshold exposure-response relationships have been identified for the health endpoints considered in this assessment.

The assessment of potential risks associated with exposure to particulate matter involves the calculation of a relative risk (RR). For the purpose of this assessment the shape of the exposure-response function used to calculate the relative risk is assumed to be linear[15]. The calculation of a relative risk based on the change in relative risk exposure concentration from baseline/existing (ie based on incremental impacts from the project) can be calculated on the basis of the following equation (Ostro 2004):

Equation 1 **RR = exp[β(X-X0)]**

Where:
X-X0 = the change in particulate matter concentration to which the population is exposed (µg/m³)
β = regression/slope coefficient, or the slope of the exposure-response function which can also be expressed as the per cent change in response per 1 µg/m³ increase in particulate matter exposure.

Based on this equation, where the published studies have derived relative risk values that are associated with a 10 micrograms per cubic metre increase in exposure, the β coefficient can be calculated using the following equation:

Equation 2

$$\beta = \frac{\ln(RR)}{10}$$

Where:

15 Some reviews have identified that a log-linear exposure-response function may be more relevant for some of the health endpoints considered in this assessment. Review of outcomes where a log-linear exposure-response function has been adopted (Ostro 2004) for $PM_{2.5}$ identified that the log-linear relationship calculated slightly higher relative risks compared with the linear relationship within the range 10–30 micrograms per cubic metre,(relevant for evaluating potential impacts associated with air quality goals or guidelines) but lower relative risks below and above this range. For this assessment (where impacts from a particular project are being evaluated) the impacts assessed relate to concentrations of $PM_{2.5}$ that are well below 10 micrograms per cubic metre and hence use of the linear relationship is expected to provide a more conservative estimate of relative risk.

RR = relative risk for the relevant health endpoint as published (µg/m³)
10 = increase in particulate matter concentration associated with the RR (where the RR is associated with a 10 µg/m³ increase in concentration).

Quantification of impact and risk

The assessment of health impacts for a particular population associated with exposure to particulate matter has been undertaken utilising the methodology presented by the WHO (Ostro 2004)[16] where the exposure-response relationships identified have been directly considered on the basis of the approach outlined below.

The calculation of changes in health endpoints associated with exposure to nitrogen dioxide and particulate matter as outlined by the WHO (Ostro 2004) has considered the following four elements:

- Estimates of the changes in particulate matter exposure levels (ie incremental impacts) due to the project for the relevant modelled scenarios
- Estimates of the number of people exposed to particulate matter at a given location
- Baseline incidence of the key health endpoints that are relevant to the population exposed
- Exposure-response relationships expressed as a percentage change in health endpoint per microgram per cubic metre change in NO_2 or particulate matter exposure, where a relative risk (RR) is determined (refer to Equation 1).

From the above, the increased incidence of a health endpoint corresponding to a particular change in particulate matter concentrations can be calculated using the following approach:

The attributable fraction/portion (AF) of health effects from air pollution, or impact factor, can be calculated from the relative risk (calculated for the incremental change in concentration considered as per Equation 1) as:

Equation 3 $$AF=\frac{RR-1}{RR}$$

The total number of cases attributable to exposure to particulate matter (where a linear dose-response is assumed) can be calculated as:

Equation 4 $$E=AF \times B \times P$$

Where:
B = baseline incidence of a given health effect (eg mortality rate per person per year)
P = relevant exposed population

The above approach (while presented slightly differently) is consistent with that presented in Australia (Burgers & Walsh 2002), US (OEHHA 2002; USEPA 2005b, 2010) and Europe (Martuzzi et al. 2002; Sjoberg et al. 2009).

The calculation of an increased incidence (ie number of cases) of a particular health endpoint is not relevant to a specific individual, rather this is relevant to a statistically relevant population. This calculation has been undertaken for populations within the suburbs surrounding the proposed project.

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16 For regional guidance, such as that provided for Europe by the WHO (WHO 2006b) regional background incidence data for relevant health endpoints are combined with exposure-response functions to present an impact function, which is expressed as the number/change in incidence/new cases per 100,000 population exposed per microgram per cubic metre change in particulate matter exposure. These impact functions are simpler to use than the approach adopted in this assessment, however in utilising this approach it is assumed that the baseline incidence of the health effects is consistent throughout the whole population (as used in the studies) and is specifically applicable to the sub-population group being evaluated. For the assessment of exposures in the areas evaluated surrounding the project it is more relevant to utilise local data in relation to baseline incidence rather than assume that the population is similar to that in Europe (where these relationships are derived).

When considering the potential impact of the project on the population, the calculation has been undertaken using the following:

- Equation 1 has been used to calculate a relative risk. The relative risk has been calculated for a population weighted annual average incremental increase in concentrations. The population weighted average has been calculated on the basis of the smallest statistical division provided by the Australian Bureau of Statistics within a suburb (ie mesh blocks – which are small blocks that cover an area of about 30 urban residences). For each mesh block in a suburb the average incremental increase in concentration has been calculated and multiplied by the population living in the mesh block (data available from the ABS for the 2011 census year). The weighted average has been calculated by summing these calculations for each mesh block in a suburb and dividing by the total population in the suburb (ie in all the mesh block)
- Equation 3 has been used to calculate an attributable fraction
- Equation 4 has been used to calculate the increased number of cases associated with the incremental impact evaluated. The calculation is undertaken utilising the baseline incidence data relevant for the endpoint considered and the population (for the relevant age groups) present in the suburb.

The above approach can be simplified (mathematically, where the incremental change in particulate concentration is low, less than one microgram per cubic metre) as follows:

Equation 5 $E=\beta \times B \times \sum_{mesh}(\Delta X_{mesh} \times P_{mesh})$

Where:
β = slope coefficient relevant to the per cent change in response to a 1 μg/m³ change in exposure concentration
B = baseline incidence of a given health effect per person (eg annual mortality rate)
ΔXmesh = change (increment) in exposure concentration in μg/m³ as an average within a small area defined as a mesh block (from the ABS – where many mesh blocks make up a suburb)
Pmesh = population (residential – based on data form the ABS) within each small mesh block

An additional risk can then be calculated as:

Equation 6 $Risk=\beta \times \Delta X \times B$

Where:
β = slope coefficient relevant to the per cent change in response to a 1 μg/m³ change in exposure
ΔX = change (increment) in exposure concentration in μg/m³ relevant to the project at the point of exposure
B = baseline incidence of a given health effect per person (eg annual mortality rate)

This calculation provides an annual risk for individuals exposed to changes in air quality from the project at specific locations (such as the maximum, or at specific sensitive receptor locations). The calculated risk does not take into account the duration of exposure at any one location and hence is considered to be representative of a population risk.

Quantification of short and long term effects

The concentration-response functions adopted for the assessment of exposure are derived from long and short term studies and relate to short or long term effects endpoints (eg change in incidence from daily changes in nitrogen dioxide or particulate matter, or chronic incidence from long term exposures to particulate matter).

Long term or chronic effects are assessed on the basis of the identified exposure-response function and annual average concentrations. These then allow the calculation of a chronic incidence of the assessed health endpoint.

Short term effects are also assessed on the basis of an exposure-response function that is expressed as a percentage change in endpoint per microgram per cubic metre change in concentration. For short term effects, the calculations relate to daily changes in nitrogen dioxide and particulate matter exposures to calculate changes in daily effects endpoints. While it may be possible to measure daily incidence of the evaluated health endpoints in a large population study specifically designed to include such data, it is not common to collect such data in hospitals nor are effects measurable in smaller communities. Instead these calculations relate to a parameter that is measurable, such as annual incidence of hospitalisations, mortality or lung cancer risks. The calculation of an annual incidence or additional risk can be undertaken using two approaches (Ostro 2004; USEPA 2010):

- Calculate the daily incidence or risk at each receptor location over every 24 hour period of the year (based on the modelled incremental 24 hour average concentration for each day of the year and daily baseline incidence data) and then sum the daily incidence/risk to get the annual risk
- Calculate the annual incidence/risk based on the incremental annual average concentration at each receptor (and using annual baseline incidence data).

In the absence of a threshold, and assuming a linear concentration-response function (as is the case in this assessment), these two approaches result in the same outcome mathematically (calculated incidence or risk). Given that it is much simpler computationally to calculate the incidence (for each receptor) based on the incremental annual average, compared with calculating effects on each day of the year and then summing, this is the preferred calculation method. It is the recommended method outlined by the WHO (Ostro 2004).

The use of the simpler approach, based on annual average concentrations should not be taken as implying or suggesting that the calculation is quantifying the effects of long term exposure.

Hence for the calculations presented in this technical working paper that relate to the expected use of the project tunnel, for both long term and short term effects, annual average concentrations of nitrogen dioxide and particulate matter have been utilised.

Where short term worst case exposures are assessed (such as those related to a breakdown in the tunnel) short term, daily, calculations have been undertaken to assessed short term health endpoints. This has been undertaken as the exposure being assessed relates to an infrequent short duration event. It would not occur each day of the year and hence it is not appropriate to assess on the basis of an annual average.

Annexure B – Approach to assessment of cancer risk

Diesel exhaust (DE) is emitted from 'on-road' diesel engines (vehicle engines) and can be formed from the gaseous compounds emitted by diesel engines (secondary particulate matter). After emission from the exhaust pipe, DE undergoes dilution and chemical and physical transformations in the atmosphere, as well as dispersion and transport in the atmosphere. The atmospheric lifetime for some compounds present in DE ranges from hours to days.

Data from the USEPA (USEPA 2002a) indicates that DE as measured as diesel particulate matter made up about six per cent of the total ambient/urban air $PM_{2.5}$. In this project, emissions to air from the operation of the tunnel include a significant proportion of diesel powered vehicles. Available evidence indicates that there are human health hazards associated with exposure to diesel particulate matter. The hazards include acute exposure-related symptoms, chronic exposure related non-cancer respiratory effects, and lung cancer.

In relation to non-carcinogenic effects, acute or short term (eg episodic) exposure to diesel particulate matter can cause acute irritation (eg eye, throat, bronchial), neurophysiological symptoms (eg light-headedness, nausea), and respiratory symptoms (cough, phlegm). There also is evidence for an immunologic effect-exacerbation of allergenic responses to known allergens and asthma-like symptoms. Chronic effects include respiratory effects. The review of these effects (USEPA 2002a) identified a threshold concentration for the assessment of chronic non-carcinogenic effects. The review conducted by the USEPA also concluded that exposures to diesel particulate matter also consider $PM_{2.5}$ goals (as these also address the presence of diesel particulate matter in urban air environments). The review found that the diesel particulate matter chronic guideline would also be met if the $PM_{2.5}$ guideline was met.

Review of exposures to diesel particulate matter (USEPA 2002a) identified that such exposures are 'likely to be carcinogenic to humans by inhalation'. A more recent review by IARC (Attfield et al. 2012; IARC 2012; Silverman et al. 2012) classified diesel engine exhaust as carcinogenic to humans (Group 1) based on sufficient evidence that exposure is associated with an increased risk for lung cancer. In addition, outdoor air pollution and particulate matter (that includes diesel particulate matter) have been classified by IARC as carcinogenic to humans based on sufficient evidence of lung cancer.

Many of the organic compounds present in DE are known to have mutagenic and carcinogenic properties and hence it is appropriate that a non-threshold approach is considered for the quantification of lung-cancer endpoints.

In relation to quantifying carcinogenic risks associated with exposure to DE, the USEPA (USEPA 2002a) has not established a non-threshold value (due to uncertainties identified in the available data).

WHO has used data from studies in rats to estimate unit risk values for cancer (WHO 1996). Using four different studies where lung cancer was the cancer endpoint, WHO calculated a range of 1.6×10^{-5} to 7.1×10^{-5} per microgram per cubic metres (mean value of 3.4×10^{-5} per microgram per cubic metres). This would suggest that an increase in lifetime exposure to diesel particulate matter between 0.14 and 0.625 microgram per cubic metres could result in a one in one hundred thousand excess risk of cancer.

The California Environmental Protection Agency has proposed a unit lifetime cancer risk of 3.0×10^{-4} per microgram per cubic metres diesel particulate matter (OEHHA 1998). This was derived from data on exposed workers and based on evidence that suggested unit risks between 1.5×10^{-4} and 15×10^{-4} per microgram per cubic metres. This would suggest that an increase in lifetime exposure to diesel particulate matter of 0.033 microgram per cubic metres could result in a one in one hundred thousand excess risk of cancer. This estimate has been widely criticised as overestimating the risk and hence has not been considered in this assessment.

On the basis of the above, the WHO cancer unit risk value (mean value of 3.4 x 10^{-5} per microgram per cubic metres) has been used to evaluate potential excess lifetime risks associated with incremental impacts from diesel particulate matter exposures. Diesel particulate matter has not been specifically modelled in **Appendix I** (Technical working paper: Air quality); rather diesel particulate matter is part of the $PM_{2.5}$ assessment. For the purpose of this assessment it has been conservatively assumed that 100 per cent of the incremental $PM_{2.5}$ (from the project only) is derived from diesel sources. This is conservative as not all the vehicles using the tunnel (and emitting $PM_{2.5}$) would be diesel powered (as currently there is a mix of petrol, diesel, LPG and hybrid-electric powered vehicles with the proportion of alternative fuels rising in the future).

For the assessment of potential lung cancer risks associated with exposure to diesel particulate matter, a non-threshold cancer risk is calculated. Non-threshold carcinogenic risks are estimated as the incremental probability of an individual developing cancer over a lifetime as a result of exposure to a potential non-threshold carcinogen. The numerical estimate of excess lifetime cancer risk is calculated as follows for inhalation exposures (USEPA 2009a):

Equation 7 Carcinogenic Risk (inhalation) = Concentration in Air x Inhalation Unit Risk x AF

Exposure adjustment factor (AF):

The above calculation assumes the receptor is exposed at the same location for 24 hours of the day, every day, for a lifetime (which is assumed to be 70 years). This assumption is overly conservative for residents and workers in the community surrounding the project. Residents do not live in the one home for a lifetime. Guidance from enHealth indicates that an appropriate assumption for the time living in the one home is 35 years (enHealth 2012a). For residents, it is assumed that they may be at home for 20 hours per day for 365 days of the year, for 35 years. This results in an adjustment factor of 0.4 (20/24 hours x 35 years/70 years). This factor has been adopted for the assessment of all exposures regardless of whether these are residential areas, schools, recreational areas or workplaces.

Annexure C – Acceptable risk levels

General

The acceptability of an additional population risk is the subject of some discussion as there are currently no guidelines available in Australia, or internationally, in relation to an acceptable level of population risk associated with exposure to particulate matter. More specifically there are no guidelines available that relate to an acceptable level of risk for a small population (associated with impacts from a specific activity or project) compared with risks that are relevant to whole urban populations (that are considered when deriving guidelines). The following provides additional discussion in relation to evaluating calculated risk levels.

'The solution to developing better criteria for environmental contaminants is not to adopt arbitrary thresholds of 'acceptable risk' in an attempt to manage the public's perception of risk, or develop oversimplified tools for enforcement or risk assessment. Rather, the solution is to standardize the process by which risks are assessed, and to undertake efforts to narrow the gap between the public's understanding of actual vs. perceived risk. A more educated public with regard to the actual sources of known risks to health, environmental or otherwise, will greatly facilitate the regulatory agencies' ability to prioritize their efforts and standards to reduce overall risks to public health.' (Kelly 1991).

Most human activities that have contributed to economic progress present also some disadvantages, including risks of different kinds that adversely affect human health. These risks include air or water pollution due to industrial activities (coal power generation, chemical plants, and transportation), food contaminants (pesticide residues, additives), and soil contamination (hazardous waste). Despite all possible efforts to reduce these threats, it is clear that the zero risk objective is unobtainable or simply not necessary for human and environmental protection and that a certain level of risk in a given situation is deemed 'acceptable' as the effects are so small as to be negligible or undetectable. Risk managers need to cope with some residual risks and thus must adopt some measure of an acceptable risk.

Much has been written about how to determine the acceptability of risk. The general consensus in the literature is that 'acceptability' of a risk is a judgment decision properly made by those exposed to the hazard or their designated health officials. It is not a scientifically derived value or a decision made by outsiders to the process. Acceptability is based on many factors, such as the number of people exposed, the consequences of the risk, the degree of control over exposure, and many other factors.

The USEPA (Hoffman 1988) 'surveyed a range of health risks that our society faces' and reviewed acceptable-risk standards of government and independent institutions. The survey found that 'No fixed level of risk could be identified as acceptable in all cases and under all regulatory programs...,' and that: '...the acceptability of risk is a relative concept and involves consideration of different factors'. Considerations may include:

- The certainty and severity of the risk
- The reversibility of the health effect
- The knowledge or familiarity of the risk
- Whether the risk is voluntarily accepted or involuntarily imposed
- Whether individuals are compensated for their exposure to the risk
- The advantages of the activity
- The risks and advantages for any alternatives.

To regulate a technology in a logically defensible way, one must consider all its consequences, ie both risks and benefits.

10^{-6} as an 'acceptable' risk level?

The concept of $1x10^{-6}$ (10^{-6}) was originally an arbitrary number, finalised by the US Food and Drug Administration (FDA) in 1977 as a screening level of 'essentially zero' or de minimus risk. The term de minimus is an abbreviation of the legal concept, 'de minimus non curat lex: the law does not concern itself with trifles.' In other words, 10^{-6} was developed as a level of risk below which risk was considered a 'trifle' and not of concern in a legal case.

This concept was traced back to a 1961 proposal by two scientists from the National Cancer Institute regarding methods to determine 'safety' levels in carcinogenicity testing. The FDA applied the concept in risk assessment in its efforts to deal with diethylstilboestrol as a growth promoter in cattle. The threshold of one in a million risk of developing cancer was established as a screening level to determine what carcinogenic animal drug residues merited further regulatory consideration. In the FDA legislation, the regulators specifically stated that this level of 'essentially zero' was not to be interpreted as equal to an acceptable level of residues in meat products. Since then, the use of risk assessment and 10^{-6} (or variations thereof) have been greatly expanded to almost all areas of chemical regulation, to the point where today one-in-a-million (10^{-6}) risk means different things to different regulatory agencies in different countries. What the FDA intended to be a lower regulatory level of 'zero risk' below which no consideration would be given as to risk to human health, for many regulators it somehow came to be considered a maximum or target level of 'acceptable' risk (Kelly 1991).

When evaluating human health risks, the quantification of risk can involve the calculation of an increased lifetime chance of cancer (as is calculated for diesel particulate matter in this assessment) or an increased probability of some adverse health effect (or disease) occurring, over and above the baseline incidence of that health effect/disease in the community (as is calculated for exposure to particulate matter).

In the context of human health risks, 10^{-6} is a shorthand description for an increased chance of 0.000001 in one (one chance in a million) of developing a specific adverse health effect due to exposure (over a lifetime or a shorter duration as relevant for particulate matter) to a substance. The number 10^{-5} represents one chance in 100,000, and so on.

Where cancer may be considered, lifetime exposure to a substance associated with a cancer risk of $1x10^{-6}$ would increase an individual's current chances of developing cancer from all causes (which is 40 per cent, or 0.4 – the background incidence of cancer in a lifetime) from 0.4 to 0.400001, an increase of 0.00025 per cent.

For other health indicators considered in this assessment, such as cardiovascular hospitalisations for people aged 65 years and older (for example), an increased risk of 10^{-6} (one chance in a million) would increase an individual's (aged 65 years and older) chance of hospitalisation for cardiovascular disease (above the baseline incidence of 23 per cent, or 0.23) from 0.23 to 0.230001, an increase of 0.00043 per cent.

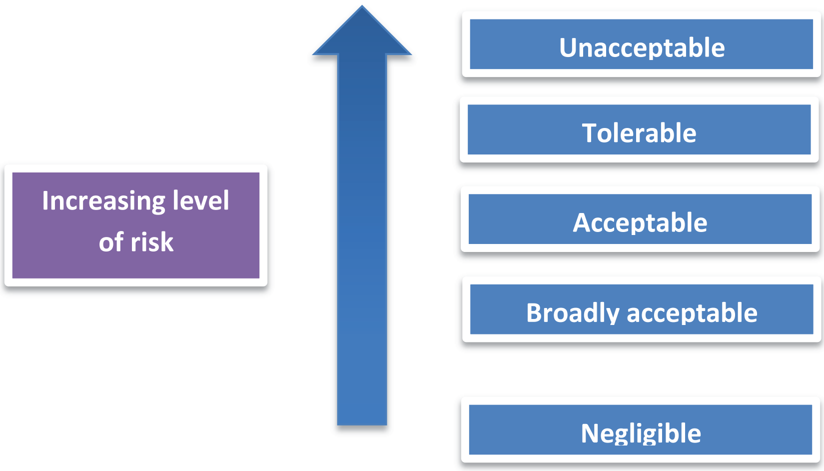
To provide more context in relation to the concept of a one in a million risk, the following presents a range of everyday life occurrences. The activity and the time spent undertaking the activity that is associated with reaching a risk of one in a million for mortality are listed below (Higson 1989; NSW Planning 2011):

- Motor vehicle accident – 2.5 days spent driving a motor vehicle to reach one in a million chance of having an accident that causes mortality (death)
- Home accidents – 3.3 days spent within a residence to reach a one in a million chance of having an accident at home that causes mortality
- Pedestrian accident (being struck by vehicles) – 10 days spent walking along roads to reach a one in a million chance of being struck by a vehicle that causes mortality
- Train accident – 12 days spent travelling on a train to reach a one in a million chance of being involved in an accident that causes mortality

- Falling down stairs [1] – 66 days spent requiring the use of stairs in day-to-day activities to reach a one in a million chance of being involved in a fall that causes mortality
- Falling objects – 121 days spent in day-to-day activities to reach a one in a million chance of being hit by a falling object that causes mortality.

This risk level should also be considered in the context that everyone has a cumulative risk of death that ultimately must equal one and the annual risk of death for most of one's life is about one in 1000.

While various terms have been applied, it is clear that the two ends of what is a spectrum of risk are the 'negligible' level and the 'unacceptable' level. Risk levels intermediate between these are frequently adopted by regulators with varying terms often used to describe the levels. When considering a risk derived for an environmental impact it is important to consider that the level of risk that may be considered acceptable would lie somewhere between what is negligible and unacceptable, as illustrated below.



The calculated individual lifetime risk of death or illness due to an exposure to a range of different environmental hazards covers many orders of magnitude, ranging from well less than 10^{-6} to levels of 10^{-3} and higher (in some situations). However, most figures for an acceptable or a tolerable risk range between 10^{-6} to 10^{-4}, used for either one year of exposure or a whole life exposure. It is noteworthy that 10^{-6} as a criterion for 'acceptable risk' has not been applied to all sources of exposure or all agents that pose risk to public health.

A review of the evolution of 10^{-6} reveals that perception of risk is a major determinant of the circumstances under which this criterion is used. The risk level 10^{-6} is not consistently applied to all environmental legislation. Rather, it seems to be applied according to the general perception of the risk associated with the source being regulated and where the risk is being regulated (with different levels selected in different countries for the same sources).

[1] Mortality risks as presented by: http://www.riskcomm.com/visualaids/riskscale/datasources.php.

A review of acceptable risk levels at the USEPA (Schoeny 2008) points out that risk assessors can identify risks and possibly calculate their value but cannot determine what is acceptable. Acceptability is a value judgment that varies with type of risk, culture, voluntariness and many other factors. Acceptability may be set by convention or law. The review also states that the USEPA aims for risk levels between 10^{-6} and 10^{-4} for risks calculated to be linear at low dose, while for other endpoints, not thought to be linear at low dose, the risk is compared to Reference Dose/Concentrations or guideline levels. The USEPA typically uses a target reference risk range of 10^{-4} to 10^{-6} for carcinogens in drinking water, which is in line with World Health Organization (WHO) guidelines for drinking water quality which, where practical, base guideline values for genotoxic carcinogens on the upper bound estimate of an excess lifetime cancer risk of 10^{-5}.

There are many different ways to define acceptable risk and each way gives different weight to the views of different stakeholders in the debate. No definition of ‘acceptable’ would be acceptable to all stakeholders. Resolving such issues, therefore, becomes a political (in the widest sense) rather than a strictly health process.

The following is a list of standpoints that could be used as a basis for determining when a risk is acceptable or, perhaps, tolerable. The WHO (Fewtrell & Bartram 2001) address standards related to water quality. They offer the following guidelines for determining acceptable risk. A risk is acceptable when:

- It falls below an arbitrary defined probability
- It falls below some level that is already tolerated
- It falls below an arbitrary defined attributable fraction of total disease burden in the community
- The cost of reducing the risk would exceed the costs saved
- The cost of reducing the risk would exceed the costs saved when the ‘costs of suffering’ are also factored in
- The opportunity costs would be better spent on other, more pressing, public health problems
- Public health professionals say it is acceptable
- The general public say it is acceptable (or more likely, do not say it is not)
- Politicians say it is acceptable.

In everyday life individual risks are rarely considered in isolation. It could be argued that a sensible approach would be to consider health risks in terms of the total disease burden of a community and to define acceptability in terms of it falling below an arbitrary defined level. A problem with this approach is that the current burden of disease attributable to a single factor, such as air pollution, may not be a good indicator of the potential reductions available from improving other environmental health factors. For diseases such as cardiovascular disease where causes are multifactorial, reducing the disease burden by one route may have little impact on the overall burden of disease.

Overall

It is not possible to provide a rigid definition of acceptable risk due to the complex and context driven nature of the challenge. It is possible to propose some general guidelines as to what might be an acceptable risk for specific development projects.

If the level of 10^{-6} (one chance in a million) were retained as a level of increased risk that would be considered as a negligible risk in the community, then the level of risk that could be considered to be tolerable would lie between this level and an upper level that is considered to be unacceptable.

While there is no guidance available on what level of risk is considered to be unacceptable in the community, a level of 10^{-4} for increased risk (one chance in 10,000) has been generally adopted by health authorities as a point where risk is considered to be unacceptable in the development of drinking water guidelines (that impact on whole populations) (for exposure to carcinogens as well as for annual risks of disease (Fewtrell & Bartram 2001)) and in the evaluation of exposures from pollutants in air (NSW DEC 2005).

Between an increased risk level considered negligible (10^{-6}) and unacceptable (10^{-4}) lie risks that may be considered to be tolerable or even acceptable. Tolerable risks are those that can be tolerated (and where the best available, and most appropriate, technology has been implemented to minimise exposure) in order to realise some benefit.

In a societal context, risks are inevitable and any new development would be accompanied by risks which are not amenable or economically feasible to reduce below a certain level. It is not good policy to impose an arbitrary risk level to such developments without consideration of the myriad factors that should be brought into play to determine what is 'tolerable'.

When considering the impacts associated with this project, it is important to note that there are a range of benefits associated with the project and the design of the project has incorporated measures to minimise exposures to traffic-related emissions in the local areas. Hence for this project the calculated risks have been considered to be tolerable when in the range of 10^{-6} and 10^{-4} of increased risk and where the increased incidence of the health impacts are considered to be insignificant.

Determination of significance of population impacts

The assessment of potential health impacts associated with emissions to air from the project has not only calculated an increased annual risk, relevant to the health endpoints considered, but also a change in the incidence, ie the additional (or saving of) number of cases, of the adverse effects occurring within the population potentially exposed. The calculated change in incidence need to be considered in terms of what may be significant.

In relation to the calculated change in incidence of an adverse health effect occurring in a population, the following is noted for the primary health indicators (based on statistics available from NSW Health):

- In relation to mortality (all causes), the health statistics available show that for the year 2011/2012 the variability in all admissions data reported (based on the 95 per cent confidence interval for data reported in Sydney) is around ± 2.5 per cent. This is the variability in the data reported in one year. Each year the mortality rate also varies with around one per cent variability reported in the mortality rate (number reported for all causes) between 2010/11 and 2011/12. Based on the population considered in this assessment and the baseline incidence, a one per cent variability results in ± 10 cases per year. Changes in mortality within this range would not be detected (above normal variability) in the health statistics
- In relation to cardiovascular disease hospitalisations, the health statistics available show that for the year 2013/2014 the variability in all admissions data reported (based on the 95 percent confidence interval for data reported in Sydney) is around ± two percent. This is the variability in the data reported in one year. Each year the rate of hospitalisations (all ages) also varies with around two to three per cent variability reported in the number of hospitalisations for people aged 65 years and older in each year between 2010/11 and 2013/14. Based on the baseline incidence of cardiovascular hospitalisations considered in this assessment for individuals aged 65 years and the population considered in this assessment a variability of two per cent equates to ± 40 cases per year. Changes in cardiovascular hospitalisations in the population aged 65 years and older within this range would not be detected (above normal variability) in the health statistics
- In relation to respiratory disease hospitalisations, the health statistics available show that for the year 2013/2014 the variability in all admissions data reported (based on the 95 per cent confidence interval for data reported in Sydney) is around ± six per cent. This is the variability in the data reported in one year. Each year the rate of hospitalisations (all ages) also varies with around three to four per cent variability reported in the number of hospitalisations (all ages) in each year between 2011 and 2014. Based on the baseline incidence of respiratory hospitalisations considered in this assessment for individuals aged 65 years and older, and the population evaluated in this assessment, a variability of three per cent equates to ± 25 cases per year. Changes in respiratory hospitalisations in the population aged 65 years and older within this range would not be detected (above normal variability) in the health statistics.

Where changes in air quality associated with this project are well below 10 cases per year they are considered to be within the normal variability of health statistics. For evaluating impacts form this project a 10 fold margin of safety has been included to determine what changes in incidence may be considered negligible within the study population. This means that changes in the population incidence of any health effect evaluated that is less than one case per year are considered negligible.

Annexure D Risk calculations: Nitrogen dioxide

Quantification of Effects - NO_2

M4-M5 Link

	2023			2023 - Cumulative			2033			2033 - Cumulative		
Air quality indicator:	NO2	NO2	NO2	NO2	NO2	NO2	NO2	NO2	NO2	NO2	NO2	NO2
Endpoint:	Mortality - All Causes (non-trauma)	Mortality - Respiratory	Asthma - ED Hospital admissions	Mortality - All Causes (non-trauma)	Mortality - Respiratory	Asthma - ED Hospital admissions	Mortality - All Causes (non-trauma)	Mortality - Respiratory	Asthma - ED Hospital admissions	Mortality - All Causes	Mortality - Respiratory	Asthma - ED Hospital admissions
Effect Exposure Duration:	Short-term	Short-term	Short-term	Short-term	Short-term	Short-term	Short-term	Short-term	Short-term	Short-term	Short-term	Short-term
Age Group:	30+	All ages	1-14 years	30+	All ages	1-14 years	30+	All ages	1-14 years	30+	All ages	1-14 years
β (change in effect per 1 μg/m³ NO2) (as per Table 6-15)	0.00188	0.00426	0.00115	0.00188	0.00426	0.00115	0.00188	0.00426	0.00115	0.00188	0.00426	0.00115
Annual Baseline Incidence (as per Table 4-5)												
Annual baseline incidence (per 100,000)	976.5	49.4	1209	976.5	49.4	1209	976.5	49.4	1209	976.5	49.4	1209
Baseline Incidence (per person per year)	0.009765	0.000494	0.01209	0.009765	0.000494	0.01209	0.009765	0.000494	0.01209	0.009765	0.000494	0.01209

Sensitive Receptors		Change in Annual Average NO2 Concentration (μg/m³)	Risk	Risk	Risk	Change in Annual Average NO2 Concentration (μg/m³)	Risk	Risk	Risk	Change in Annual Average NO2 Concentration (μg/m³)	Risk	Risk	Risk	Change in Annual Average NO2 Concentration (μg/m³)	Risk	Risk	Risk
Impacts from tunnel ventilation outlets																	
Grid receptors: maximum regardless of landuse		**5.70**	**1E-04**	**1E-05**	**8E-05**	**8.8**	**2E-04**	**2E-05**	**1E-04**	**6.3**	**1E-04**	**1E-05**	**9E-05**	**8.7**	**2E-04**	**2E-05**	**1E-04**
Grid receptors: maximum residential		**2.68**	**5E-05**	**6E-06**	**4E-05**	**2.79**	**5E-05**	**6E-06**	**4E-05**	**3.3**	**6E-05**	**7E-06**	**5E-05**	**2.4**	**4E-05**	**5E-06**	**3E-05**
Grid receptors: commercial/industrial		**5.70**	**1E-04**	**1E-05**	**8E-05**	**8.8**	**2E-04**	**2E-05**	**1E-04**	**6.3**	**1E-04**	**1E-05**	**9E-05**	**8.7**	**2E-04**	**2E-05**	**1E-04**
Grid receptors: maximum childcare		**1.70**	**3E-05**	**4E-06**	**2E-05**	**0.72**	**1E-05**	**2E-06**	**1E-05**	**2.36**	**4E-05**	**5E-06**	**3E-05**	**0.88**	**2E-05**	**2E-06**	**1E-05**
Grid receptors: maximum school		**1.18**	**2E-05**	**2E-06**	**2E-05**	**0.58**	**1E-05**	**1E-06**	**8E-06**	**0.96**	**2E-05**	**2E-06**	**1E-05**	**0.55**	**1E-05**	**1E-06**	**8E-06**
Grid receptors: maximum aged care		**0.22**	**4E-06**	**5E-07**	**3E-06**	**0.11**	**2E-06**	**2E-07**	**2E-06**	**0.36**	**7E-06**	**8E-07**	**5E-06**	**0.37**	**7E-06**	**8E-07**	**5E-06**
Grid receptors: maximum hospital and medical		**1.57**	**3E-05**	**3E-06**	**2E-05**	**0.46**	**8E-06**	**1E-06**	**6E-06**	**2**	**4E-05**	**4E-06**	**3E-05**	**0.71**	**1E-05**	**1E-06**	**1E-05**
Grid receptors: open space		**2.70**	**5E-05**	**6E-06**	**4E-05**	**0.98**	**2E-05**	**2E-06**	**1E-05**	**3**	**6E-05**	**6E-06**	**4E-05**	**1.4**	**3E-05**	**3E-06**	**2E-05**
Community Receptors																	
The Jimmy Little Community Centre	Community	-0.811	-1E-05	-2E-06	-1E-05	-0.643	-1E-05	-1E-06	-9E-06	-0.481	-9E-06	-1E-06	-7E-06	-0.373	-7E-06	-8E-07	-5E-06
Balmain Cove Early Learning Centre	Child care	-0.397	-7E-06	-8E-07	-6E-06	0.144	3E-06	3E-07	2E-06	-0.920	-2E-05	-2E-06	-1E-05	-0.699	-1E-05	-1E-06	-1E-05
Rosebud Cottage Child Care Centre	Child care	-3.111	-6E-05	-7E-06	-4E-05	-2.856	-5E-05	-6E-06	-4E-05	-2.448	-4E-05	-5E-06	-3E-05	-2.419	-4E-05	-5E-06	-3E-05
Sydney Community College	School/education	-1.218	-2E-05	-3E-06	-2E-05	-0.654	-1E-05	-1E-06	-9E-06	-0.854	-2E-05	-2E-06	-1E-05	-0.746	-1E-05	-2E-06	-1E-05
Rozelle Total Health	Health	-0.182	-3E-06	-4E-07	-3E-06	0.004	8E-08	9E-09	6E-08	-0.045	-8E-07	-9E-08	-6E-07	0.166	3E-06	3E-07	2E-06
Laurel Tree House Child Care Centre	Child care	-0.599	-1E-05	-1E-06	-8E-06	-0.076	-1E-06	-2E-07	-1E-06	0.090	2E-06	2E-07	1E-06	0.011	2E-07	2E-08	2E-07
Bridge Road School	School	-1.370	-3E-05	-3E-06	-2E-05	-0.623	-1E-05	-1E-06	-9E-06	-0.601	-1E-05	-1E-06	-8E-06	-0.960	-2E-05	-2E-06	-1E-05
NHMRC Clinical Trials Centre	Health	-0.610	-1E-05	-1E-06	-8E-06	-1.006	-2E-05	-2E-06	-1E-05	-0.882	-2E-05	-2E-06	-1E-05	-0.805	-1E-05	-2E-06	-1E-05
Annandale Public School	School	-0.574	-1E-05	-1E-06	-8E-06	-0.540	-1E-05	-1E-06	-8E-06	-0.408	-7E-06	-9E-07	-6E-06	-0.135	-2E-06	-3E-07	-2E-06
The University of Notre Dame Australia, Broadway	School/education	-0.408	-7E-06	-9E-07	-6E-06	-0.928	-2E-05	-2E-06	-1E-05	-0.318	-6E-06	-7E-07	-4E-06	-0.794	-1E-05	-2E-06	-1E-05
Laverty Pathology Annandale	Health	0.096	2E-06	2E-07	1E-06	-0.599	-1E-05	-1E-06	-8E-06	-0.667	-1E-05	-1E-06	-9E-06	-0.930	-2E-05	-2E-06	-1E-05
Little VIP's Child Care Centre	Child care	0.848	2E-05	2E-06	1E-05	-0.335	-6E-06	-7E-07	-5E-06	-0.166	-3E-06	-3E-07	-2E-06	-0.136	-2E-06	-3E-07	-2E-06
Dobroyd Point Public School	School	-0.588	-1E-05	-1E-06	-8E-06	-1.057	-2E-05	-2E-06	-1E-05	-0.055	-1E-06	-1E-07	-8E-07	-0.411	-8E-06	-9E-07	-6E-06
Peek A Boo Early Learning Centre Haberfield	Child care	-0.565	-1E-05	-1E-06	-8E-06	-0.927	-2E-05	-2E-06	-1E-05	-0.752	-1E-05	-2E-06	-1E-05	-1.138	-2E-05	-2E-06	-2E-05
Rozelle CCC	Child care	-0.308	-6E-06	-6E-07	-4E-06	-0.650	-1E-05	-1E-06	-9E-06	-1.010	-2E-05	-2E-06	-1E-05	-1.247	-2E-05	-3E-06	-2E-05
Sydney Secondary College Leichhardt Campus	School - Secondary	-0.824	-2E-05	-2E-06	-1E-05	-0.261	-5E-06	-5E-07	-4E-06	-0.345	-6E-06	-7E-07	-5E-06	-0.350	-6E-06	-7E-07	-5E-06
Rose Cottage Child Care Centre	Child care	0.003	6E-08	7E-09	4E-08	-0.288	-5E-06	-6E-07	-4E-06	-0.770	-1E-05	-2E-06	-1E-05	-0.338	-6E-06	-7E-07	-5E-06
Inner Sydney Montessori - Lilyfield	School	-0.507	-9E-06	-1E-06	-7E-06	-0.656	-1E-05	-1E-06	-9E-06	-0.631	-1E-05	-1E-06	-9E-06	-0.659	-1E-05	-1E-06	-9E-06
Leichhardt Little Stars Nursery & Early Learning Centre	Child care	-0.941	-2E-05	-2E-06	-1E-05	-0.538	-1E-05	-1E-06	-7E-06	-0.677	-1E-05	-1E-06	-9E-06	-0.461	-8E-06	-1E-06	-6E-06
Leichhardt Montessori Academy	School	-1.535	-3E-05	-3E-06	-2E-05	-1.520	-3E-05	-3E-06	-2E-05	-0.558	-1E-05	-1E-06	-8E-06	-0.204	-4E-06	-4E-07	-3E-06
St Basil's Sister Dorothea Village	Aged care	-0.195	-4E-06	-4E-07	-3E-06	-0.543	-1E-05	-1E-06	-8E-06	0.201	4E-06	4E-07	3E-06	0.346	6E-06	7E-07	5E-06
St Thomas Child Care Centre	Child care	-3.672	-7E-05	-8E-06	-5E-05	-3.174	-6E-05	-7E-06	-4E-05	-2.458	-5E-05	-5E-06	-3E-05	-2.129	-4E-05	-4E-06	-3E-05
Billy Kids Lilyfield Early Learning Centre	Child care	-2.977	-5E-05	-6E-06	-4E-05	-3.796	-7E-05	-8E-06	-5E-05	-2.698	-5E-05	-6E-06	-4E-05	-2.787	-5E-05	-6E-06	-4E-05
Little Learning School - Alexandria	Child care	0.937	2E-05	2E-06	1E-05	-0.087	-2E-06	-2E-07	-1E-06	0.687	1E-05	1E-06	1E-05	0.276	5E-06	6E-07	4E-06
Newtown Public School Combined OSHC	School	-0.112	-2E-06	-2E-07	-2E-06	-0.437	-8E-06	-9E-07	-6E-06	-0.420	-8E-06	-9E-07	-6E-06	-0.464	-9E-06	-1E-06	-6E-06
The Athena School	School	-0.602	-1E-05	-1E-06	-8E-06	-0.583	-1E-05	-1E-06	-8E-06	-0.194	-4E-06	-4E-07	-3E-06	-0.024	-4E-07	-5E-08	-3E-07
Camdenville Public School	School	-0.264	-5E-06	-6E-07	-4E-06	-0.689	-1E-05	-1E-06	-1E-05	-0.581	-1E-05	-1E-06	-8E-06	-0.513	-9E-06	-1E-06	-7E-06
St Joan of Arc Home for the Aged	Aged care	-0.239	-4E-06	-5E-07	-3E-06	-0.620	-1E-05	-1E-06	-9E-06	-0.543	-1E-05	-1E-06	-8E-06	-0.389	-7E-06	-8E-07	-5E-06
Inner West Education Centre	School	-0.552	-1E-05	-1E-06	-8E-06	-0.273	-5E-06	-6E-07	-4E-06	-0.224	-4E-06	-5E-07	-3E-06	0.170	3E-06	4E-07	2E-06
St Peters Community Pre-school	School	0.237	4E-06	5E-07	3E-06	0.387	7E-06	8E-07	5E-06	0.979	2E-05	2E-06	1E-05	0.345	6E-06	7E-07	5E-06

Annexure E – Population incidence calculations: Nitrogen dioxide

Assessment of Increased Incidence - NO_2
M4-M5 Link: 2023

Health Endpoint:	Mortality - All Causes (non-trauma), Short-term	Mortality - Respiratory, Short-term	Morbidity - Asthma ED Admissions - Short-term
Age Group:	≥ 30 years	All ages	1-14 years
β (change in effect per 1 µg/m³ PM) (as per Table 6-15)	0.00188	0.00426	0.00115
Canada Bay LGA			
Total Population in study area:	67644	67644	67644
% population in assessment age-group:	63%	100%	16%
total change	-2067.5	-2067.5	-2067.5
Population weighted Δx (µg/m³):	-0.03056443	-0.03056443	-0.03056443
Baseline Incidence (per 100,000) (as per Table 4-5)	977	49.4	1209.0
Baseline Incidence (per person)	0.00977	0.00049	0.01209
Relative Risk:	0.999943	0.999870	0.999965
Attributable fraction (AF):	-5.7E-05	-1.3E-04	-3.5E-05
Increased number of cases in population:	-0.024	-0.0044	-0.0045
Risk:	-5.6E-07	-6.4E-08	-4.2E-07
Individual suburbs within LGA			
Concord - Mortlake - Cabarita			
Total Population in study area:	19204	19204	19204
total change	-146.1	-146.1	-146.1
Population weighted Δx (µg/m³):	-0.00760779	-0.00760779	-0.00760779
Increased number of cases in population:	-0.00170	-0.00031	-0.00031
Concord West			
Total Population in study area:	10692	10692	10692
total change	278	278	278
Population weighted Δx (µg/m³):	0.02600075	0.02600075	0.02600075
Increased number of cases in population:	0.00324	0.00059	0.00060
Drummoyne - Rodd Pt			
Total Population in study area:	17456	17456	17456
total change	-6.9	-6.9	-6.9
Population weighted Δx (µg/m³):	-0.00039528	-0.00039528	-0.00039528
Increased number of cases in population:	-0.000080	-0.00001452	-0.00001487
Five Dock			
Total Population in study area:	19111	19111	19111
total change	-1744.5	-1744.5	-1744.5
Population weighted Δx (µg/m³):	-0.09128251	-0.09128251	-0.09128251
Increased number of cases in population:	-0.0203	-0.0037	-0.0038
Gladesville			
Total Population in study area:	590	590	590
total change	-312	-312	-312
Population weighted Δx (µg/m³):	-0.52881356	-0.52881356	-0.52881356
Increased number of cases in population:	-0.00363	-0.00066	-0.00067
Hunters Hill			
Total Population in study area:	591	591	591
total change	-145.7	-145.7	-145.7
Population weighted Δx (µg/m³):	-0.24653130	-0.24653130	-0.24653130
Increased number of cases in population:	-0.00170	-0.00031	-0.00031

Health Endpoint:	Mortality - All Causes (non-trauma), Short-term	Mortality - Respiratory, Short-term	Morbidity - Asthma ED Admissions - Short-term
Age Group:	≥ 30 years	All ages	1-14 years
β (change in effect per 1 µg/m^3 PM) (as per Table 6-15)	0.00188	0.00426	0.00115
Strathfield LGA			
Total Population in study area:	25473	25473	25473
% population in assessment age-group:	60%	100%	14%
total change	274.6	274.6	274.6
Population weighted Δx (µg/m^3):	0.0	0.01078004	0.01078004
Baseline Incidence (per 100,000) (as per Table 4-5)	977	49.4	1209.0
Baseline Incidence (per person)	0.00977	0.00049	0.01209
Relative Risk:	1.000020	1.000046	1.000012
Attributable fraction (AF):	2.0E-05	4.6E-05	1.2E-05
Increased number of cases in population:	0.0030	0.00058	0.00055
Risk:	2.0E-07	2.3E-08	1.5E-07
Individual suburbs within LGA			
Homebush			
Total Population in study area:	5075	5075	5075
total change	970.4	970.4	970.4
Population weighted Δx (µg/m^3):	0.19121182	0.19121182	0.19121182
Increased number of cases in population:	0.0107	0.0020	0.0019
Homebush Bay			
Total Population in study area:	63	63	63
total change	10.3	10.3	10.3
Population weighted Δx (µg/m^3):	0.16349206	0.16349206	0.16349206
Increased number of cases in population:	0.00011	0.000022	0.000020
Strathfield			
Total Population in study area:	20335	20335	20335
total change	-706.1	-706.1	-706.1
Population weighted Δx (µg/m^3):	-0.03472338	-0.03472338	-0.03472338
Increased number of cases in population:	-0.0078	-0.0015	-0.0014
Burwood LGA			
Total Population in study area:	20986	20986	20986
% population in assessment age-group:	60%	100%	14%
total change	-1462	-1462	-1462
Population weighted Δx (µg/m^3):	-0.06966549	-0.06966549	-0.06966549
Baseline Incidence (per 100,000) (as per Table 4-5)	977	49.4	1209.0
Baseline Incidence (per person)	0.00977	0.00049	0.01209
Relative Risk:	0.999869	0.999703	0.999920
Attributable fraction (AF):	-1.3E-04	-3.0E-04	-8.0E-05
Increased number of cases in population:	-0.016	-0.0031	-0.0029
Risk:	-1.3E-06	-1.5E-07	-9.7E-07

Health Endpoint:	Mortality - All Causes (non-trauma), Short-term	Mortality - Respiratory, Short-term	Morbidity - Asthma ED Admissions - Short-term
Age Group:	≥ 30 years	All ages	1-14 years
β (change in effect per 1 μg/m^3 PM) (as per Table 6-15)	0.00188	0.00426	0.00115
Sydney Inner West LGA			
Total Population in study area:	180589	180589	180589
% population in assessment age-group:	67%	100%	15%
total change	-93522	-93522	-93522
Population weighted Δx (μg/m^3):	-0.51787207	-0.51787207	-0.51787207
Baseline Incidence (per 100,000) (as per Table 4-5)	977	49.4	1209.0
Baseline Incidence (per person)	0.00977	0.00049	0.01209
Relative Risk:	0.999027	0.997796	0.999405
Attributable fraction (AF):	-9.7E-04	-2.2E-03	-6.0E-04
Increased number of cases in population:	-1.2	-0.20	-0.19
Risk:	-9.5E-06	-1.1E-06	-7.2E-06
Individual suburbs within LGA			
Ashfield			
Total Population in study area:	22769	22769	22769
total change	-4046	-4046	-4046
Population weighted Δx (μg/m^3):	-0.17769775	-0.17769775	-0.17769775
Increased number of cases in population:	-0.0499	-0.0085	-0.0084
Canterbury North-Ashbury			
Total Population in study area:	9390	9390	9390
total change	-2510.6	-2510.6	-2510.6
Population weighted Δx (μg/m^3):	-0.26736954	-0.26736954	-0.26736954
Increased number of cases in population:	-0.0310	-0.0053	-0.0052
Croyden Park			
Total Population in study area:	16360	16360	16360
total change	-1539	-1539	-1539
Population weighted Δx (μg/m^3):	-0.09407090	-0.09407090	-0.09407090
Increased number of cases in population:	-0.0190	-0.0032	-0.0032
Dulwich Hill			
Total Population in study area:	15862	15862	15862
total change	-5678.8	-5678.8	-5678.8
Population weighted Δx (μg/m^3):	-0.35801286	-0.35801286	-0.35801286
Increased number of cases in population:	-0.0701	-0.0120	-0.0118
Haberfield			
Total Population in study area:	13245	13245	13245
total change	-8171	-8171	-8171
Population weighted Δx (μg/m^3):	-0.61691204	-0.61691204	-0.61691204
Increased number of cases in population:	-0.1009	-0.0172	-0.0169
Balmain			
Total Population in study area:	14794	14794	14794
total change	-12697.8	-12697.8	-12697.8
Population weighted Δx (μg/m^3):	-0.85830742	-0.85830742	-0.85830742
Increased number of cases in population:	-0.1568	-0.0268	-0.0263
Leichardt			
Total Population in study area:	24443	24443	24443
total change	-20849	-20849	-20849
Population weighted Δx (μg/m^3):	-0.85296404	-0.85296404	-0.85296404
Increased number of cases in population:	-0.2574	-0.0440	-0.0432
Lilyfield			
Total Population in study area:	13073	13073	13073
total change	-12506.1	-12506.1	-12506.1
Population weighted Δx (μg/m^3):	-0.95663581	-0.95663581	-0.95663581
Increased number of cases in population:	-0.1544	-0.0264	-0.0259
Marrickville			
Total Population in study area:	24632	24632	24632
total change	-9498.9	-9498.9	-9498.9
Population weighted Δx (μg/m^3):	-0.38563251	-0.38563251	-0.38563251
Increased number of cases in population:	-0.1172	-0.0200	-0.0197
Petersham			
Total Population in study area:	18817	18817	18817
total change	-12888.9	-12888.9	-12888.9
Population weighted Δx (μg/m^3):	-0.68496041	-0.68496041	-0.68496041
Increased number of cases in population:	-0.1591	-0.0272	-0.0267
Sydenham			
Total Population in study area:	7204	7204	7204
total change	-3135.9	-3135.9	-3135.9
Population weighted Δx (μg/m^3):	-0.43529983	-0.43529983	-0.43529983
Increased number of cases in population:	-0.0387	-0.0066	-0.0065

Health Endpoint:	Mortality - All Causes (non-trauma), Short-term	Mortality - Respiratory, Short-term	Morbidity - Asthma ED Admissions - Short-term
Age Group:	≥ 30 years	All ages	1-14 years
β (change in effect per 1 μg/m^3 PM) (as per Table 6-15)	0.00188	0.00426	0.00115
Sydney LGA			
Total Population in study area:	125509	125509	125509
% population in assessment age-group:	59%	100%	6%
total change	-31885.5	-31885.5	-31885.5
Population weighted Δx (μg/m^3):	-0.25404951	-0.25404951	-0.25404951
Baseline Incidence (per 100,000) (as per Table 4-5)	977	49.4	1209.0
Baseline Incidence (per person)	0.00977	0.00049	0.01209
Relative Risk:	0.999523	0.998918	0.999708
Attributable fraction (AF):	-4.8E-04	-1.1E-03	-2.9E-04
Increased number of cases in population:	-0.35	-0.067	-0.027
Risk:	-4.7E-06	-5.3E-07	-3.5E-06
Individual suburbs within LGA			
Erskinville			
Total Population in study area:	13908	13908	13908
total change	-3542.3	-3542.3	-3542.3
Population weighted Δx (μg/m^3):	-0.25469514	-0.25469514	-0.25469514
Increased number of cases in population:	-0.0384	-0.0075	-0.0031
Glebe			
Total Population in study area:	16595	16595	16595
total change	-4007.5	-4007.5	-4007.5
Population weighted Δx (μg/m^3):	-0.24148840	-0.24148840	-0.24148840
Increased number of cases in population:	-0.0435	-0.0084	-0.0035
Newtown			
Total Population in study area:	21480	21480	21480
total change	-13048	-13048	-13048
Population weighted Δx (μg/m^3):	-0.60744879	-0.60744879	-0.60744879
Increased number of cases in population:	-0.1416	-0.0275	-0.0113
Pyrmont			
Total Population in study area:	18720	18720	18720
total change	1254	1254	1254
Population weighted Δx (μg/m^3):	0.06698718	0.06698718	0.06698718
Increased number of cases in population:	0.0136	0.0026	0.0011
Redfern			
Total Population in study area:	12628	12628	12628
total change	-1989.8	-1989.8	-1989.8
Population weighted Δx (μg/m^3):	-0.15757048	-0.15757048	-0.15757048
Increased number of cases in population:	-0.0216	-0.0042	-0.0017
Surry Hills			
Total Population in study area:	4190	4190	4190
total change	-1582.4	-1582.4	-1582.4
Population weighted Δx (μg/m^3):	-0.37766110	-0.37766110	-0.37766110
Increased number of cases in population:	-0.0172	-0.0033	-0.0014
Sydney			
Total Population in study area:	21726	21726	21726
total change	-4225.3	-4225.3	-4225.3
Population weighted Δx (μg/m^3):	-0.19448127	-0.19448127	-0.19448127
Increased number of cases in population:	-0.0459	-0.0089	-0.0036
Waterloo			
Total Population in study area:	11306	11306	11306
total change	-4043.4	-4043.4	-4043.4
Population weighted Δx (μg/m^3):	-0.35763312	-0.35763312	-0.35763312
Increased number of cases in population:	-0.0439	-0.0085	-0.0035
Crows Nest			
Total Population in study area:	50	50	50
total change	-12.6	-12.6	-12.6
Population weighted Δx (μg/m^3):	-0.25200000	-0.25200000	-0.25200000
Increased number of cases in population:	-0.000137	-0.000027	-0.000011
North Sydney			
Total Population in study area:	4906	4906	4906
total change	-688.2	-688.2	-688.2
Population weighted Δx (μg/m^3):	-0.14027721	-0.14027721	-0.14027721
Increased number of cases in population:	-0.0075	-0.0014	-0.0006

Health Endpoint:	Mortality - All Causes (non-trauma), Short-term	Mortality - Respiratory, Short-term	Morbidity - Asthma ED Admissions - Short-term
Age Group:	≥ 30 years	All ages	1-14 years
β (change in effect per 1 μg/m^3 PM) (as per Table 6-15)	0.00188	0.00426	0.00115
Botany LGA			
Total Population in study area:	25700	25700	25700
% population in assessment age-group:	62%	100%	17%
total change	13058.7	13058.7	13058.7
Population weighted Δx (μg/m^3):	0.50812062	0.50812062	0.50812062
Baseline Incidence (per 100,000) (as per Table 4-5)	977	49.4	1209.0
Baseline Incidence (per person)	0.00977	0.00049	0.01209
Relative Risk:	1.000956	1.002167	1.000585
Attributable fraction (AF):	9.5E-04	2.2E-03	5.8E-04
Increased number of cases in population:	0.15	0.027	0.030
Risk:	9.3E-06	1.1E-06	7.1E-06
Individual suburbs within LGA			
Botany			
Total Population in study area:	8915	8915	8915
total change	1285.5	1285.5	1285.5
Population weighted Δx (μg/m^3):	0.14419518	0.14419518	0.14419518
Increased number of cases in population:	0.0145	0.0027	0.0030
Mascot			
Total Population in study area:	16215	16215	16215
total change	11451.7	11451.7	11451.7
Population weighted Δx (μg/m^3):	0.70624113	0.70624113	0.70624113
Increased number of cases in population:	0.1294	0.0241	0.0267
Pagewood			
Total Population in study area:	567	567	567
total change	318.3	318.3	318.3
Population weighted Δx (μg/m^3):	0.56137566	0.56137566	0.56137566
Increased number of cases in population:	0.0036	0.00067	0.00074

Health Endpoint:	Mortality - All Causes (non-trauma), Short-term	Mortality - Respiratory, Short-term	Morbidity - Asthma ED Admissions - Short-term
Age Group:	≥ 30 years	All ages	1-14 years
β (change in effect per 1 μg/m^3 PM) (as per Table 6-15)	0.00188	0.00426	0.00115
Rockdale LGA			
Total Population in study area:	82293	82293	82293
% population in assessment age-group:	62%	100%	16%
total change	-16255.60	-16255.6	-16255.6
Population weighted Δx (μg/m^3):	-0.19753320	-0.19753320	-0.19753320
Baseline Incidence (per 100,000) (as per Table 4-5)	977	49.4	1209.0
Baseline Incidence (per person)	0.00977	0.00049	0.01209
Relative Risk:	0.999629	0.999159	0.999773
Attributable fraction (AF):	-3.7E-04	-8.4E-04	-2.3E-04
Increased number of cases in population:	-0.18	-0.034	-0.036
Risk:	-3.6E-06	-4.2E-07	-2.7E-06
Individual suburbs within LGA			
Arncliffe			
Total Population in study area:	14669	14669	14669
total change	-3058.3	-3058.3	-3058.3
Population weighted Δx (μg/m^3):	-0.20848729	-0.20848729	-0.20848729
Increased number of cases in population:	-0.0346	-0.0064	-0.0068
Bexley			
Total Population in study area:	25123	25123	25123
total change	-4365.3	-4365.3	-4365.3
Population weighted Δx (μg/m^3):	-0.17375711	-0.17375711	-0.17375711
Increased number of cases in population:	-0.0495	-0.0092	-0.0097
Kingsgrove - South			
Total Population in study area:	11981	11981	11981
total change	-2602.4	-2602.4	-2602.4
Population weighted Δx (μg/m^3):	-0.21721058	-0.21721058	-0.21721058
Increased number of cases in population:	-0.0295	-0.0055	-0.0058
Monterey			
Total Population in study area:	12192	12192	12192
total change	-2680	-2680	-2680
Population weighted Δx (μg/m^3):	-0.21981627	-0.21981627	-0.21981627
Increased number of cases in population:	-0.0304	-0.0056	-0.0060
Rockdale			
Total Population in study area:	18328	18328	18328
total change	-3549.6	-3549.6	-3549.6
Population weighted Δx (μg/m^3):	-0.19367089	-0.19367089	-0.19367089
Increased number of cases in population:	-0.0402	-0.0075	-0.0079

Health Endpoint:	Mortality - All Causes (non-trauma), Short-term	Mortality - Respiratory, Short-term	Morbidity - Asthma ED Admissions - Short-term
Age Group:	≥ 30 years	All ages	1-14 years
β (change in effect per 1 μg/m³ PM) (as per Table 6-15)	0.00188	0.00426	0.00115
Canterbury - Bankstown LGA			
Total Population in study area:	76834	76834	76834
% population in assessment age-group:	58%	100%	19%
total change	-12420.8	-12420.8	-12420.8
Population weighted Δx (μg/m³):	-0.16165760	-0.16165760	-0.16165760
Baseline Incidence (per 100,000) (as per Table 4-5)	977	49.4	1209.0
Baseline Incidence (per person)	0.00977	0.00049	0.01209
Relative Risk:	0.999696	0.999312	0.999814
Attributable fraction (AF):	-3.0E-04	-6.9E-04	-1.9E-04
Increased number of cases in population:	-0.13	-0.026	-0.033
Risk:	-3.0E-06	-3.4E-07	-2.2E-06
Individual suburbs within LGA			
Belmore			
Total Population in study area:	18330	18330	18330
total change	-2437.9	-2437.9	-2437.9
Population weighted Δx (μg/m³):	-0.13300055	-0.13300055	-0.13300055
Increased number of cases in population:	-0.0261	-0.0051	-0.0065
Canterbury (South)			
Total Population in study area:	26841	26841	26841
total change	-3885	-3885	-3885
Population weighted Δx (μg/m³):	-0.14474125	-0.14474125	-0.14474125
Increased number of cases in population:	-0.0415	-0.0082	-0.0104
Kinsgrove - North			
Total Population in study area:	22489	22489	22489
total change	-3690.9	-3690.9	-3690.9
Population weighted Δx (μg/m³):	-0.16412024	-0.16412024	-0.16412024
Increased number of cases in population:	-0.0394	-0.0078	-0.0099
Lakemba			
Total Population in study area:	3643	3643	3643
total change	-823.6	-823.6	-823.6
Population weighted Δx (μg/m³):	-0.22607741	-0.22607741	-0.22607741
Increased number of cases in population:	-0.0088	-0.0017	-0.0022
Roselands			
Total Population in study area:	5561	5561	5561
total change	-1583.4	-1583.4	-1583.4
Population weighted Δx (μg/m³):	-0.28473296	-0.28473296	-0.28473296
Increased number of cases in population:	-0.0169	-0.0033	-0.0042

Health Endpoint:	Mortality - All Causes (non-trauma), Short-term	Mortality - Respiratory, Short-term	Morbidity - Asthma ED Admissions - Short-term
Age Group:	≥ 30 years	All ages	1-14 years
β (change in effect per 1 μg/m^3 PM) (as per Table 6-15)	0.00188	0.00426	0.00115
Georges River LGA			
Total Population in study area:	66896	66896	66896
% population in assessment age-group:	61%	100%	16%
total change	-8749.2	-8749.2	-8749.2
Population weighted Δx (μg/m^3):	-0.13078809	-0.13078809	-0.13078809
Baseline Incidence (per 100,000) (as per Table 4.4)	977	49.4	1209.0
Baseline Incidence (per person)	0.00977	0.00049	0.01209
Relative Risk:	0.999754	0.999443	0.999850
Attributable fraction (AF):	-2.5E-04	-5.6E-04	-1.5E-04
Increased number of cases in population:	-0.098	-0.018	-0.020
Risk:	-2.4E-06	-2.8E-07	-1.8E-06
Hurstville			
Total Population in study area:	20164	20164	20164
total change	-2409	-2409	-2409
Population weighted Δx (μg/m^3):	-0.11947034	-0.11947034	-0.11947034
Increased number of cases in population:	-0.0271	-0.0051	-0.0055
Kogorah			
Total Population in study area:	9484	9484	9484
total change	-1309.5	-1309.5	-1309.5
Population weighted Δx (μg/m^3):	-0.13807465	-0.13807465	-0.13807465
Increased number of cases in population:	-0.0147	-0.0028	-0.0030
Kogorah Bay			
Total Population in study area:	9469	9469	9469
total change	-444.3	-444.3	-444.3
Population weighted Δx (μg/m^3):	-0.04692153	-0.04692153	-0.04692153
Increased number of cases in population:	-0.0050	-0.0009	-0.0010
Mortdale			
Total Population in study area:	11002	11002	11002
total change	-387.1	-387.1	-387.1
Population weighted Δx (μg/m^3):	-0.03518451	-0.03518451	-0.03518451
Increased number of cases in population:	-0.0043	-0.0008	-0.0009
Narwee			
Total Population in study area:	4884	4884	4884
total change	-1420.9	-1420.9	-1420.9
Population weighted Δx (μg/m^3):	-0.29092957	-0.29092957	-0.29092957
Increased number of cases in population:	-0.0160	-0.0030	-0.0032
Oatley			
Total Population in study area:	4322	4322	4322
total change	-2535.7	-2535.7	-2535.7
Population weighted Δx (μg/m^3):	-0.58669597	-0.58669597	-0.58669597
Increased number of cases in population:	-0.0285	-0.0053	-0.0058
South Hurstville			
Total Population in study area:	7571	7571	7571
total change	-242.7	-242.7	-242.7
Population weighted Δx (μg/m^3):	-0.03205653	-0.03205653	-0.03205653
Increased number of cases in population:	-0.0027	-0.0005	-0.0006
Total population incidence - All Suburbs	**-2**	**-0.3**	**-0.3**

Assessment of Increased Incidence - NO_2
M4-M5 Link: 2023 Cumulative

Health Endpoint:	Mortality - All Causes (non-trauma), Short-term	Mortality - Respiratory, Short-term	Morbidity - Asthma ED Admissions - Short-term
Age Group:	≥ 30 years	All ages	1-14 years
β (change in effect per 1 μg/m³ PM) (as per Table 6-15)	0.00188	0.00426	0.00115
Canada Bay LGA			
Total Population in study area:	67644	67644	67644
% population in assessment age-group:	63%	100%	16%
total change	959.5	959.5	959.5
Population weighted Δx (μg/m³):	0.01418455	0.01418455	0.01418455
Baseline Incidence (per 100,000) (as per Table 4-5)	977	49.4	1209.0
Baseline Incidence (per person)	0.00977	0.00049	0.01209
Relative Risk:	1.000027	1.000060	1.000016
Attributable fraction (AF):	2.7E-05	6.0E-05	1.6E-05
Increased number of cases in population:	0.011	0.0020	0.0021
Risk:	2.6E-07	3.0E-08	2.0E-07
Individual suburbs within LGA			
Concord - Mortlake - Cabarita			
Total Population in study area:	19204	19204	19204
total change	-90.2	-90.2	-90.2
Population weighted Δx (μg/m³):	-0.00469694	-0.00469694	-0.00469694
Increased number of cases in population:	-0.001050	-0.0002	-0.0002
Concord West			
Total Population in study area:	10692	10692	10692
total change	428.2	428.2	428.2
Population weighted Δx (μg/m³):	0.04004863	0.04004863	0.04004863
Increased number of cases in population:	0.004984	0.0009	0.0009
Drummoyne - Rodd Pt			
Total Population in study area:	17456	17456	17456
total change	1714.8	1714.8	1714.8
Population weighted Δx (μg/m³):	0.09823556	0.09823556	0.09823556
Increased number of cases in population:	0.019957	0.0036	0.0037
Five Dock			
Total Population in study area:	19111	19111	19111
total change	-710	-710	-710
Population weighted Δx (μg/m³):	-0.03715138	-0.03715138	-0.03715138
Increased number of cases in population:	-0.008264	-0.0015	-0.0015
Gladesville			
Total Population in study area:	590	590	590
total change	-307.7	-307.7	-307.7
Population weighted Δx (μg/m³):	-0.52152542	-0.52152542	-0.52152542
Increased number of cases in population:	-0.00358	-0.00065	-0.00066
Hunters Hill			
Total Population in study area:	591	591	591
total change	-139.7	-139.7	-139.7
Population weighted Δx (μg/m³):	-0.23637902	-0.23637902	-0.23637902
Increased number of cases in population:	-0.00163	-0.00029	-0.00030

Health Endpoint:	Mortality - All Causes (non-trauma), Short-term	Mortality - Respiratory, Short-term	Morbidity - Asthma ED Admissions - Short-term
Age Group:	≥ 30 years	All ages	1-14 years
β (change in effect per 1 μg/m^3 PM) (as per Table 6-15)	0.00188	0.00426	0.00115
Strathfield LGA			
Total Population in study area:	25473	25473	25473
% population in assessment age-group:	60%	100%	14%
total change	-2937.2	-2937.2	-2937.2
Population weighted Δx (μg/m^3):	-0.1	-0.11530640	-0.11530640
Baseline Incidence (per 100,000) (as per Table 4-5)	977	49.4	1209.0
Baseline Incidence (per person)	0.00977	0.00049	0.01209
Relative Risk:	0.999783	0.999509	0.999867
Attributable fraction (AF):	-2.2E-04	-4.9E-04	-1.3E-04
Increased number of cases in population:	-0.032	-0.0062	-0.0058
Risk:	-2.1E-06	-2.4E-07	-1.6E-06
Individual suburbs within LGA			
Homebush			
Total Population in study area:	5075	5075	5075
total change	-352.2	-352.2	-352.2
Population weighted Δx (μg/m^3):	-0.06939901	-0.06939901	-0.06939901
Increased number of cases in population:	-0.0039	-0.00074	-0.00070
Homebush Bay			
Total Population in study area:	63	63	63
total change	9.9	9.9	9.9
Population weighted Δx (μg/m^3):	0.15714286	0.15714286	0.15714286
Increased number of cases in population:	0.00011	0.000021	0.000020
Strathfield			
Total Population in study area:	20335	20335	20335
total change	-2594.9	-2594.9	-2594.9
Population weighted Δx (μg/m^3):	-0.12760757	-0.12760757	-0.12760757
Increased number of cases in population:	-0.0285	-0.0055	-0.0052
Burwood LGA			
Total Population in study area:	20986	20986	20986
% population in assessment age-group:	60%	100%	14%
totqal change	-2253	-2253	-2253
Population weighted Δx (μg/m^3):	-0.10735729	-0.10735729	-0.10735729
Baseline Incidence (per 100,000) (as per Table 4-5)	977	49.4	1209.0
Baseline Incidence (per person)	0.00977	0.00049	0.01209
Relative Risk:	0.999798	0.999543	0.999877
Attributable fraction (AF):	-2.0E-04	-4.6E-04	-1.2E-04
Increased number of cases in population:	-0.025	-0.0047	-0.0045
Risk:	-2.0E-06	-2.3E-07	-1.5E-06

Health Endpoint:	Mortality - All Causes (non-trauma), Short-term	Mortality - Respiratory, Short-term	Morbidity - Asthma ED Admissions - Short-term
Age Group:	≥ 30 years	All ages	1-14 years
β (change in effect per 1 μg/m^3 PM) (as per Table 6-15)	0.00188	0.00426	0.00115
Sydney Inner West LGA			
Total Population in study area:	180589	180589	180589
% population in assessment age-group:	67%	100%	15%
total change	-96098.7	-96098.7	-96098.7
Population weighted Δx (μg/m^3):	-0.53214039	-0.53214039	-0.53214039
Baseline Incidence (per 100,000) (as per Table 4-5)	977	49.4	1209.0
Baseline Incidence (per person)	0.00977	0.00049	0.01209
Relative Risk:	0.999000	0.997736	0.999388
Attributable fraction (AF):	-1.0E-03	-2.3E-03	-6.1E-04
Increased number of cases in population:	-1.2	-0.20	-0.20
Risk:	-9.8E-06	-1.1E-06	-7.4E-06
Individual suburbs within LGA			
Ashfield			
Total Population in study area:	22769	22769	22769
total change	-3906.9	-3906.9	-3906.9
Population weighted Δx (μg/m^3):	-0.17158856	-0.17158856	-0.17158856
Increased number of cases in population:	-0.0482	-0.0082	-0.0081
Canterbury North-Ashbury			
Total Population in study area:	9390	9390	9390
total change	-2784.9	-2784.9	-2784.9
Population weighted Δx (μg/m^3):	-0.29658147	-0.29658147	-0.29658147
Increased number of cases in population:	-0.0344	-0.0059	-0.0058
Croyden Park			
Total Population in study area:	16360	16360	16360
total change	-2355.8	-2355.8	-2355.8
Population weighted Δx (μg/m^3):	-0.14399756	-0.14399756	-0.14399756
Increased number of cases in population:	-0.0291	-0.0050	-0.0049
Dulwich Hill			
Total Population in study area:	15862	15862	15862
total change	-5679.8	-5679.8	-5679.8
Population weighted Δx (μg/m^3):	-0.35807590	-0.35807590	-0.35807590
Increased number of cases in population:	-0.0701	-0.0120	-0.0118
Haberfield			
Total Population in study area:	13245	13245	13245
total change	-7866.3	-7866.3	-7866.3
Population weighted Δx (μg/m^3):	-0.59390713	-0.59390713	-0.59390713
Increased number of cases in population:	-0.0971	-0.0166	-0.0163
Balmain			
Total Population in study area:	14794	14794	14794
total change	-13543.9	-13543.9	-13543.9
Population weighted Δx (μg/m^3):	-0.91549953	-0.91549953	-0.91549953
Increased number of cases in population:	-0.1672	-0.0286	-0.0281
Leichardt			
Total Population in study area:	24443	24443	24443
total change	-21516.6	-21516.6	-21516.6
Population weighted Δx (μg/m^3):	-0.88027656	-0.88027656	-0.88027656
Increased number of cases in population:	-0.2657	-0.0454	-0.0446
Lilyfield			
Total Population in study area:	13073	13073	13073
total change	-13434.3	-13434.3	-13434.3
Population weighted Δx (μg/m^3):	-1.02763711	-1.02763711	-1.02763711
Increased number of cases in population:	-0.1659	-0.0283	-0.0278
Marrickville			
Total Population in study area:	24632	24632	24632
total change	-9203.4	-9203.4	-9203.4
Population weighted Δx (μg/m^3):	-0.37363592	-0.37363592	-0.37363592
Increased number of cases in population:	-0.1136	-0.0194	-0.0191
Petersham			
Total Population in study area:	18817	18817	18817
total change	-12563.7	-12563.7	-12563.7
Population weighted Δx (μg/m^3):	-0.66767816	-0.66767816	-0.66767816
Increased number of cases in population:	-0.1551	-0.0265	-0.0260
Sydenham			
Total Population in study area:	7204	7204	7204
total change	-3243.1	-3243.1	-3243.1
Population weighted Δx (μg/m^3):	-0.45018046	-0.45018046	-0.45018046
Increased number of cases in population:	-0.0400	-0.0068	-0.0067

Health Endpoint:	Mortality - All Causes (non-trauma), Short-term	Mortality - Respiratory, Short-term	Morbidity - Asthma ED Admissions - Short-term
Age Group:	≥ 30 years	All ages	1-14 years
β (change in effect per 1 μg/m^3 PM) (as per Table 6-15)	0.00188	0.00426	0.00115
Sydney LGA			
Total Population in study area:	125509	125509	125509
% population in assessment age-group:	59%	100%	6%
total change	-55436.5	-55436.5	-55436.5
Population weighted Δx (μg/m^3):	-0.44169342	-0.44169342	-0.44169342
Baseline Incidence (per 100,000) (as per Table 4-5)	977	49.4	1209.0
Baseline Incidence (per person)	0.00977	0.00049	0.01209
Relative Risk:	0.999170	0.998120	0.999492
Attributable fraction (AF):	-8.3E-04	-1.9E-03	-5.1E-04
Increased number of cases in population:	-0.60	-0.12	-0.048
Risk:	-8.1E-06	-9.3E-07	-6.1E-06
Individual suburbs within LGA			
Erskinville			
Total Population in study area:	13908	13908	13908
total change	-5203.8	-5203.8	-5203.8
Population weighted Δx (μg/m^3):	-0.37415876	-0.37415876	-0.37415876
Increased number of cases in population:	-0.0565	-0.0110	-0.0045
Glebe			
Total Population in study area:	16595	16595	16595
total change	-10066.3	-10066.3	-10066.3
Population weighted Δx (μg/m^3):	-0.60658632	-0.60658632	-0.60658632
Increased number of cases in population:	-0.1093	-0.0212	-0.0087
Newtown			
Total Population in study area:	21480	21480	21480
total change	-12329	-12329	-12329
Population weighted Δx (μg/m^3):	-0.57397579	-0.57397579	-0.57397579
Increased number of cases in population:	-0.1338	-0.0260	-0.0106
Pyrmont			
Total Population in study area:	18720	18720	18720
total change	-6164.8	-6164.8	-6164.8
Population weighted Δx (μg/m^3):	-0.32931624	-0.32931624	-0.32931624
Increased number of cases in population:	-0.0669	-0.0130	-0.0053
Redfern			
Total Population in study area:	12628	12628	12628
total change	-5089.5	-5089.5	-5089.5
Population weighted Δx (μg/m^3):	-0.40303294	-0.40303294	-0.40303294
Increased number of cases in population:	-0.0552	-0.0107	-0.0044
Surry Hills			
Total Population in study area:	4190	4190	4190
total change	-1913.2	-1913.2	-1913.2
Population weighted Δx (μg/m^3):	-0.45661098	-0.45661098	-0.45661098
Increased number of cases in population:	-0.0208	-0.0040	-0.0016
Sydney			
Total Population in study area:	21726	21726	21726
total change	-9007.1	-9007.1	-9007.1
Population weighted Δx (μg/m^3):	-0.41457700	-0.41457700	-0.41457700
Increased number of cases in population:	-0.0978	-0.0190	-0.0078
Waterloo			
Total Population in study area:	11306	11306	11306
total change	-4674.3	-4674.3	-4674.3
Population weighted Δx (μg/m^3):	-0.41343534	-0.41343534	-0.41343534
Increased number of cases in population:	-0.0507	-0.0098	-0.0040
Crows Nest			
Total Population in study area:	50	50	50
total change	-48.6	-48.6	-48.6
Population weighted Δx (μg/m^3):	-0.97200000	-0.97200000	-0.97200000
Increased number of cases in population:	-0.00053	-0.000102	-0.000042
North Sydney			
Total Population in study area:	4906	4906	4906
total change	-939.9	-939.9	-939.9
Population weighted Δx (μg/m^3):	-0.19158174	-0.19158174	-0.19158174
Increased number of cases in population:	-0.0102	-0.0020	-0.0008

Health Endpoint:	Mortality - All Causes (non-trauma), Short-term	Mortality - Respiratory, Short-term	Morbidity - Asthma ED Admissions - Short-term
Age Group:	≥ 30 years	All ages	1-14 years
β (change in effect per 1 μg/m^3 PM) (as per Table 6-15)	0.00188	0.00426	0.00115
Botany LGA			
Total Population in study area:	25700	25700	25700
% population in assessment age-group:	62%	100%	17%
total change	-4707.7	-4707.7	-4707.7
Population weighted Δx (μg/m^3):	-0.18317899	-0.18317899	-0.18317899
Baseline Incidence (per 100,000) (as per Table 4-5)	977	49.4	1209.0
Baseline Incidence (per person)	0.00977	0.00049	0.01209
Relative Risk:	0.999656	0.999220	0.999789
Attributable fraction (AF):	-3.4E-04	-7.8E-04	-2.1E-04
Increased number of cases in population:	-0.053	-0.0099	-0.011
Risk:	-3.4E-06	-3.9E-07	-2.5E-06
Individual suburbs within LGA			
Botany			
Total Population in study area:	8915	8915	8915
total change	-515.4	-515.4	-515.4
Population weighted Δx (μg/m^3):	-0.05781268	-0.05781268	-0.05781268
Increased number of cases in population:	-0.0058	-0.0011	-0.0012
Mascot			
Total Population in study area:	16215	16215	16215
total change	-4173	-4173	-4173
Population weighted Δx (μg/m^3):	-0.25735430	-0.25735430	-0.25735430
Increased number of cases in population:	-0.0472	-0.0088	-0.0097
Pagewood			
Total Population in study area:	567	567	567
total change	-18.7	-18.7	-18.7
Population weighted Δx (μg/m^3):	-0.03298060	-0.03298060	-0.03298060
Increased number of cases in population:	-0.00021	-0.000039	-0.000044

Health Endpoint:	Mortality - All Causes (non-trauma), Short-term	Mortality - Respiratory, Short-term	Morbidity - Asthma ED Admissions - Short-term
Age Group:	≥ 30 years	All ages	1-14 years
β (change in effect per 1 μg/m^3 PM) (as per Table 6-15)	0.00188	0.00426	0.00115
Rockdale LGA			
Total Population in study area:	82293	82293	82293
% population in assessment age-group:	62%	100%	16%
total change	-22825.1	-22825.1	-22825.1
Population weighted Δx (μg/m^3):	-0.27736381	-0.27736381	-0.27736381
Baseline Incidence (per 100,000) (as per Table 4-5)	977	49.4	1209.0
Baseline Incidence (per person)	0.00977	0.00049	0.01209
Relative Risk:	0.999479	0.998819	0.999681
Attributable fraction (AF):	-5.2E-04	-1.2E-03	-3.2E-04
Increased number of cases in population:	-0.26	-0.048	-0.051
Risk:	-5.1E-06	-5.8E-07	-3.9E-06
Individual suburbs within LGA			
Arncliffe			
Total Population in study area:	14669	14669	14669
total change	-4659.1	-4659.1	-4659.1
Population weighted Δx (μg/m^3):	-0.31761538	-0.31761538	-0.31761538
Increased number of cases in population:	-0.0528	-0.0098	-0.0104
Bexley			
Total Population in study area:	25123	25123	25123
total change	-5640.7	-5640.7	-5640.7
Population weighted Δx (μg/m^3):	-0.22452335	-0.22452335	-0.22452335
Increased number of cases in population:	-0.0639	-0.0119	-0.0125
Kingsgrove - South			
Total Population in study area:	11981	11981	11981
total change	-4405.9	-4405.9	-4405.9
Population weighted Δx (μg/m^3):	-0.36774059	-0.36774059	-0.36774059
Increased number of cases in population:	-0.0499	-0.0093	-0.0098
Monterey			
Total Population in study area:	12192	12192	12192
total change	-3128.1	-3128.1	-3128.1
Population weighted Δx (μg/m^3):	-0.25656988	-0.25656988	-0.25656988
Increased number of cases in population:	-0.0354	-0.0066	-0.0070
Rockdale			
Total Population in study area:	18328	18328	18328
total change	-4991.3	-4991.3	-4991.3
Population weighted Δx (μg/m^3):	-0.27233195	-0.27233195	-0.27233195
Increased number of cases in population:	-0.0566	-0.0105	-0.0111

Health Endpoint:	Mortality - All Causes (non-trauma), Short-term	Mortality - Respiratory, Short-term	Morbidity - Asthma ED Admissions - Short-term
Age Group:	≥ 30 years	All ages	1-14 years
β (change in effect per 1 μg/m^3 PM) (as per Table 6-15)	0.00188	0.00426	0.00115
Canterbury - Bankstown LGA			
Total Population in study area:	76834	76834	76834
% population in assessment age-group:	58%	100%	19%
total change	-17906.2000	-17906.2	-17906.2
Population weighted Δx (μg/m^3):	-0.23305047	-0.23305047	-0.23305047
Baseline Incidence (per 100,000) (as per Table 4-5)	977	49.4	1209.0
Baseline Incidence (per person)	0.00977	0.00049	0.01209
Relative Risk:	0.999562	0.999008	0.999732
Attributable fraction (AF):	-4.4E-04	-9.9E-04	-2.7E-04
Increased number of cases in population:	-0.19	-0.038	-0.048
Risk:	-4.3E-06	-4.9E-07	-3.2E-06
Individual suburbs within LGA			
Belmore			
Total Population in study area:	18330	18330	18330
total change	-3620.1	-3620.1	-3620.1
Population weighted Δx (μg/m^3):	-0.19749591	-0.19749591	-0.19749591
Increased number of cases in population:	-0.0387	-0.0076	-0.0097
Canterbury (South)			
Total Population in study area:	26841	26841	26841
total change	-5898.8	-5898.8	-5898.8
Population weighted Δx (μg/m^3):	-0.21976826	-0.21976826	-0.21976826
Increased number of cases in population:	-0.0630	-0.0124	-0.0157
Kinsgrove - North			
Total Population in study area:	22489	22489	22489
total change	-5377	-5377	-5377
Population weighted Δx (μg/m^3):	-0.23909467	-0.23909467	-0.23909467
Increased number of cases in population:	-0.0575	-0.0113	-0.0144
Lakemba			
Total Population in study area:	3643	3643	3643
total change	-1004.8	-1004.8	-1004.8
Population weighted Δx (μg/m^3):	-0.27581663	-0.27581663	-0.27581663
Increased number of cases in population:	-0.0107	-0.0021	-0.0027
Roselands			
Total Population in study area:	5531	5531	5531
total change	-2005.5	-2005.5	-2005.5
Population weighted Δx (μg/m^3):	-0.36259266	-0.36259266	-0.36259266
Increased number of cases in population:	-0.0214	-0.0042	-0.0054

Health Endpoint:	Mortality - All Causes (non-trauma), Short-term	Mortality - Respiratory, Short-term	Morbidity - Asthma ED Admissions - Short-term
Age Group:	≥ 30 years	All ages	1-14 years
β (change in effect per 1 $\mu g/m^3$ PM) (as per Table 6-15)	0.00188	0.00426	0.00115
Georges River LGA			
Total Population in study area:	66896	66896	66896
% population in assessment age-group:	61%	100%	16%
total change	-12549.7	-12549.7	-12549.7
Population weighted Δx ($\mu g/m^3$):	-0.18760016	-0.18760016	-0.18760016
Baseline Incidence (per 100,000) (as per Table 4.4)	977	49.4	1209.0
Baseline Incidence (per person)	0.00977	0.00049	0.01209
Relative Risk:	0.999647	0.999201	0.999784
Attributable fraction (AF):	-3.5E-04	-8.0E-04	-2.2E-04
Increased number of cases in population:	-0.14	-0.026	-0.029
Risk:	-3.4E-06	-3.9E-07	-2.6E-06
Hurstville			
Total Population in study area:	20164	20164	20164
total change	-3927.1	-3927.1	-3927.1
Population weighted Δx ($\mu g/m^3$):	-0.19475798	-0.19475798	-0.19475798
Increased number of cases in population:	-0.0441	-0.0083	-0.0090
Kogorah			
Total Population in study area:	9484	9484	9484
total change	-1663.9	-1663.9	-1663.9
Population weighted Δx ($\mu g/m^3$):	-0.17544285	-0.17544285	-0.17544285
Increased number of cases in population:	-0.0187	-0.0035	-0.0038
Kogorah Bay			
Total Population in study area:	9469	9469	9469
total change	-727.6	-727.6	-727.6
Population weighted Δx ($\mu g/m^3$):	-0.07684022	-0.07684022	-0.07684022
Increased number of cases in population:	-0.0082	-0.0015	-0.0017
Mortdale			
Total Population in study area:	11002	11002	11002
total change	-1530.1	-1530.1	-1530.1
Population weighted Δx ($\mu g/m^3$):	-0.13907471	-0.13907471	-0.13907471
Increased number of cases in population:	-0.0172	-0.0032	-0.0035
Narwee			
Total Population in study area:	4884	4884	4884
total change	-1578.6	-1578.6	-1578.6
Population weighted Δx ($\mu g/m^3$):	-0.32321867	-0.32321867	-0.32321867
Increased number of cases in population:	-0.0177	-0.0033	-0.0036
Oatley			
Total Population in study area:	4322	4322	4322
total change	-2531.4	-2531.4	-2531.4
Population weighted Δx ($\mu g/m^3$):	-0.58570106	-0.58570106	-0.58570106
Increased number of cases in population:	-0.0285	-0.0053	-0.0058
South Hurstville			
Total Population in study area:	7571	7571	7571
total change	-591	-591	-591
Population weighted Δx ($\mu g/m^3$):	-0.07806102	-0.07806102	-0.07806102
Increased number of cases in population:	-0.0066	-0.0012	-0.0013
Total population incidence - All Suburbs	**-2**	**-0.5**	**-0.4**

Assessment of Increased Incidence - NO_2
M4-M5 Link: 2033

Health Endpoint:	Mortality - All Causes (non-trauma), Short-term	Mortality - Respiratory, Short-term	Morbidity - Asthma ED Admissions - Short-term
Age Group:	≥ 30 years	All ages	1-14 years
β (change in effect per 1 μg/m³ PM) (as per Table 6-15)	0.00188	0.00426	0.00115
Canada Bay LGA			
Total Population in study area:	67644	67644	67644
% population in assessment age-group:	63%	100%	16%
total change	-3505.0	-3505	-3505
Population weighted Δx (μg/m³):	-0.05181539	-0.05181539	-0.05181539
Baseline Incidence (per 100,000) (as per Table 4-5)	977	49.4	1209.0
Baseline Incidence (per person)	0.00977	0.00049	0.01209
Relative Risk:	0.999903	0.999779	0.999940
Attributable fraction (AF):	-9.7E-05	-2.2E-04	-6.0E-05
Increased number of cases in population:	-0.041	-0.0074	-0.0076
Risk:	-9.5E-07	-1.1E-07	-7.2E-07
Individual suburbs within LGA			
Concord - Mortlake - Cabarita			
Total Population in study area:	19204	19204	19204
total change	-450.5	-450.5	-450.5
Population weighted Δx (μg/m³):	-0.02345865	-0.02345865	-0.02345865
Increased number of cases in population:	-0.005244	-0.0009	-0.0010
Concord West			
Total Population in study area:	10692	10692	10692
total change	-168.7	-168.7	-168.7
Population weighted Δx (μg/m³):	-0.01577815	-0.01577815	-0.01577815
Increased number of cases in population:	-0.001964	-0.0004	-0.0004
Drummoyne - Rodd Pt			
Total Population in study area:	17456	17456	17456
total change	-509	-509	-509
Population weighted Δx (μg/m³):	-0.02915903	-0.02915903	-0.02915903
Increased number of cases in population:	-0.005924	-0.0011	-0.0011
Five Dock			
Total Population in study area:	19111	19111	19111
total change	-1998.8	-1998.8	-1998.8
Population weighted Δx (μg/m³):	-0.10458898	-0.10458898	-0.10458898
Increased number of cases in population:	-0.023267	-0.0042	-0.0043
Gladesville			
Total Population in study area:	590	590	590
total change	-132.4	-132.4	-132.4
Population weighted Δx (μg/m³):	-0.22440678	-0.22440678	-0.22440678
Increased number of cases in population:	-0.001541	-0.0003	-0.0003
Hunters Hill			
Total Population in study area:	591	591	591
total change	-169.5	-169.5	-169.5
Population weighted Δx (μg/m³):	-0.28680203	-0.28680203	-0.28680203
Increased number of cases in population:	-0.001973	-0.0004	-0.0004

Health Endpoint:	Mortality - All Causes (non-trauma), Short-term	Mortality - Respiratory, Short-term	Morbidity - Asthma ED Admissions - Short-term
Age Group:	≥ 30 years	All ages	1-14 years
β (change in effect per 1 μg/m^3 PM) (as per Table 6-15)	0.00188	0.00426	0.00115
Strathfield LGA			
Total Population in study area:	25473	25473	25473
% population in assessment age-group:	60%	100%	14%
total change	1626.8	1626.8	1626.8
Population weighted Δx (μg/m^3):	0.1	0.06386370	0.06386370
Baseline Incidence (per 100,000) (as per Table 4-5)	977	49.4	1209.0
Baseline Incidence (per person)	0.00977	0.00049	0.01209
Relative Risk:	1.000120	1.000272	1.000073
Attributable fraction (AF):	1.2E-04	2.7E-04	7.3E-05
Increased number of cases in population:	0.018	0.0034	0.0032
Risk:	1.2E-06	1.3E-07	8.9E-07
Individual suburbs within LGA			
Homebush			
Total Population in study area:	25473	25473	25473
total change	1639.8	1639.8	1639.8
Population weighted Δx (μg/m^3):	0.06437404	0.06437404	0.06437404
Increased number of cases in population:	0.0180	0.0035	0.0033
Homebush Bay			
Total Population in study area:	63	63	63
total change	2.7	2.7	2.7
Population weighted Δx (μg/m^3):	0.04285714	0.04285714	0.04285714
Increased number of cases in population:	0.000030	0.0000057	0.0000054
Strathfield			
Total Population in study area:	20335	20335	20335
total change	-15.7	-15.7	-15.7
Population weighted Δx (μg/m^3):	-0.00077207	-0.00077207	-0.00077207
Increased number of cases in population:	-0.00017	-0.000033	-0.000031
Burwood LGA			
Total Population in study area:	20986	20986	20986
% population in assessment age-group:	60%	100%	14%
totqal change	-1687	-1687	-1687
Population weighted Δx (μg/m^3):	-0.08038692	-0.08038692	-0.08038692
Baseline Incidence (per 100,000) (as per Table 4-5)	977	49.4	1209.0
Baseline Incidence (per person)	0.00977	0.00049	0.01209
Relative Risk:	0.999849	0.999658	0.999908
Attributable fraction (AF):	-1.5E-04	-3.4E-04	-9.2E-05
Increased number of cases in population:	-0.019	-0.0036	-0.0034
Risk:	-1.5E-06	-1.7E-07	-1.1E-06

Health Endpoint:	Mortality - All Causes (non-trauma), Short-term	Mortality - Respiratory, Short-term	Morbidity - Asthma ED Admissions - Short-term
Age Group:	≥ 30 years	All ages	1-14 years
β (change in effect per 1 $\mu g/m^3$ PM) (as per Table 6-15)	0.00188	0.00426	0.00115
Sydney Inner West LGA			
Total Population in study area:	180589	180589	180589
% population in assessment age-group:	67%	100%	15%
total change	-87860.7	-87860.7	-87860.7
Population weighted Δx ($\mu g/m^3$):	-0.48652299	-0.48652299	-0.48652299
Baseline Incidence (per 100,000) (as per Table 4-5)	977	49.4	1209.0
Baseline Incidence (per person)	0.00977	0.00049	0.01209
Relative Risk:	0.999086	0.997930	0.999441
Attributable fraction (AF):	-9.2E-04	-2.1E-03	-5.6E-04
Increased number of cases in population:	-1.1	-0.19	-0.18
Risk:	-8.9E-06	-1.0E-06	-6.8E-06
Individual suburbs within LGA			
Ashfield			
Total Population in study area:	22769	22769	22769
total change	-4148.8	-4148.8	-4148.8
Population weighted Δx ($\mu g/m^3$):	-0.18221266	-0.18221266	-0.18221266
Increased number of cases in population:	-0.0512	-0.0087	-0.0086
Canterbury North-Ashbury			
Total Population in study area:	9390	9390	9390
total change	-2018.3	-2018.3	-2018.3
Population weighted Δx ($\mu g/m^3$):	-0.21494143	-0.21494143	-0.21494143
Increased number of cases in population:	-0.0249	-0.0042	-0.0042
Croyden Park			
Total Population in study area:	16360	16360	16360
total change	-1748.4	-1748.4	-1748.4
Population weighted Δx ($\mu g/m^3$):	-0.10687042	-0.10687042	-0.10687042
Increased number of cases in population:	-0.0216	-0.0037	-0.0036
Dulwich Hill			
Total Population in study area:	15862	15862	15862
total change	-5324	-5324	-5324
Population weighted Δx ($\mu g/m^3$):	-0.33564494	-0.33564494	-0.33564494
Increased number of cases in population:	-0.0657	-0.0112	-0.0110
Haberfield			
Total Population in study area:	13245	13245	13245
total change	-7043.5	-7043.5	-7043.5
Population weighted Δx ($\mu g/m^3$):	-0.53178558	-0.53178558	-0.53178558
Increased number of cases in population:	-0.0869	-0.0148	-0.0146
Balmain			
Total Population in study area:	14794	14794	14794
total change	-11907.1	-11907.1	-11907.1
Population weighted Δx ($\mu g/m^3$):	-0.80486008	-0.80486008	-0.80486008
Increased number of cases in population:	-0.1470	-0.0251	-0.0247
Leichardt			
Total Population in study area:	24443	24443	24443
total change	-19907.5	-19907.5	-19907.5
Population weighted Δx ($\mu g/m^3$):	-0.81444585	-0.81444585	-0.81444585
Increased number of cases in population:	-0.2458	-0.0420	-0.0413
Lilyfield			
Total Population in study area:	13073	13073	13073
total change	-12367	-12367	-12367
Population weighted Δx ($\mu g/m^3$):	-0.94599556	-0.94599556	-0.94599556
Increased number of cases in population:	-0.1527	-0.0261	-0.0256
Marrickville			
Total Population in study area:	24632	24632	24632
total change	-8008.6	-8008.6	-8008.6
Population weighted Δx ($\mu g/m^3$):	-0.32512991	-0.32512991	-0.32512991
Increased number of cases in population:	-0.0988	-0.0169	-0.0166
Petersham			
Total Population in study area:	18817	18817	18817
total change	-12233.1	-12233.1	-12233.1
Population weighted Δx ($\mu g/m^3$):	-0.65010894	-0.65010894	-0.65010894
Increased number of cases in population:	-1809.4000	-0.0258	-0.0254
Sydenham			
Total Population in study area:	7204	7204	7204
total change	-3154.4	-3154.4	-3154.4
Population weighted Δx ($\mu g/m^3$):	-0.43786785	-0.43786785	-0.43786785
Increased number of cases in population:	-0.0389	-0.0066	-0.0065

Health Endpoint:	Mortality - All Causes (non-trauma), Short-term	Mortality - Respiratory, Short-term	Morbidity - Asthma ED Admissions - Short-term
Age Group:	≥ 30 years	All ages	1-14 years
β (change in effect per 1 μg/m^3 PM) (as per Table 6-15)	0.00188	0.00426	0.00115
Sydney LGA			
Total Population in study area:	125509	125509	125509
% population in assessment age-group:	59%	100%	6%
total change	-13416.4	-13416.4	-13416.4
Population weighted Δx (μg/m^3):	-0.10689592	-0.10689592	-0.10689592
Baseline Incidence (per 100,000) (as per Table 4-5)	977	49.4	1209.0
Baseline Incidence (per person)	0.00977	0.00049	0.01209
Relative Risk:	0.999799	0.999545	0.999877
Attributable fraction (AF):	-2.0E-04	-4.6E-04	-1.2E-04
Increased number of cases in population:	-0.15	-0.028	-0.012
Risk:	-2.0E-06	-2.2E-07	-1.5E-06
Individual suburbs within LGA			
Erskinville			
Total Population in study area:	13908	13908	13908
total change	-3256.5	-3256.5	-3256.5
Population weighted Δx (μg/m^3):	-0.23414582	-0.23414582	-0.23414582
Increased number of cases in population:	-0.0353	-0.0069	-0.0028
Glebe			
Total Population in study area:	16595	16595	16595
total change	-1674	-1674	-1674
Population weighted Δx (μg/m^3):	-0.10087376	-0.10087376	-0.10087376
Increased number of cases in population:	-0.0182	-0.0035	-0.0014
Newtown			
Total Population in study area:	21480	21480	21480
total change	-11054.5	-11054.5	-11054.5
Population weighted Δx (μg/m^3):	-0.51464153	-0.51464153	-0.51464153
Increased number of cases in population:	-0.1200	-0.0233	-0.0095
Pyrmont			
Total Population in study area:	18720	18720	18720
total change	7619.5	7619.5	7619.5
Population weighted Δx (μg/m^3):	0.40702457	0.40702457	0.40702457
Increased number of cases in population:	0.0826	0.0160	0.0066
Redfern			
Total Population in study area:	12628	12628	12628
total change	1430.8	1430.8	1430.8
Population weighted Δx (μg/m^3):	0.11330377	0.11330377	0.11330377
Increased number of cases in population:	0.0155	0.0030	0.0012
Surry Hills			
Total Population in study area:	4190	4190	4190
total change	-1119.4	-1119.4	-1119.4
Population weighted Δx (μg/m^3):	-0.26715990	-0.26715990	-0.26715990
Increased number of cases in population:	-0.0121	-0.0024	-0.0010
Sydney			
Total Population in study area:	21726	21726	21726
total change	-1299.3	-1299.3	-1299.3
Population weighted Δx (μg/m^3):	-0.05980392	-0.05980392	-0.05980392
Increased number of cases in population:	-0.0141	-0.0027	-0.0011
Waterloo			
Total Population in study area:	11306	11306	11306
total change	-2998.3	-2998.3	-2998.3
Population weighted Δx (μg/m^3):	-0.26519547	-0.26519547	-0.26519547
Increased number of cases in population:	-0.0325	-0.0063	-0.0026
Crows Nest			
Total Population in study area:	50	50	50
total change	-12.4	-12.4	-12.4
Population weighted Δx (μg/m^3):	-0.24800000	-0.24800000	-0.24800000
Increased number of cases in population:	-0.00013	-0.000026	-0.000011
North Sydney			
Total Population in study area:	4906	4906	4906
total change	-1052.3	-1052.3	-1052.3
Population weighted Δx (μg/m^3):	-0.21449246	-0.21449246	-0.21449246
Increased number of cases in population:	-0.0114	-0.0022	-0.0009

Health Endpoint:	Mortality - All Causes (non-trauma), Short-term	Mortality - Respiratory, Short-term	Morbidity - Asthma ED Admissions - Short-term
Age Group:	≥ 30 years	All ages	1-14 years
β (change in effect per 1 $\mu g/m^3$ PM) (as per Table 6-15)	0.00188	0.00426	0.00115
Botany LGA			
Total Population in study area:	25700	25700	25700
% population in assessment age-group:	62%	100%	17%
total change	18272.1	18272.1	18272.1
Population weighted Δx ($\mu g/m^3$):	0.71097665	0.71097665	0.71097665
Baseline Incidence (per 100,000) (as per Table 4-5)	977	49.4	1209.0
Baseline Incidence (per person)	0.00977	0.00049	0.01209
Relative Risk:	1.001338	1.003033	1.000818
Attributable fraction (AF):	1.3E-03	3.0E-03	8.2E-04
Increased number of cases in population:	0.21	0.038	0.043
Risk:	1.3E-05	1.5E-06	9.9E-06
Individual suburbs within LGA			
Botany			
Total Population in study area:	8915	8915	8915
total change	2021.8	2021.8	2021.8
Population weighted Δx ($\mu g/m^3$):	0.22678632	0.22678632	0.22678632
Increased number of cases in population:	0.0229	0.0043	0.0047
Mascot			
Total Population in study area:	16215	16215	16215
total change	16253.6	16253.6	16253.6
Population weighted Δx ($\mu g/m^3$):	1.00238051	1.00238051	1.00238051
Increased number of cases in population:	0.1836	0.0341	0.0379
Pagewood			
Total Population in study area:	567	567	567
total change	-2.4	-2.4	-2.4
Population weighted Δx ($\mu g/m^3$):	-0.00423280	-0.00423280	-0.00423280
Increased number of cases in population:	-0.000027	-0.0000051	-0.0000056

Health Endpoint:	Mortality - All Causes (non-trauma), Short-term	Mortality - Respiratory, Short-term	Morbidity - Asthma ED Admissions - Short-term
Age Group:	≥ 30 years	All ages	1-14 years
β (change in effect per 1 μg/m^3 PM) (as per Table 6-15)	0.00188	0.00426	0.00115
Rockdale LGA			
Total Population in study area:	82293	82293	82293
% population in assessment age-group:	62%	100%	16%
total change	-18530.8	-18530.8	-18530.8
Population weighted Δx (μg/m^3):	-0.22518076	-0.22518076	-0.22518076
Baseline Incidence (per 100,000) (as per Table 4-5)	977	49.4	1209.0
Baseline Incidence (per person)	0.00977	0.00049	0.01209
Relative Risk:	0.999577	0.999041	0.999741
Attributable fraction (AF):	-4.2E-04	-9.6E-04	-2.6E-04
Increased number of cases in population:	-0.21	-0.039	-0.041
Risk:	-4.1E-06	-4.7E-07	-3.1E-06
Individual suburbs within LGA			
Arncliffe			
Total Population in study area:	14669	14669	14669
total change	-3622	-3622	-3622
Population weighted Δx (μg/m^3):	-0.24691526	-0.24691526	-0.24691526
Increased number of cases in population:	-0.0410	-0.0076	-0.0081
Bexley			
Total Population in study area:	25123	25123	25123
total change	-4596.2	-4596.2	-4596.2
Population weighted Δx (μg/m^3):	-0.18294790	-0.18294790	-0.18294790
Increased number of cases in population:	-0.0521	-0.0097	-0.0102
Kingsgrove - South			
Total Population in study area:	11981	11981	11981
total change	-2751.7	-2751.7	-2751.7
Population weighted Δx (μg/m^3):	-0.22967198	-0.22967198	-0.22967198
Increased number of cases in population:	-0.0312	-0.0058	-0.0061
Monterey			
Total Population in study area:	12192	12192	12192
total change	-2998	-2998	-2998
Population weighted Δx (μg/m^3):	-0.24589895	-0.24589895	-0.24589895
Increased number of cases in population:	-0.0340	-0.0063	-0.0067
Rockdale			
Total Population in study area:	18328	18328	18328
total change	-4562.9	-4562.9	-4562.9
Population weighted Δx (μg/m^3):	-0.24895788	-0.24895788	-0.24895788
Increased number of cases in population:	-0.0517	-0.0096	-0.0102

Health Endpoint:	Mortality - All Causes (non-trauma), Short-term	Mortality - Respiratory, Short-term	Morbidity - Asthma ED Admissions - Short-term
Age Group:	≥ 30 years	All ages	1-14 years
β (change in effect per 1 $\mu g/m^3$ PM) (as per Table 6-15)	0.00188	0.00426	0.00115
Canterbury - Bankstown LGA			
Total Population in study area:	76834	76834	76834
% population in assessment age-group:	58%	100%	19%
total change	-11876.1000	-11876.1	-11876.1
Population weighted Δx ($\mu g/m^3$):	-0.15456829	-0.15456829	-0.15456829
Baseline Incidence (per 100,000) (as per Table 4-5)	977	49.4	1209.0
Baseline Incidence (per person)	0.00977	0.00049	0.01209
Relative Risk:	0.999709	0.999342	0.999822
Attributable fraction (AF):	-2.9E-04	-6.6E-04	-1.8E-04
Increased number of cases in population:	-0.13	-0.025	-0.032
Risk:	-2.8E-06	-3.3E-07	-2.1E-06
Individual suburbs within LGA			
Belmore			
Total Population in study area:	18330	18330	18330
total change	-3179.9	-3179.9	-3179.9
Population weighted Δx ($\mu g/m^3$):	-0.17348063	-0.17348063	-0.17348063
Increased number of cases in population:	-0.0340	-0.0067	-0.0085
Canterbury (South)			
Total Population in study area:	26841	26841	26841
total change	-4086.5	-4086.5	-4086.5
Population weighted Δx ($\mu g/m^3$):	-0.15224843	-0.15224843	-0.15224843
Increased number of cases in population:	-0.0437	-0.0086	-0.0109
Kinsgrove - North			
Total Population in study area:	22489	22489	22489
total change	-3001.3	-3001.3	-3001.3
Population weighted Δx ($\mu g/m^3$):	-0.13345636	-0.13345636	-0.13345636
Increased number of cases in population:	-0.0321	-0.0063	-0.0080
Lakemba			
Total Population in study area:	3643	3643	3643
total change	-512.4	-512.4	-512.4
Population weighted Δx ($\mu g/m^3$):	-0.14065331	-0.14065331	-0.14065331
Increased number of cases in population:	-0.0055	-0.0011	-0.0014
Roselands			
Total Population in study area:	5531	5531	5531
total change	-1096	-1096	-1096
Population weighted Δx ($\mu g/m^3$):	-0.19815585	-0.19815585	-0.19815585
Increased number of cases in population:	-0.0117	-0.0023	-0.0029

Health Endpoint:	Mortality - All Causes (non-trauma), Short-term	Mortality - Respiratory, Short-term	Morbidity - Asthma ED Admissions - Short-term
Age Group:	≥ 30 years	All ages	1-14 years
β (change in effect per 1 μg/m^3 PM) (as per Table 6-15)	0.00188	0.00426	0.00115
Georges River LGA			
Total Population in study area:	66896	66896	66896
% population in assessment age-group:	61%	100%	16%
total change	-10368.6	-10368.6	-10368.6
Population weighted Δx (μg/m^3):	-0.15499581	-0.15499581	-0.15499581
Baseline Incidence (per 100,000) (as per Table 4.4)	977	49.4	1209.0
Baseline Incidence (per person)	0.00977	0.00049	0.01209
Relative Risk:	0.999709	0.999340	0.999822
Attributable fraction (AF):	-2.9E-04	-6.6E-04	-1.8E-04
Increased number of cases in population:	-0.12	-0.022	-0.0236
Risk:	-2.8E-06	-3.3E-07	-2.2E-06
Hurstville			
Total Population in study area:	20164	20164	20164
total change	-3191.8	-3191.8	-3191.8
Population weighted Δx (μg/m^3):	-0.15829201	-0.15829201	-0.15829201
Increased number of cases in population:	-0.0359	-0.0067	-0.0073
Kogorah			
Total Population in study area:	9484	9484	9484
total change	-1978.2	-1978.2	-1978.2
Population weighted Δx (μg/m^3):	-0.20858288	-0.20858288	-0.20858288
Increased number of cases in population:	-0.0222	-0.0042	-0.0045
Kogorah Bay			
Total Population in study area:	9469	9469	9469
total change	-602.1	-602.1	-602.1
Population weighted Δx (μg/m^3):	-0.06358644	-0.06358644	-0.06358644
Increased number of cases in population:	-0.0068	-0.0013	-0.0014
Mortdale			
Total Population in study area:	11002	11002	11002
total change	-1315.9	-1315.9	-1315.9
Population weighted Δx (μg/m^3):	-0.11960553	-0.11960553	-0.11960553
Increased number of cases in population:	-0.0148	-0.0028	-0.0030
Narwee			
Total Population in study area:	4884	4884	4884
total change	-836.3	-836.3	-836.3
Population weighted Δx (μg/m^3):	-0.17123260	-0.17123260	-0.17123260
Increased number of cases in population:	-0.0094	-0.0018	-0.0019
Oatley			
Total Population in study area:	4322	4322	4322
total change	-2012.4	-2012.4	-2012.4
Population weighted Δx (μg/m^3):	-0.46561777	-0.46561777	-0.46561777
Increased number of cases in population:	-0.0226	-0.0042	-0.0046
South Hurstville			
Total Population in study area:	7571	7571	7571
total change	-431.9	-431.9	-431.9
Population weighted Δx (μg/m^3):	-0.05704663	-0.05704663	-0.05704663
Increased number of cases in population:	-0.0049	-0.0009	-0.0010
Total population incidence - All Suburbs	**-2**	**-0.3**	**-0.3**

Assessment of Increased Incidence - NO_2
M4-M5 Link: 2033 Cumulative

Health Endpoint:	Mortality - All Causes (non-trauma), Short-term	Mortality - Respiratory, Short-term	Morbidity - Asthma ED Admissions - Short-term
Age Group:	≥ 30 years	All ages	1-14 years
β (change in effect per 1 μg/m^3 PM) (as per Table 6-15)	0.00188	0.00426	0.00115
Canada Bay LGA			
Total Population in study area:	67644	67644	67644
% population in assessment age-group:	63%	100%	16%
total change	-1681.4	-1681.4	-1681.4
Population weighted Δx (μg/m^3):	-0.02485660	-0.02485660	-0.02485660
Baseline Incidence (per 100,000) (as per Table 4-5)	977	49.4	1209.0
Baseline Incidence (per person)	0.00977	0.00049	0.01209
Relative Risk:	0.999953	0.999894	0.999971
Attributable fraction (AF):	-4.7E-05	-1.1E-04	-2.9E-05
Increased number of cases in population:	-0.020	-0.0035	-0.0036
Risk:	-4.6E-07	-5.2E-08	-3.5E-07
Individual suburbs within LGA			
Concord - Mortlake - Cabarita			
Total Population in study area:	19204	19204	19204
total change	-74.1	-74.1	-74.1
Population weighted Δx (μg/m^3):	-0.00385857	-0.00385857	-0.00385857
Increased number of cases in population:	-0.000862	-0.00016	-0.00016
Concord West			
Total Population in study area:	10692	10692	10692
total change	60.6	60.6	60.6
Population weighted Δx (μg/m^3):	0.00566779	0.00566779	0.00566779
Increased number of cases in population:	0.000705	0.00013	0.00013
Drummoyne - Rodd Pt			
Total Population in study area:	17456	17456	17456
total change	460	460	460
Population weighted Δx (μg/m^3):	0.02635197	0.02635197	0.02635197
Increased number of cases in population:	0.005354	0.0010	0.0010
Five Dock			
Total Population in study area:	19111	19111	19111
total change	-1600.8	-1600.8	-1600.8
Population weighted Δx (μg/m^3):	-0.08376328	-0.08376328	-0.08376328
Increased number of cases in population:	-0.018633	-0.0034	-0.0034
Gladesville			
Total Population in study area:	590	590	590
total change	-224.9	-224.9	-224.9
Population weighted Δx (μg/m^3):	-0.38118644	-0.38118644	-0.38118644
Increased number of cases in population:	-0.002619	-0.0005	-0.0005
Hunters Hill			
Total Population in study area:	591	591	591
total change	-251.4	-251.4	-251.4
Population weighted Δx (μg/m^3):	-0.42538071	-0.42538071	-0.42538071
Increased number of cases in population:	-0.002927	-0.0005	-0.0005

Health Endpoint:	Mortality - All Causes (non-trauma), Short-term	Mortality - Respiratory, Short-term	Morbidity - Asthma ED Admissions - Short-term
Age Group:	≥ 30 years	All ages	1-14 years
β (change in effect per 1 μg/m^3 PM) (as per Table 6-15)	0.00188	0.00426	0.00115
Strathfield LGA			
Total Population in study area:	25473	25473	25473
% population in assessment age-group:	60%	100%	14%
total change	-1749.1	-1749.1	-1749.1
Population weighted Δx (μg/m^3):	-0.1	-0.06866486	-0.06866486
Baseline Incidence (per 100,000) (as per Table 4-5)	977	49.4	1209.0
Baseline Incidence (per person)	0.00977	0.00049	0.01209
Relative Risk:	0.999871	0.999708	0.999921
Attributable fraction (AF):	-1.3E-04	-2.9E-04	-7.9E-05
Increased number of cases in population:	-0.019	-0.0037	-0.0035
Risk:	-1.3E-06	-1.4E-07	-9.5E-07
Individual suburbs within LGA			
Homebush			
Total Population in study area:	5075	5075	5075
total change	-173.3	-173.3	-173.3
Population weighted Δx (μg/m^3):	-0.03414778	-0.03414778	-0.03414778
Increased number of cases in population:	-0.0019	-0.0004	-0.0003
Homebush Bay			
Total Population in study area:	63	63	63
total change	-0.1	-0.1	-0.1
Population weighted Δx (μg/m^3):	-0.00158730	-0.00158730	-0.00158730
Increased number of cases in population:	-0.0000011	-0.00000021	-0.00000020
Strathfield			
Total Population in study area:	20335	20335	20335
total change	-1575.7	-1575.7	-1575.7
Population weighted Δx (μg/m^3):	-0.07748709	-0.07748709	-0.07748709
Increased number of cases in population:	-0.0173	-0.0033	-0.0031
Burwood LGA			
Total Population in study area:	20986	20986	20986
% population in assessment age-group:	60%	100%	14%
totqal change	-2119.9	-2119.9	-2119.9
Population weighted Δx (μg/m^3):	-0.10101496	-0.10101496	-0.10101496
Baseline Incidence (per 100,000) (as per Table 4-5)	977	49.4	1209.0
Baseline Incidence (per person)	0.00977	0.00049	0.01209
Relative Risk:	0.999810	0.999570	0.999884
Attributable fraction (AF):	-1.9E-04	-4.3E-04	-1.2E-04
Increased number of cases in population:	-0.023	-0.0045	-0.0042
Risk:	-1.9E-06	-2.1E-07	-1.4E-06

Health Endpoint:	Mortality - All Causes (non-trauma), Short-term	Mortality - Respiratory, Short-term	Morbidity - Asthma ED Admissions - Short-term
Age Group:	≥ 30 years	All ages	1-14 years
β (change in effect per 1 μg/m^3 PM) (as per Table 6-15)	0.00188	0.00426	0.00115
Sydney Inner West LGA			
Total Population in study area:	180589	180589	180589
% population in assessment age-group:	67%	100%	15%
total change	-93247.2	-93247.2	-93247.2
Population weighted Δx (μg/m^3):	-0.51635039	-0.51635039	-0.51635039
Baseline Incidence (per 100,000) (as per Table 4-5)	977	49.4	1209.0
Baseline Incidence (per person)	0.00977	0.00049	0.01209
Relative Risk:	0.999030	0.997803	0.999406
Attributable fraction (AF):	-9.7E-04	-2.2E-03	-5.9E-04
Increased number of cases in population:	-1.2	-0.20	-0.19
Risk:	-9.5E-06	-1.1E-06	-7.2E-06
Individual suburbs within LGA			
Ashfield			
Total Population in study area:	22769	22769	22769
total change	-4575.8	-4575.8	-4575.8
Population weighted Δx (μg/m^3):	-0.20096623	-0.20096623	-0.20096623
Increased number of cases in population:	-0.0565	-0.0096	-0.0095
Canterbury North-Ashbury			
Total Population in study area:	9390	9390	9390
total change	-3563.6	-3563.6	-3563.6
Population weighted Δx (μg/m^3):	-0.37951012	-0.37951012	-0.37951012
Increased number of cases in population:	-0.0440	-0.0075	-0.0074
Croyden Park			
Total Population in study area:	16360	16360	16360
total change	-2735.1	-2735.1	-2735.1
Population weighted Δx (μg/m^3):	-0.16718215	-0.16718215	-0.16718215
Increased number of cases in population:	-0.0337	-0.0058	-0.0057
Dulwich Hill			
Total Population in study area:	15862	15862	15862
total change	-5730.5	-5730.5	-5730.5
Population weighted Δx (μg/m^3):	-0.36127222	-0.36127222	-0.36127222
Increased number of cases in population:	-0.0707	-0.0121	-0.0119
Haberfield			
Total Population in study area:	13245	13245	13245
total change	-6871.4	-6871.4	-6871.4
Population weighted Δx (μg/m^3):	-0.51879200	-0.51879200	-0.51879200
Increased number of cases in population:	-0.0848	-0.0145	-0.0142
Balmain			
Total Population in study area:	14794	14794	14794
total change	-13395.7	-13395.7	-13395.7
Population weighted Δx (μg/m^3):	-0.90548195	-0.90548195	-0.90548195
Increased number of cases in population:	-0.1654	-0.0282	-0.0278
Leichardt			
Total Population in study area:	24443	24443	24443
total change	-20232.3	-20232.3	-20232.3
Population weighted Δx (μg/m^3):	-0.82773391	-0.82773391	-0.82773391
Increased number of cases in population:	-0.2498	-0.0427	-0.0419
Lilyfield			
Total Population in study area:	13073	13073	13073
total change	-12192.6	-12192.6	-12192.6
Population weighted Δx (μg/m^3):	-0.93265509	-0.93265509	-0.93265509
Increased number of cases in population:	-0.1505	-0.0257	-0.0253
Marrickville			
Total Population in study area:	24632	24632	24632
total change	-7771.6	-7771.6	-7771.6
Population weighted Δx (μg/m^3):	-0.31550828	-0.31550828	-0.31550828
Increased number of cases in population:	-0.0959	-0.0164	-0.0161
Petersham			
Total Population in study area:	18817	18817	18817
total change	-12803.4	-12803.4	-12803.4
Population weighted Δx (μg/m^3):	-0.68041664	-0.68041664	-0.68041664
Increased number of cases in population:	-0.1581	-0.0270	-0.0265
Sydenham			
Total Population in study area:	7204	7204	7204
total change	-3375.2	-3375.2	-3375.2
Population weighted Δx (μg/m^3):	-0.46851749	-0.46851749	-0.46851749
Increased number of cases in population:	-0.0417	-0.0071	-0.0070

Health Endpoint:	Mortality - All Causes (non-trauma), Short-term	Mortality - Respiratory, Short-term	Morbidity - Asthma ED Admissions - Short-term
Age Group:	≥ 30 years	All ages	1-14 years
β (change in effect per 1 μg/m^3 PM) (as per Table 6-15)	0.00188	0.00426	0.00115
Sydney LGA			
Total Population in study area:	125509	125509	125509
% population in assessment age-group:	59%	100%	6%
total change	-64526.4	-64526.4	-64526.4
Population weighted Δx (μg/m^3):	-0.51411771	-0.51411771	-0.51411771
Baseline Incidence (per 100,000) (as per Table 4-5)	977	49.4	1209.0
Baseline Incidence (per person)	0.00977	0.00049	0.01209
Relative Risk:	0.999034	0.997812	0.999409
Attributable fraction (AF):	-9.7E-04	-2.2E-03	-5.9E-04
Increased number of cases in population:	-0.70	-0.14	-0.056
Risk:	-9.4E-06	-1.1E-06	-7.1E-06
Individual suburbs within LGA			
Erskinville			
Total Population in study area:	13908	13908	13908
total change	-5814.8	-5814.8	-5814.8
Population weighted Δx (μg/m^3):	-0.41809031	-0.41809031	-0.41809031
Increased number of cases in population:	-0.0631	-0.0122	-0.0050
Glebe			
Total Population in study area:	16595	16595	16595
total change	-12136.4	-12136.4	-12136.4
Population weighted Δx (μg/m^3):	-0.73132871	-0.73132871	-0.73132871
Increased number of cases in population:	-0.1318	-0.0256	-0.0105
Newtown			
Total Population in study area:	21480	21480	21480
total change	-11815.1	-11815.1	-11815.1
Population weighted Δx (μg/m^3):	-0.55005121	-0.55005121	-0.55005121
Increased number of cases in population:	-0.1283	-0.0249	-0.0102
Pyrmont			
Total Population in study area:	18720	18720	18720
total change	-15627.3	-15627.3	-15627.3
Population weighted Δx (μg/m^3):	-0.83479167	-0.83479167	-0.83479167
Increased number of cases in population:	-0.1697	-0.0329	-0.0135
Redfern			
Total Population in study area:	12628	12628	12628
total change	-3898.5	-3898.5	-3898.5
Population weighted Δx (μg/m^3):	-0.30871872	-0.30871872	-0.30871872
Increased number of cases in population:	-0.0423	-0.0082	-0.0034
Surry Hills			
Total Population in study area:	4190	4190	4190
total change	-1886.2	-1886.2	-1886.2
Population weighted Δx (μg/m^3):	-0.45016706	-0.45016706	-0.45016706
Increased number of cases in population:	-0.0205	-0.0040	-0.0016
Sydney			
Total Population in study area:	21726	21726	21726
total change	-6940.6	-6940.6	-6940.6
Population weighted Δx (μg/m^3):	-0.31946055	-0.31946055	-0.31946055
Increased number of cases in population:	-0.0753	-0.0146	-0.0060
Waterloo			
Total Population in study area:	11306	11306	11306
total change	-4669.4	-4669.4	-4669.4
Population weighted Δx (μg/m^3):	-0.41300195	-0.41300195	-0.41300195
Increased number of cases in population:	-0.0507	-0.0098	-0.0040
Crows Nest			
Total Population in study area:	50	50	50
total change	-72.3	-72.3	-72.3
Population weighted Δx (μg/m^3):	-1.44600000	-1.44600000	-1.44600000
Increased number of cases in population:	-0.00079	-0.00015	-0.000062
North Sydney			
Total Population in study area:	4906	4906	4906
total change	-1665.8	-1665.8	-1665.8
Population weighted Δx (μg/m^3):	-0.33954342	-0.33954342	-0.33954342
Increased number of cases in population:	-0.0181	-0.0035	-0.0014

Health Endpoint:	Mortality - All Causes (non-trauma), Short-term	Mortality - Respiratory, Short-term	Morbidity - Asthma ED Admissions - Short-term
Age Group:	≥ 30 years	All ages	1-14 years
β (change in effect per 1 μg/m^3 PM) (as per Table 6-15)	0.00188	0.00426	0.00115
Botany LGA			
Total Population in study area:	25700	25700	25700
% population in assessment age-group:	62%	100%	17%
total change	-1953.4	-1953.4	-1953.4
Population weighted Δx (μg/m^3):	-0.07600778	-0.07600778	-0.07600778
Baseline Incidence (per 100,000) (as per Table 4-5)	977	49.4	1209.0
Baseline Incidence (per person)	0.00977	0.00049	0.01209
Relative Risk:	0.999857	0.999676	0.999913
Attributable fraction (AF):	-1.4E-04	-3.2E-04	-8.7E-05
Increased number of cases in population:	-0.022	-0.0041	-0.0046
Risk:	-1.4E-06	-1.6E-07	-1.1E-06
Individual suburbs within LGA			
Botany			
Total Population in study area:	8915	8915	8915
total change	1019.1	1019.1	1019.1
Population weighted Δx (μg/m^3):	0.11431296	0.11431296	0.11431296
Increased number of cases in population:	0.0115	0.0021	0.0024
Mascot			
Total Population in study area:	16215	16215	16215
total change	-2869.2	-2869.2	-2869.2
Population weighted Δx (μg/m^3):	-0.17694727	-0.17694727	-0.17694727
Increased number of cases in population:	-0.0325	-0.0060	-0.0067
Pagewood			
Total Population in study area:	567	567	567
total change	-104.5	-104.5	-104.5
Population weighted Δx (μg/m^3):	-0.18430335	-0.18430335	-0.18430335
Increased number of cases in population:	-0.0012	-0.0002	-0.0002

Health Endpoint:	Mortality - All Causes (non-trauma), Short-term	Mortality - Respiratory, Short-term	Morbidity - Asthma ED Admissions - Short-term
Age Group:	≥ 30 years	All ages	1-14 years
β (change in effect per 1 µg/m³ PM) (as per Table 6-15)	0.00188	0.00426	0.00115
Rockdale LGA			
Total Population in study area:	82293	82293	82293
% population in assessment age-group:	62%	100%	16%
total change	-31761.8	-31761.8	-31761.8
Population weighted Δx (µg/m³):	-0.38595992	-0.38595992	-0.38595992
Baseline Incidence (per 100,000) (as per Table 4-5)	977	49.4	1209.0
Baseline Incidence (per person)	0.00977	0.00049	0.01209
Relative Risk:	0.999275	0.998357	0.999556
Attributable fraction (AF):	-7.3E-04	-1.6E-03	-4.4E-04
Increased number of cases in population:	-0.36	-0.067	-0.071
Risk:	-7.1E-06	-8.1E-07	-5.4E-06
Individual suburbs within LGA			
Arncliffe			
Total Population in study area:	14669	14669	14669
total change	-7255.2	-7255.2	-7255.2
Population weighted Δx (µg/m³):	-0.49459404	-0.49459404	-0.49459404
Increased number of cases in population:	-0.0822	-0.0153	-0.0161
Bexley			
Total Population in study area:	25123	25123	25123
total change	-7730.5	-7730.5	-7730.5
Population weighted Δx (µg/m³):	-0.30770609	-0.30770609	-0.30770609
Increased number of cases in population:	-0.0876	-0.0163	-0.0172
Kingsgrove - South			
Total Population in study area:	11981	11981	11981
total change	-4415.6	-4415.6	-4415.6
Population weighted Δx (µg/m³):	-0.36855020	-0.36855020	-0.36855020
Increased number of cases in population:	-0.0500	-0.0093	-0.0098
Monterey			
Total Population in study area:	12192	12192	12192
total change	-4840.6	-4840.6	-4840.6
Population weighted Δx (µg/m³):	-0.39703084	-0.39703084	-0.39703084
Increased number of cases in population:	-0.0548	-0.0102	-0.0108
Rockdale			
Total Population in study area:	18328	18328	18328
total change	-7519.9	-7519.9	-7519.9
Population weighted Δx (µg/m³):	-0.41029572	-0.41029572	-0.41029572
Increased number of cases in population:	-0.0852	-0.0158	-0.0167

Health Endpoint:	Mortality - All Causes (non-trauma), Short-term	Mortality - Respiratory, Short-term	Morbidity - Asthma ED Admissions - Short-term
Age Group:	≥ 30 years	All ages	1-14 years
β (change in effect per 1 μg/m^3 PM) (as per Table 6-15)	0.00188	0.00426	0.00115
Canterbury - Bankstown LGA			
Total Population in study area:	76834	76834	76834
% population in assessment age-group:	58%	100%	19%
total change	-18619.7	-18619.7	-18619.7
Population weighted Δx (μg/m^3):	-0.24233673	-0.24233673	-0.24233673
Baseline Incidence (per 100,000) (as per Table 4-5)	977	49.4	1209.0
Baseline Incidence (per person)	0.00977	0.00049	0.01209
Relative Risk:	0.999545	0.998968	0.999721
Attributable fraction (AF):	-4.6E-04	-1.0E-03	-2.8E-04
Increased number of cases in population:	-0.20	-0.039	-0.050
Risk:	-4.4E-06	-5.1E-07	-3.4E-06
Individual suburbs within LGA			
Belmore			
Total Population in study area:	18330	18330	18330
total change	-4739.3	-4739.3	-4739.3
Population weighted Δx (μg/m^3):	-0.25855428	-0.25855428	-0.25855428
Increased number of cases in population:	-0.0506	-0.0100	-0.0127
Canterbury (South)			
Total Population in study area:	26841	26841	26841
total change	-5816.3	-5816.3	-5816.3
Population weighted Δx (μg/m^3):	-0.21669461	-0.21669461	-0.21669461
Increased number of cases in population:	-0.0622	-0.0122	-0.0155
Kinsgrove - North			
Total Population in study area:	22489	22489	22489
total change	-5179.9	-5179.9	-5179.9
Population weighted Δx (μg/m^3):	-0.23033038	-0.23033038	-0.23033038
Increased number of cases in population:	-0.0554	-0.0109	-0.0138
Lakemba			
Total Population in study area:	3643	3643	3643
total change	-888.7	-888.7	-888.7
Population weighted Δx (μg/m^3):	-0.24394730	-0.24394730	-0.24394730
Increased number of cases in population:	-0.0095	-0.0019	-0.0024
Roselands			
Total Population in study area:	5531	5531	5531
total change	-1995.5	-1995.5	-1995.5
Population weighted Δx (μg/m^3):	-0.36078467	-0.36078467	-0.36078467
Increased number of cases in population:	-0.0213	-0.0042	-0.0053

Health Endpoint:	Mortality - All Causes (non-trauma), Short-term	Mortality - Respiratory, Short-term	Morbidity - Asthma ED Admissions - Short-term
Age Group:	≥ 30 years	All ages	1-14 years
β (change in effect per 1 µg/m^3 PM) (as per Table 6-15)	0.00188	0.00426	0.00115
Georges River LGA			
Total Population in study area:	66896	66896	66896
% population in assessment age-group:	61%	100%	16%
total change	-13393.5	-13393.5	-13393.5
Population weighted Δx (µg/m^3):	-0.20021376	-0.20021376	-0.20021376
Baseline Incidence (per 100,000) (as per Table 4.4)	977	49.4	1209.0
Baseline Incidence (per person)	0.00977	0.00049	0.01209
Relative Risk:	0.999624	0.999147	0.999770
Attributable fraction (AF):	-3.8E-04	-8.5E-04	-2.3E-04
Increased number of cases in population:	-0.15	-0.028	-0.031
Risk:	-3.7E-06	-4.2E-07	-2.8E-06
Hurstville			
Total Population in study area:	20164	20164	20164
total change	-3712	-3712	-3712
Population weighted Δx (µg/m^3):	-0.18409046	-0.18409046	-0.18409046
Increased number of cases in population:	-0.0417	-0.0078	-0.0085
Kogorah			
Total Population in study area:	9484	9484	9484
total change	-2573	-2573	-2573
Population weighted Δx (µg/m^3):	-0.27129903	-0.27129903	-0.27129903
Increased number of cases in population:	-0.0289	-0.0054	-0.0059
Kogorah Bay			
Total Population in study area:	9469	9469	9469
total change	-878.9	-878.9	-878.9
Population weighted Δx (µg/m^3):	-0.09281867	-0.09281867	-0.09281867
Increased number of cases in population:	-0.0099	-0.0018	-0.0020
Mortdale			
Total Population in study area:	11002	11002	11002
total change	-2024.3	-2024.3	-2024.3
Population weighted Δx (µg/m^3):	-0.18399382	-0.18399382	-0.18399382
Increased number of cases in population:	-0.0227	-0.0043	-0.0046
Narwee			
Total Population in study area:	4884	4884	4884
total change	-1488.6	-1488.6	-1488.6
Population weighted Δx (µg/m^3):	-0.30479115	-0.30479115	-0.30479115
Increased number of cases in population:	-0.0167	-0.0031	-0.0034
Oatley			
Total Population in study area:	4322	4322	4322
total change	-2067.5	-2067.5	-2067.5
Population weighted Δx (µg/m^3):	-0.47836650	-0.47836650	-0.47836650
Increased number of cases in population:	-0.0232	-0.0044	-0.0047
South Hurstville			
Total Population in study area:	7571	7571	7571
total change	-649.2	-649.2	-649.2
Population weighted Δx (µg/m^3):	-0.08574825	-0.08574825	-0.08574825
Increased number of cases in population:	-0.0073	-0.0014	-0.0015
Total population incidence - All Suburbs	**-3**	**-0.5**	**-0.4**

Annexure F – Risk calculations: Particulate matter

Quantification of Effects - $PM_{2.5}$ and PM_{10}
M4-M5 Link: 2023

Air quality indicator:				$PM_{2.5}$	$PM_{2.5}$	$PM_{2.5}$	PM_{10}	$PM_{2.5}$	$PM_{2.5}$	$PM_{2.5}$	$PM_{2.5}$	$PM_{2.5}$	DPM
Endpoint:				**Mortality - All Causes**	**Hospitalisations - Cardiovascular**	**Hospitalisations - Respiratory**	**Mortality - All Causes**	**Mortality - All Causes**	**Mortality - Cardiopulmonary**	**Mortality - Cardiovascular**	**Mortality - Respiratory**	**Morbidity - Asthma ED Admissions**	**Increased risk - lung cancer**
Effect Exposure Duration:				Long-term	Short-term	Short-term	Short-Term	Short-Term	Long-term	Short-Term	Short-Term	Short-Term	Based on WHO
Age Group:				≥ 30 years	≥ 65 years	≥ 65 years	All ages	All ages	≥ 30 years	All ages	All ages	1-14 years	inhalation unit risk
β (change in effect per 1 μg/m³) (as per Table 6-22)				0.0058	0.0008	0.00041	0.0006	0.00094	0.013	0.00097	0.0019	0.00148	3.40E-05
Annual Baseline Incidence (as per Table 4-5)													(ug/m3)-1
Annual baseline incidence (per 100,000)				1026	9235	3978	493	493	412	134.7	49.4	1209	
Baseline Incidence (per person per year)				0.01026	0.09235	0.03978	0.00493	0.00493	0.00412	0.001347	0.000494	0.01209	
Sensitive Receptors		**Change in Annual Average PM10 Concentration (μg/m³)**	**Change in Annual Average PM2.5 Concentration (μg/m³)**	**Risk**	**Risk**	**Risk**	**Risk**	**Risk**	**Risk**	**Risk**	**Risk**	**Risk**	**Risk**
Impacts from tunnel ventilation outlets													
Grid receptors: maximum regardless of landuse		**1.86**	**1.16**	**7E-05**	**9E-05**	**2E-05**	**6E-06**	**5E-06**	**6E-05**	**2E-06**	**1E-06**	**2E-05**	**4E-05**
Grid receptors: maximum residential		**0.85**	**0.51**	**3E-05**	**4E-05**	**8E-06**	**3E-06**	**2E-06**	**3E-05**	**7E-07**	**5E-07**	**9E-06**	**2E-05**
Grid receptors: maximum childcare		**0.33**	**0.43**	**3E-05**	**3E-05**	**7E-06**	**1E-06**	**2E-06**	**2E-05**	**6E-07**	**4E-07**	**8E-06**	**1E-05**
Grid receptors: maximum school		**0.29**	**0.12**	**7E-06**	**9E-06**	**2E-06**	**9E-07**	**6E-07**	**6E-06**	**2E-07**	**1E-07**	**2E-06**	**4E-06**
Grid receptors: maximum aged care		**0.06**	**0.06**	**4E-06**	**4E-06**	**1E-06**	**2E-07**	**3E-07**	**3E-06**	**8E-08**	**6E-08**	**1E-06**	**2E-06**
Grid receptors: maximum hospital and medical		**0.69**	**0.20**	**1E-05**	**1E-05**	**3E-06**	**2E-06**	**9E-07**	**1E-05**	**3E-07**	**2E-07**	**4E-06**	**7E-06**
Grid receptors: commercial/industrial		**1.70**	**1.16**	**7E-05**	**9E-05**	**2E-05**	**5E-06**	**5E-06**	**6E-05**	**2E-06**	**1E-06**	**2E-05**	**4E-05**
Grid receptors: open space		**1.24**	**0.78**	**5E-05**	**6E-05**	**1E-05**	**4E-06**	**4E-06**	**4E-05**	**1E-06**	**7E-07**	**1E-05**	**3E-05**
Community Receptors													
The Jimmy Little Community Centre	Community	-0.1409	-0.0692	-4E-06	-5E-06	-1E-06	-4E-07	-3E-07	-4E-06	-9E-08	-6E-08	-1E-06	**-2E-06**
Balmain Cove Early Learning Centre	Child care	-0.1485	0.0171	1E-06	1E-06	3E-07	-4E-07	8E-08	9E-07	2E-08	2E-08	3E-07	**6E-07**
Rosebud Cottage Child Care Centre	Child care	-0.8114	-0.6042	-4E-05	-4E-05	-1E-05	-2E-06	-3E-06	-3E-05	-8E-07	-6E-07	-1E-05	**-2E-05**
Sydney Community College	School/education	-0.2478	-0.0996	-6E-06	-7E-06	-2E-06	-7E-07	-5E-07	-5E-06	-1E-07	-9E-08	-2E-06	**-3E-06**
Rozelle Total Health	Health	-0.1623	-0.1233	-7E-06	-9E-06	-2E-06	-5E-07	-6E-07	-7E-06	-2E-07	-1E-07	-2E-06	**-4E-06**
Laurel Tree House Child Care Centre	Child care	-0.0989	0.0936	6E-06	7E-06	2E-06	-3E-07	4E-07	5E-06	1E-07	9E-08	2E-06	**3E-06**
Bridge Road School	School	-0.4070	-0.1628	-1E-05	-1E-05	-3E-06	-1E-06	-8E-07	-9E-06	-2E-07	-2E-07	-3E-06	**-6E-06**
NHMRC Clinical Trials Centre	Health	-0.2670	-0.2266	-1E-05	-2E-05	-4E-06	-8E-07	-1E-06	-1E-05	-3E-07	-2E-07	-4E-06	**-8E-06**
Annandale Public School	School	-0.0388	0.0104	6E-07	8E-07	2E-07	-1E-07	5E-08	6E-07	1E-08	1E-08	2E-07	**4E-07**
The University of Notre Dame Australia, Broadway	School/education	-0.4861	-0.2226	-1E-05	-2E-05	-4E-06	-1E-06	-1E-06	-1E-05	-3E-07	-2E-07	-4E-06	**-8E-06**
Laverty Pathology Annandale	Health	-0.2035	-0.0334	-2E-06	-2E-06	-5E-07	-6E-07	-2E-07	-2E-06	-4E-08	-3E-08	-6E-07	**-1E-06**
Little VIP's Child Care Centre	Child care	-0.3057	0.1529	9E-06	1E-05	2E-06	-9E-07	7E-07	8E-06	2E-07	1E-07	3E-06	**5E-06**
Dobroyd Point Public School	School	-0.0443	-0.0890	-5E-06	-7E-06	-1E-06	-1E-07	-4E-07	-5E-06	-1E-07	-8E-08	-2E-06	**-3E-06**
Peek A Boo Early Learning Centre Haberfield	Child care	-0.3562	-0.1873	-1E-05	-1E-05	-3E-06	-1E-06	-9E-07	-1E-05	-2E-07	-2E-07	-3E-06	**-6E-06**
Rozelle CCC	Child care	-0.0402	-0.1965	-1E-05	-1E-05	-3E-06	-1E-07	-9E-07	-1E-05	-3E-07	-2E-07	-4E-06	**-7E-06**
Sydney Secondary College Leichhardt Campus	School - Secondary	-0.4164	-0.0581	-3E-06	-4E-06	-9E-07	-1E-06	-3E-07	-3E-06	-8E-08	-5E-08	-1E-06	**-2E-06**
Rose Cottage Child Care Centre	Child care	0.0051	-0.1079	-6E-06	-8E-06	-2E-06	2E-08	-5E-07	-6E-06	-1E-07	-1E-07	-2E-06	**-4E-06**
Inner Sydney Montessori - Lilyfield	School	-0.1495	-0.1540	-9E-06	-1E-05	-3E-06	-4E-07	-7E-07	-8E-06	-2E-07	-1E-07	-3E-06	**-5E-06**
Leichhardt Little Stars Nursery & Early Learning Centre	Child care	0.0090	-0.1179	-7E-06	-9E-06	-2E-06	3E-08	-5E-07	-6E-06	-2E-07	-1E-07	-2E-06	**-4E-06**
Leichhardt Montessori Academy	School	-0.1404	-0.0302	-2E-06	-2E-06	-5E-07	-4E-07	-1E-07	-2E-06	-4E-08	-3E-08	-5E-07	**-1E-06**
St Basil's Sister Dorothea Village	Aged care	-0.0701	-0.0874	-5E-06	-6E-06	-1E-06	-2E-07	-4E-07	-5E-06	-1E-07	-8E-08	-2E-06	**-3E-06**
St Thomas Child Care Centre	Child care	-0.8999	-0.7683	-5E-05	-6E-05	-1E-05	-3E-06	-4E-06	-4E-05	-1E-06	-7E-07	-1E-05	**-3E-05**
Billy Kids Lilyfield Early Learning Centre	Child care	-0.8823	-0.7042	-4E-05	-5E-05	-1E-05	-3E-06	-3E-06	-4E-05	-9E-07	-7E-07	-1E-05	**-2E-05**
Little Learning School - Alexandria	Child care	0.0181	-0.0497	-3E-06	-4E-06	-8E-07	5E-08	-2E-07	-3E-06	-6E-08	-5E-08	-9E-07	**-2E-06**
Newtown Public School Combined OSHC	School	0.0302	-0.0640	-4E-06	-5E-06	-1E-06	9E-08	-3E-07	-3E-06	-8E-08	-6E-08	-1E-06	**-2E-06**
The Athena School	School	-0.2528	-0.1649	-1E-05	-1E-05	-3E-06	-7E-07	-8E-07	-9E-06	-2E-07	-2E-07	-3E-06	**-6E-06**
Camdenville Public School	School	0.1395	0.0534	3E-06	4E-06	9E-07	4E-07	2E-07	3E-06	7E-08	5E-08	1E-06	**2E-06**
St Joan of Arc Home for the Aged	Aged care	-0.0864	-0.0668	-4E-06	-5E-06	-1E-06	-3E-07	-3E-07	-4E-06	-9E-08	-6E-08	-1E-06	**-2E-06**
Inner West Education Centre	School	-0.3920	-0.0097	-6E-07	-7E-07	-2E-07	-1E-06	-5E-08	-5E-07	-1E-08	-9E-09	-2E-07	**-3E-07**
St Peters Community Pre-school	School	-0.0344	0.0689	4E-06	5E-06	1E-06	-1E-07	3E-07	4E-06	9E-08	6E-08	1E-06	**2E-06**

Quantification of Effects - $PM_{2.5}$ and PM_{10}
M4-M5 Link: 2023 - Cumulative

Air quality indicator:				$PM_{2.5}$	$PM_{2.5}$	$PM_{2.5}$	PM_{10}	$PM_{2.5}$	$PM_{2.5}$	$PM_{2.5}$	$PM_{2.5}$	$PM_{2.5}$	DPM
Endpoint:				**Mortality - All Causes**	**Hospitalisations - Cardiovascular**	**Hospitalisations - Respiratory**	**Mortality - All Causes**	**Mortality - All Causes**	**Mortality - Cardiopulmonary**	**Mortality - Cardiovascular**	**Mortality - Respiratory**	**Morbidity - Asthma ED Admissions**	**Increased risk - lung cancer**
Effect Exposure Duration:				Long-term	Short-term	Short-term	Short-Term	Short-Term	Long-term	Short-Term	Short-Term	Short-Term	Based on WHO
Age Group:				≥ 30 years	≥ 65 years	≥ 65 years	All ages	All ages	≥ 30 years	All ages	All ages	1-14 years	inhalation unit risk
β (change in effect per 1 µg/m³) (as per Table 6-22)				0.0058	0.0008	0.00041	0.0006	0.00094	0.013	0.00097	0.0019	0.00148	3.40E-05
Annual Baseline Incidence (as per Table 4-5)													(ug/m3)-1
Annual baseline incidence (per 100,000)				1026	9235	3978	493	493	412	134.7	49.4	1209	
Baseline Incidence (per person per year)				0.01026	0.09235	0.03978	0.00493	0.00493	0.00412	0.001347	0.000494	0.01209	
Sensitive Receptors		**Change in Annual Average PM10 Concentration (µg/m³)**	**Change in Annual Average PM2.5 Concentration (µg/m³)**	**Risk**	**Risk**	**Risk**	**Risk**	**Risk**	**Risk**	**Risk**	**Risk**	**Risk**	**Risk**
Impacts from tunnel ventilation outlets													
Grid receptors: maximum regardless of landuse		**3.36**	**2.25**	**1E-04**	**2E-04**	**4E-05**	**1E-05**	**1E-05**	**1E-04**	**3E-06**	**2E-06**	**4E-05**	**8E-05**
Grid receptors: maximum residential		**0.94**	**0.62**	**4E-05**	**5E-05**	**1E-05**	**3E-06**	**3E-06**	**3E-05**	**8E-07**	**6E-07**	**1E-05**	**2E-05**
Grid receptors: maximum childcare		**0.36**	**0.26**	**2E-05**	**2E-05**	**4E-06**	**1E-06**	**1E-06**	**1E-05**	**3E-07**	**2E-07**	**5E-06**	**9E-06**
Grid receptors: maximum school		**0.26**	**0.15**	**9E-06**	**1E-05**	**2E-06**	**8E-07**	**7E-07**	**8E-06**	**2E-07**	**1E-07**	**3E-06**	**5E-06**
Grid receptors: maximum aged care		**0.10**	**0.08**	**5E-06**	**6E-06**	**1E-06**	**3E-07**	**4E-07**	**4E-06**	**1E-07**	**8E-08**	**1E-06**	**3E-06**
Grid receptors: maximum hospital and medical		**0.23**	**0.12**	**7E-06**	**9E-06**	**2E-06**	**7E-07**	**6E-07**	**6E-06**	**2E-07**	**1E-07**	**2E-06**	**4E-06**
Grid receptors: commercial/industrial		**3.36**	**2.25**	**1E-04**	**2E-04**	**4E-05**	**1E-05**	**1E-05**	**1E-04**	**3E-06**	**2E-06**	**4E-05**	**8E-05**
Grid receptors: open space		**1.05**	**0.54**	**3E-05**	**4E-05**	**9E-06**	**3E-06**	**3E-06**	**3E-05**	**7E-07**	**5E-07**	**1E-05**	**2E-05**
Community Receptors													
The Jimmy Little Community Centre	Community	-0.0444	0.0868	5E-06	6E-06	1E-06	-1E-07	4E-07	5E-06	1E-07	8E-08	2E-06	**3E-06**
Balmain Cove Early Learning Centre	Child care	0.0918	-0.0015	-9E-08	-1E-07	-2E-08	3E-07	-7E-09	-8E-08	-2E-09	-1E-09	-3E-08	**-5E-08**
Rosebud Cottage Child Care Centre	Child care	-0.9091	-0.6921	-4E-05	-5E-05	-1E-05	-3E-06	-3E-06	-4E-05	-9E-07	-6E-07	-1E-05	**-2E-05**
Sydney Community College	School/education	-0.2487	-0.0625	-4E-06	-5E-06	-1E-06	-7E-07	-3E-07	-3E-06	-8E-08	-6E-08	-1E-06	**-2E-06**
Rozelle Total Health	Health	-0.1847	-0.0229	-1E-06	-2E-06	-4E-07	-5E-07	-1E-07	-1E-06	-3E-08	-2E-08	-4E-07	**-8E-07**
Laurel Tree House Child Care Centre	Child care	0.0095	-0.0052	-3E-07	-4E-07	-9E-08	3E-08	-2E-08	-3E-07	-7E-09	-5E-09	-9E-08	**-2E-07**
Bridge Road School	School	-0.1372	-0.3179	-2E-05	-2E-05	-5E-06	-4E-07	-1E-06	-2E-05	-4E-07	-3E-07	-6E-06	**-1E-05**
NHMRC Clinical Trials Centre	Health	-0.2458	-0.1246	-7E-06	-9E-06	-2E-06	-7E-07	-6E-07	-7E-06	-2E-07	-1E-07	-2E-06	**-4E-06**
Annandale Public School	School	-0.1061	-0.0105	-6E-07	-8E-07	-2E-07	-3E-07	-5E-08	-6E-07	-1E-08	-1E-08	-2E-07	**-4E-07**
The University of Notre Dame Australia, Broadway	School/education	-0.4865	-0.2291	-1E-05	-2E-05	-4E-06	-1E-06	-1E-06	-1E-05	-3E-07	-2E-07	-4E-06	**-8E-06**
Laverty Pathology Annandale	Health	-0.0888	-0.1211	-7E-06	-9E-06	-2E-06	-3E-07	-6E-07	-6E-06	-2E-07	-1E-07	-2E-06	**-4E-06**
Little VIP's Child Care Centre	Child care	-0.1385	0.1079	6E-06	8E-06	2E-06	-4E-07	5E-07	6E-06	1E-07	1E-07	2E-06	**4E-06**
Dobroyd Point Public School	School	-0.0110	-0.1481	-9E-06	-1E-05	-2E-06	-3E-08	-7E-07	-8E-06	-2E-07	-1E-07	-3E-06	**-5E-06**
Peek A Boo Early Learning Centre Haberfield	Child care	-0.1045	-0.2470	-1E-05	-2E-05	-4E-06	-3E-07	-1E-06	-1E-05	-3E-07	-2E-07	-4E-06	**-8E-06**
Rozelle CCC	Child care	0.1039	-0.0482	-3E-06	-4E-06	-8E-07	3E-07	-2E-07	-3E-06	-6E-08	-5E-08	-9E-07	**-2E-06**
Sydney Secondary College Leichhardt Campus	School - Secondary	-0.4412	0.0831	5E-06	6E-06	1E-06	-1E-06	4E-07	4E-06	1E-07	8E-08	1E-06	**3E-06**
Rose Cottage Child Care Centre	Child care	0.0083	-0.2129	-1E-05	-2E-05	-3E-06	2E-08	-1E-06	-1E-05	-3E-07	-2E-07	-4E-06	**-7E-06**
Inner Sydney Montessori - Lilyfield	School	-0.1450	-0.0600	-4E-06	-4E-06	-1E-06	-4E-07	-3E-07	-3E-06	-8E-08	-6E-08	-1E-06	**-2E-06**
Leichhardt Little Stars Nursery & Early Learning Centre	Child care	0.0143	-0.0788	-5E-06	-6E-06	-1E-06	4E-08	-4E-07	-4E-06	-1E-07	-7E-08	-1E-06	**-3E-06**
Leichhardt Montessori Academy	School	-0.2025	-0.0997	-6E-06	-7E-06	-2E-06	-6E-07	-5E-07	-5E-06	-1E-07	-9E-08	-2E-06	**-3E-06**
St Basil's Sister Dorothea Village	Aged care	-0.0408	-0.0957	-6E-06	-7E-06	-2E-06	-1E-07	-4E-07	-5E-06	-1E-07	-9E-08	-2E-06	**-3E-06**
St Thomas Child Care Centre	Child care	-0.7384	-0.6637	-4E-05	-5E-05	-1E-05	-2E-06	-3E-06	-4E-05	-9E-07	-6E-07	-1E-05	**-2E-05**
Billy Kids Lilyfield Early Learning Centre	Child care	-1.0373	-0.7501	-4E-05	-6E-05	-1E-05	-3E-06	-3E-06	-4E-05	-1E-06	-7E-07	-1E-05	**-3E-05**
Little Learning School - Alexandria	Child care	-0.0745	0.1304	8E-06	1E-05	2E-06	-2E-07	6E-07	7E-06	2E-07	1E-07	2E-06	**4E-06**
Newtown Public School Combined OSHC	School	0.1428	-0.0439	-3E-06	-3E-06	-7E-07	4E-07	-2E-07	-2E-06	-6E-08	-4E-08	-8E-07	**-1E-06**
The Athena School	School	-0.2336	-0.1390	-8E-06	-1E-05	-2E-06	-7E-07	-6E-07	-7E-06	-2E-07	-1E-07	-2E-06	**-5E-06**
Camdenville Public School	School	0.1428	0.0788	5E-06	6E-06	1E-06	4E-07	4E-07	4E-06	1E-07	7E-08	1E-06	**3E-06**
St Joan of Arc Home for the Aged	Aged care	-0.1663	-0.0585	-3E-06	-4E-06	-1E-06	-5E-07	-3E-07	-3E-06	-8E-08	-5E-08	-1E-06	**-2E-06**
Inner West Education Centre	School	-0.0829	0.0881	5E-06	7E-06	1E-06	-2E-07	4E-07	5E-06	1E-07	8E-08	2E-06	**3E-06**
St Peters Community Pre-school	School	0.1121	0.1758	1E-05	1E-05	3E-06	3E-07	8E-07	9E-06	2E-07	2E-07	3E-06	**6E-06**

Quantification of Effects - $PM_{2.5}$ and PM_{10}
M4-M5 Link: 2033

Air quality indicator:				$PM_{2.5}$	$PM_{2.5}$	$PM_{2.5}$	PM_{10}	$PM_{2.5}$	$PM_{2.5}$	$PM_{2.5}$	$PM_{2.5}$	$PM_{2.5}$	DPM
Endpoint:				Mortality - All Causes	Hospitalisations - Cardiovascular	Hospitalisations - Respiratory	Mortality - All Causes	Mortality - All Causes	Mortality - Cardiopulmonary	Mortality - Cardiovascular	Mortality - Respiratory	Morbidity - Asthma ED Admissions	Increased risk - lung cancer
Effect Exposure Duration:				Long-term	Short-term	Short-term	Short-Term	Short-Term	Long-term	Short-Term	Short-Term	Short-Term	Based on WHO
Age Group:				≥ 30 years	≥ 65 years	≥ 65 years	All ages	All ages	≥ 30 years	All ages	All ages	1-14 years	inhalation unit risk
β (change in effect per 1 µg/m³) (as per Table 6-22)				0.0058	0.0008	0.00041	0.0006	0.00094	0.013	0.00097	0.0019	0.00148	3.40E-05
Annual Baseline Incidence (as per Table 4-5)													(ug/m3)-1
Annual baseline incidence (per 100,000)				1026	9235	3978	493	493	412	134.7	49.4	1209	
Baseline Incidence (per person per year)				0.01026	0.09235	0.03978	0.00493	0.00493	0.00412	0.001347	0.000494	0.01209	
Sensitive Receptors		**Change in Annual Average PM10 Concentration (µg/m³)**	**Change in Annual Average PM2.5 Concentration (µg/m³)**	**Risk**	**Risk**	**Risk**	**Risk**	**Risk**	**Risk**	**Risk**	**Risk**	**Risk**	**Risk**
Impacts from tunnel ventilation outlets													
Grid receptors: maximum regardless of landuse		**1.94**	**1.43**	**9E-05**	**1E-04**	**2E-05**	**6E-06**	**7E-06**	**8E-05**	**2E-06**	**1E-06**	**3E-05**	**5E-05**
Grid receptors: maximum residential		**1.12**	**0.56**	**3E-05**	**4E-05**	**9E-06**	**3E-06**	**3E-06**	**3E-05**	**7E-07**	**5E-07**	**1E-05**	**2E-05**
Grid receptors: maximum childcare		**0.67**	**0.39**	**2E-05**	**3E-05**	**6E-06**	**2E-06**	**2E-06**	**2E-05**	**5E-07**	**4E-07**	**7E-06**	**1E-05**
Grid receptors: maximum school		**0.37**	**0.15**	**9E-06**	**1E-05**	**2E-06**	**1E-06**	**7E-07**	**8E-06**	**2E-07**	**1E-07**	**3E-06**	**5E-06**
Grid receptors: maximum aged care		**0.11**	**0.11**	**7E-06**	**8E-06**	**2E-06**	**3E-07**	**5E-07**	**6E-06**	**1E-07**	**1E-07**	**2E-06**	**4E-06**
Grid receptors: maximum hospital and medical		**0.42**	**0.33**	**2E-05**	**2E-05**	**5E-06**	**1E-06**	**2E-06**	**2E-05**	**4E-07**	**3E-07**	**6E-06**	**1E-05**
Grid receptors: commercial/industrial		**1.94**	**1.43**	**9E-05**	**1E-04**	**2E-05**	**6E-06**	**7E-06**	**8E-05**	**2E-06**	**1E-06**	**3E-05**	**5E-05**
Grid receptors: open space		**1.40**	**0.83**	**5E-05**	**6E-05**	**1E-05**	**4E-06**	**4E-06**	**4E-05**	**1E-06**	**8E-07**	**1E-05**	**3E-05**
Community Receptors													
The Jimmy Little Community Centre	Community	-0.0421	-0.0251	-1E-06	-2E-06	-4E-07	-1E-07	-1E-07	-1E-06	-3E-08	-2E-08	-4E-07	**-9E-07**
Balmain Cove Early Learning Centre	Child care	-0.0829	-0.0527	-3E-06	-4E-06	-9E-07	-2E-07	-2E-07	-3E-06	-7E-08	-5E-08	-9E-07	**-2E-06**
Rosebud Cottage Child Care Centre	Child care	-0.7968	-0.3290	-2E-05	-2E-05	-5E-06	-2E-06	-2E-06	-2E-05	-4E-07	-3E-07	-6E-06	**-1E-05**
Sydney Community College	School/education	-0.1776	-0.2660	-2E-05	-2E-05	-4E-06	-5E-07	-1E-06	-1E-05	-3E-07	-2E-07	-5E-06	**-9E-06**
Rozelle Total Health	Health	-0.2659	-0.0085	-5E-07	-6E-07	-1E-07	-8E-07	-4E-08	-5E-07	-1E-08	-8E-09	-2E-07	**-3E-07**
Laurel Tree House Child Care Centre	Child care	-0.1689	-0.2128	-1E-05	-2E-05	-3E-06	-5E-07	-1E-06	-1E-05	-3E-07	-2E-07	-4E-06	**-7E-06**
Bridge Road School	School	-0.1854	-0.2063	-1E-05	-2E-05	-3E-06	-5E-07	-1E-06	-1E-05	-3E-07	-2E-07	-4E-06	**-7E-06**
NHMRC Clinical Trials Centre	Health	-0.3139	-0.2645	-2E-05	-2E-05	-4E-06	-9E-07	-1E-06	-1E-05	-3E-07	-2E-07	-5E-06	**-9E-06**
Annandale Public School	School	-0.3387	-0.0839	-5E-06	-6E-06	-1E-06	-1E-06	-4E-07	-4E-06	-1E-07	-8E-08	-2E-06	**-3E-06**
The University of Notre Dame Australia, Broadway	School/education	0.2261	0.1220	7E-06	9E-06	2E-06	7E-07	6E-07	7E-06	2E-07	1E-07	2E-06	**4E-06**
Laverty Pathology Annandale	Health	-0.1955	-0.0220	-1E-06	-2E-06	-4E-07	-6E-07	-1E-07	-1E-06	-3E-08	-2E-08	-4E-07	**-7E-07**
Little VIP's Child Care Centre	Child care	0.0078	0.0172	1E-06	1E-06	3E-07	2E-08	8E-08	9E-07	2E-08	2E-08	3E-07	**6E-07**
Dobroyd Point Public School	School	-0.0414	-0.0838	-5E-06	-6E-06	-1E-06	-1E-07	-4E-07	-4E-06	-1E-07	-8E-08	-1E-06	**-3E-06**
Peek A Boo Early Learning Centre Haberfield	Child care	-0.2257	-0.2007	-1E-05	-1E-05	-3E-06	-7E-07	-9E-07	-1E-05	-3E-07	-2E-07	-4E-06	**-7E-06**
Rozelle CCC	Child care	0.1442	-0.0397	-2E-06	-3E-06	-6E-07	4E-07	-2E-07	-2E-06	-5E-08	-4E-08	-7E-07	**-1E-06**
Sydney Secondary College Leichhardt Campus	School - Secondary	-0.0318	-0.1723	-1E-05	-1E-05	-3E-06	-9E-08	-8E-07	-9E-06	-2E-07	-2E-07	-3E-06	**-6E-06**
Rose Cottage Child Care Centre	Child care	-0.1019	-0.0808	-5E-06	-6E-06	-1E-06	-3E-07	-4E-07	-4E-06	-1E-07	-8E-08	-1E-06	**-3E-06**
Inner Sydney Montessori - Lilyfield	School	-0.1976	-0.0878	-5E-06	-6E-06	-1E-06	-6E-07	-4E-07	-5E-06	-1E-07	-8E-08	-2E-06	**-3E-06**
Leichhardt Little Stars Nursery & Early Learning Centre	Child care	-0.0207	-0.0694	-4E-06	-5E-06	-1E-06	-6E-08	-3E-07	-4E-06	-9E-08	-7E-08	-1E-06	**-2E-06**
Leichhardt Montessori Academy	School	-0.2068	-0.0290	-2E-06	-2E-06	-5E-07	-6E-07	-1E-07	-2E-06	-4E-08	-3E-08	-5E-07	**-1E-06**
St Basil's Sister Dorothea Village	Aged care	-0.0485	-0.0452	-3E-06	-3E-06	-7E-07	-1E-07	-2E-07	-2E-06	-6E-08	-4E-08	-8E-07	**-2E-06**
St Thomas Child Care Centre	Child care	-1.0505	-0.4236	-3E-05	-3E-05	-7E-06	-3E-06	-2E-06	-2E-05	-6E-07	-4E-07	-8E-06	**-1E-05**
Billy Kids Lilyfield Early Learning Centre	Child care	-0.4659	-0.4066	-2E-05	-3E-05	-7E-06	-1E-06	-2E-06	-2E-05	-5E-07	-4E-07	-7E-06	**-1E-05**
Little Learning School - Alexandria	Child care	0.1552	0.1316	8E-06	1E-05	2E-06	5E-07	6E-07	7E-06	2E-07	1E-07	2E-06	**4E-06**
Newtown Public School Combined OSHC	School	-0.1269	-0.0257	-2E-06	-2E-06	-4E-07	-4E-07	-1E-07	-1E-06	-3E-08	-2E-08	-5E-07	**-9E-07**
The Athena School	School	-0.1686	0.0378	2E-06	3E-06	6E-07	-5E-07	2E-07	2E-06	5E-08	4E-08	7E-07	**1E-06**
Camdenville Public School	School	0.2221	-0.0446	-3E-06	-3E-06	-7E-07	7E-07	-2E-07	-2E-06	-6E-08	-4E-08	-8E-07	**-2E-06**
St Joan of Arc Home for the Aged	Aged care	-0.0830	-0.1373	-8E-06	-1E-05	-2E-06	-2E-07	-6E-07	-7E-06	-2E-07	-1E-07	-2E-06	**-5E-06**
Inner West Education Centre	School	-0.1750	-0.0031	-2E-07	-2E-07	-5E-08	-5E-07	-1E-08	-2E-07	-4E-09	-3E-09	-6E-08	**-1E-07**
St Peters Community Pre-school	School	0.1017	0.1422	8E-06	1E-05	2E-06	3E-07	7E-07	8E-06	2E-07	1E-07	3E-06	**5E-06**

Quantification of Effects - $PM_{2.5}$ and PM_{10}
M4-M5 Link: 2033 - Cumulative

			Air quality indicator:	$PM_{2.5}$	$PM_{2.5}$	$PM_{2.5}$	PM_{10}	$PM_{2.5}$	$PM_{2.5}$	$PM_{2.5}$	$PM_{2.5}$	$PM_{2.5}$	DPM
			Endpoint:	**Mortality - All Causes**	**Hospitalisations - Cardiovascular**	**Hospitalisations - Respiratory**	**Mortality - All Causes**	**Mortality - All Causes**	**Mortality - Cardiopulmonary**	**Mortality - Cardiovascular**	**Mortality - Respiratory**	**Morbidity - Asthma ED Admissions**	**Increased risk - lung cancer**
			Effect Exposure Duration:	Long-term	Short-term	Short-term	Short-Term	Short-Term	Long-term	Short-Term	Short-Term	Short-Term	Based on WHO
			Age Group:	≥ 30 years	≥ 65 years	≥ 65 years	All ages	All ages	≥ 30 years	All ages	All ages	1-14 years	inhalation unit risk
			β (change in effect per 1 μg/m³) (as per Table 6-22)	0.0058	0.0008	0.00041	0.0006	0.00094	0.013	0.00097	0.0019	0.00148	3.40E-05
			Annual Baseline Incidence (as per Table 4-5)										(ug/m3)-1
			Annual baseline incidence (per 100,000)	1026	9235	3978	493	493	412	134.7	49.4	1209	
			Baseline Incidence (per person per year)	0.01026	0.09235	0.03978	0.00493	0.00493	0.00412	0.001347	0.000494	0.01209	
Sensitive Receptors		**Change in Annual Average PM10 Concentration (μg/m³)**	**Change in Annual Average PM2.5 Concentration (μg/m³)**	**Risk**	**Risk**	**Risk**	**Risk**	**Risk**	**Risk**	**Risk**	**Risk**	**Risk**	**Risk**
Impacts from tunnel ventilation outlets													
Grid receptors: maximum regardless of landuse		**3.74**	**2.33**	**1E-04**	**2E-04**	**4E-05**	**1E-05**	**1E-05**	**1E-04**	**3E-06**	**2E-06**	**4E-05**	**8E-05**
Grid receptors: maximum residential		**1.02**	**0.55**	**3E-05**	**4E-05**	**9E-06**	**3E-06**	**3E-06**	**3E-05**	**7E-07**	**5E-07**	**1E-05**	**2E-05**
Grid receptors: maximum childcare		**0.22**	**0.20**	**1E-05**	**1E-05**	**3E-06**	**7E-07**	**9E-07**	**1E-05**	**3E-07**	**2E-07**	**4E-06**	**7E-06**
Grid receptors: maximum school		**0.29**	**0.19**	**1E-05**	**1E-05**	**3E-06**	**9E-07**	**9E-07**	**1E-05**	**2E-07**	**2E-07**	**3E-06**	**6E-06**
Grid receptors: maximum aged care		**0.16**	**0.06**	**4E-06**	**4E-06**	**1E-06**	**5E-07**	**3E-07**	**3E-06**	**8E-08**	**6E-08**	**1E-06**	**2E-06**
Grid receptors: maximum hospital and medical		**0.52**	**0.31**	**2E-05**	**2E-05**	**5E-06**	**2E-06**	**1E-06**	**2E-05**	**4E-07**	**3E-07**	**6E-06**	**1E-05**
Grid receptors: commercial/industrial		**3.74**	**2.33**	**1E-04**	**2E-04**	**4E-05**	**1E-05**	**1E-05**	**1E-04**	**3E-06**	**2E-06**	**4E-05**	**8E-05**
Grid receptors: open space		**0.92**	**0.56**	**3E-05**	**4E-05**	**9E-06**	**3E-06**	**3E-06**	**3E-05**	**7E-07**	**5E-07**	**1E-05**	**2E-05**
Community Receptors													
The Jimmy Little Community Centre	Community	-0.0661	0.0265	2E-06	2E-06	4E-07	-2E-07	1E-07	1E-06	3E-08	2E-08	5E-07	**9E-07**
Balmain Cove Early Learning Centre	Child care	0.0370	0.0577	3E-06	4E-06	9E-07	1E-07	3E-07	3E-06	8E-08	5E-08	1E-06	**2E-06**
Rosebud Cottage Child Care Centre	Child care	-0.6800	-0.3861	-2E-05	-3E-05	-6E-06	-2E-06	-2E-06	-2E-05	-5E-07	-4E-07	-7E-06	**-1E-05**
Sydney Community College	School/education	-0.1054	-0.0786	-5E-06	-6E-06	-1E-06	-3E-07	-4E-07	-4E-06	-1E-07	-7E-08	-1E-06	**-3E-06**
Rozelle Total Health	Health	-0.1900	0.0767	5E-06	6E-06	1E-06	-6E-07	4E-07	4E-06	1E-07	7E-08	1E-06	**3E-06**
Laurel Tree House Child Care Centre	Child care	-0.0467	-0.0377	-2E-06	-3E-06	-6E-07	-1E-07	-2E-07	-2E-06	-5E-08	-4E-08	-7E-07	**-1E-06**
Bridge Road School	School	-0.4213	-0.2415	-1E-05	-2E-05	-4E-06	-1E-06	-1E-06	-1E-05	-3E-07	-2E-07	-4E-06	**-8E-06**
NHMRC Clinical Trials Centre	Health	-0.2883	-0.3289	-2E-05	-2E-05	-5E-06	-9E-07	-2E-06	-2E-05	-4E-07	-3E-07	-6E-06	**-1E-05**
Annandale Public School	School	-0.3737	0.0203	1E-06	1E-06	3E-07	-1E-06	9E-08	1E-06	3E-08	2E-08	4E-07	**7E-07**
The University of Notre Dame Australia, Broadway	School/education	-0.0500	-0.1263	-8E-06	-9E-06	-2E-06	-1E-07	-6E-07	-7E-06	-2E-07	-1E-07	-2E-06	**-4E-06**
Laverty Pathology Annandale	Health	-0.1772	-0.0452	-3E-06	-3E-06	-7E-07	-5E-07	-2E-07	-2E-06	-6E-08	-4E-08	-8E-07	**-2E-06**
Little VIP's Child Care Centre	Child care	0.2576	0.1462	9E-06	1E-05	2E-06	8E-07	7E-07	8E-06	2E-07	1E-07	3E-06	**5E-06**
Dobroyd Point Public School	School	-0.0977	0.0282	2E-06	2E-06	5E-07	-3E-07	1E-07	2E-06	4E-08	3E-08	5E-07	**1E-06**
Peek A Boo Early Learning Centre Haberfield	Child care	-0.1408	-0.0669	-4E-06	-5E-06	-1E-06	-4E-07	-3E-07	-4E-06	-9E-08	-6E-08	-1E-06	**-2E-06**
Rozelle CCC	Child care	0.0146	0.1181	7E-06	9E-06	2E-06	4E-08	5E-07	6E-06	2E-07	1E-07	2E-06	**4E-06**
Sydney Secondary College Leichhardt Campus	School - Secondary	0.0531	-0.1925	-1E-05	-1E-05	-3E-06	2E-07	-9E-07	-1E-05	-3E-07	-2E-07	-3E-06	**-7E-06**
Rose Cottage Child Care Centre	Child care	-0.0349	-0.0517	-3E-06	-4E-06	-8E-07	-1E-07	-2E-07	-3E-06	-7E-08	-5E-08	-9E-07	**-2E-06**
Inner Sydney Montessori - Lilyfield	School	-0.1359	-0.0860	-5E-06	-6E-06	-1E-06	-4E-07	-4E-07	-5E-06	-1E-07	-8E-08	-2E-06	**-3E-06**
Leichhardt Little Stars Nursery & Early Learning Centre	Child care	0.0364	0.0047	3E-07	4E-07	8E-08	1E-07	2E-08	3E-07	6E-09	4E-09	8E-08	**2E-07**
Leichhardt Montessori Academy	School	0.0063	0.0850	5E-06	6E-06	1E-06	2E-08	4E-07	5E-06	1E-07	8E-08	2E-06	**3E-06**
St Basil's Sister Dorothea Village	Aged care	0.1392	0.0703	4E-06	5E-06	1E-06	4E-07	3E-07	4E-06	9E-08	7E-08	1E-06	**2E-06**
St Thomas Child Care Centre	Child care	-1.0339	-0.3247	-2E-05	-2E-05	-5E-06	-3E-06	-2E-06	-2E-05	-4E-07	-3E-07	-6E-06	**-1E-05**
Billy Kids Lilyfield Early Learning Centre	Child care	-0.6111	-0.5031	-3E-05	-4E-05	-8E-06	-2E-06	-2E-06	-3E-05	-7E-07	-5E-07	-9E-06	**-2E-05**
Little Learning School - Alexandria	Child care	0.2768	0.0674	4E-06	5E-06	1E-06	8E-07	3E-07	4E-06	9E-08	6E-08	1E-06	**2E-06**
Newtown Public School Combined OSHC	School	-0.0536	-0.0496	-3E-06	-4E-06	-8E-07	-2E-07	-2E-07	-3E-06	-6E-08	-5E-08	-9E-07	**-2E-06**
The Athena School	School	0.0184	0.0351	2E-06	3E-06	6E-07	5E-08	2E-07	2E-06	5E-08	3E-08	6E-07	**1E-06**
Camdenville Public School	School	0.2084	0.0409	2E-06	3E-06	7E-07	6E-07	2E-07	2E-06	5E-08	4E-08	7E-07	**1E-06**
St Joan of Arc Home for the Aged	Aged care	-0.0598	-0.2570	-2E-05	-2E-05	-4E-06	-2E-07	-1E-06	-1E-05	-3E-07	-2E-07	-5E-06	**-9E-06**
Inner West Education Centre	School	0.1578	-0.0345	-2E-06	-3E-06	-6E-07	5E-07	-2E-07	-2E-06	-5E-08	-3E-08	-6E-07	**-1E-06**
St Peters Community Pre-school	School	-0.0226	0.0913	5E-06	7E-06	1E-06	-7E-08	4E-07	5E-06	1E-07	9E-08	2E-06	**3E-06**

Annexure G – Population incidence calculations: Particulate matter

Assessment of Increased Incidence - $PM_{2.5}$
M4-M5 Link: 2023

	Primary Indicators			Secondary Indicators				
Health Endpoint:	**Mortality - All Causes, Long-term**	**Hospitalisations - Cardiovascular, Short-term**	**Hospitalisations - Respiratory, Short-term**	**Mortality - All Causes, Short-term**	**Mortality - Cardiopulmonary, Long-term**	**Mortality - Cardiovascular, Short-term**	**Mortality - Respiratory, Short-term**	**Morbidity - Asthma ED Admissions - Short-term**
Age Group:	≥ 30 years	≥ 65 years	≥ 65 years	All ages	≥ 30 years	All ages	All ages	1-14 years
β (change in effect per 1 μg/m^3 PM) (as per Table 6-22)	0.0058	0.0008	0.00041	0.00094	0.013	0.00097	0.0019	0.00148
Canada Bay LGA								
Total Population in study area:	67644	67644	67644	67644	67644	67644	67644	67644
% population in assessment age-group:	63%	14%	14%	100%	63%	100%	100%	16%
Population weighted Δx (μg/m^3):	-0.00000291	-0.00000291	-0.00000291	-0.00000291	-0.00000291	-0.00000291	-0.00000291	-0.00000291
Baseline Incidence (per 100,000) (as per Table 4-5)	1026	9235	3978	403.3	412.0	113.4	49.4	1209.0
Baseline Incidence (per person)	0.01026	0.09235	0.03978	0.00403	0.00412	0.00113	0.00049	0.01209
Increased number of cases in population:	-0.000007	-0.0000020	-0.00000045	-0.00000075	-0.0000067	-0.00000022	-0.00000018	-0.00000055
Risk:	-1.7E-10	-2.1E-10	-4.7E-11	-1.1E-11	-1.6E-10	-3.2E-12	-2.7E-12	-5.2E-11
Individual subrubs within LGA								
Concord - Mortlake - Cabarita								
Total Population in study area:	19204	19204	19204	19204	19204	19204	19204	19204
total change	46.9	46.9	46.9	46.9	46.9	46.9	46.9	46.9
Population weighted Δx (μg/m^3):	0.00244220	0.00244220	0.00244220	0.00244220	0.00244220	0.00244220	0.00244220	0.00244220
Attributable fraction (AF):	1.4E-05	2.0E-06	1.0E-06	2.3E-06	3.2E-05	2.4E-06	4.6E-06	3.6E-06
Increased number of cases in population:	0.0018	0.00049	0.00011	0.00018	0.0016	0.000052	0.000044	0.00013
Concord West								
Total Population in study area:	10692	10692	10692	10692	10692	10692	10692	10692
total change	148.6	148.6	148.6	148.6	148.6	148.6	148.6	148.6
Population weighted Δx (μg/m^3):	0.01389824	0.01389824	0.01389824	0.01389824	0.01389824	0.01389824	0.01389824	0.01389824
Increased number of cases in population:	0.0056	0.0015	0.00034	0.00056	0.0050	0.00016	0.00014	0.0004
Drummoyne - Rodd Pt								
Total Population in study area:	17456	17456	17456	17456	17456	17456	17456	17456
total change	-40	-40	-40	-40	-40	-40	-40	-40
Population weighted Δx (μg/m^3):	-0.00229148	-0.00229148	-0.00229148	-0.00229148	-0.00229148	-0.00229148	-0.00229148	-0.00229148
Increased number of cases in population:	-0.0015	-0.00041	-0.000091	-0.00015	-0.0014	-0.000044	-0.000038	-0.00011
Five Dock								
Total Population in study area:	19111	19111	19111	19111	19111	19111	19111	19111
total change	-171.9	-171.9	-171.9	-171.9	-171.9	-171.9	-171.9	-171.9
Population weighted Δx (μg/m^3):	-0.00899482	-0.00899482	-0.00899482	-0.00899482	-0.00899482	-0.00899482	-0.00899482	-0.00899482
Increased number of cases in population:	-0.0065	-0.0018	-0.00039	-0.00065	-0.0058	-0.00019	-0.00016	-0.00048
Gladesville								
Total Population in study area:	590	590	590	590	590	590	590	590
total change	-1.4	-1.4	-1.4	-1.4	-1.4	-1.4	-1.4	-1.4
Population weighted Δx (μg/m^3):	-0.00237288	-0.00237288	-0.00237288	-0.00237288	-0.00237288	-0.00237288	-0.00237288	-0.00237288
Increased number of cases in population:	-0.000053	-0.0000145	-0.00000320	-0.00000531	-0.0000475	-0.00000154	-0.00000131	-0.00000388
Hunters Hill								
Total Population in study area:	591	591	591	591	591	591	591	591
total change	-1.9	-1.9	-1.9	-1.9	-1.9	-1.9	-1.9	-1.9
Population weighted Δx (μg/m^3):	-0.00321489	-0.00321489	-0.00321489	-0.00321489	-0.00321489	-0.00321489	-0.00321489	-0.00321489
Increased number of cases in population:	-0.000072	-0.0000197	-0.00000434	-0.00000720	-0.0000645	-0.00000209	-0.00000178	-0.00000527

	Primary Indicators			Secondary Indicators				
Health Endpoint:	**Mortality - All Causes, Long-term**	**Hospitalisations - Cardiovascular, Short-term**	**Hospitalisations - Respiratory, Short-term**	**Mortality - All Causes, Short-term**	**Mortality - Cardiopulmonary, Long-term**	**Mortality - Cardiovascular, Short-term**	**Mortality - Respiratory, Short-term**	**Morbidity - Asthma ED Admissions - Short-term**
Age Group:	≥ 30 years	≥ 65 years	≥ 65 years	All ages	≥ 30 years	All ages	All ages	1-14 years
β (change in effect per 1 $\mu g/m^3$ PM) (as per Table 6-22)	0.0058	0.0008	0.00041	0.00094	0.013	0.00097	0.0019	0.00148
Strathfield LGA								
Total Population in study area:	25473	25473	25473	25473	25473	25473	25473	25473
% population in assessment age-group:	60%	13%	13%	100%	60%	100%	100%	14%
Population weighted Δx ($\mu g/m^3$):	-0.00128	-0.00128	-0.00128	-0.00128	-0.00128	-0.00128	-0.00128	-0.00128
Baseline Incidence (per 100,000) (as per Table 4-5)	1026	9235	3978	443.1	412.0	135.2	49.4	1209.0
Baseline Incidence (per person)	0.01026	0.09235	0.03978	0.00443	0.00412	0.00135	0.00049	0.01209
Increased number of cases in population:	-0.0012	-0.00032	-0.000070	-0.00014	-0.0010	-0.000043	-0.000031	-0.000083
Risk:	-7.6E-08	-9.5E-08	-2.1E-08	-5.3E-09	-6.9E-08	-1.7E-09	-1.2E-09	-2.3E-08
Individual subrubs within LGA								
Homebush								
Total Population in study area:	5075	5075	5075	5075	5075	5075	5075	5075
total change	-25.3	-25.3	-25.3	-25.3	-25.3	-25.3	-25.3	-25.3
Population weighted Δx ($\mu g/m^3$):	-0.00499	-0.00499	-0.00499	-0.00499	-0.00499	-0.00499	-0.00499	-0.00499
Increased number of cases in population:	-0.00090	-0.00024	-0.000054	-0.00011	-0.00081	-0.000033	-0.000024	-0.000065
Homebush Bay								
Total Population in study area:	63	63	63	63	63	63	63	63
total change	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7
Population weighted Δx ($\mu g/m^3$):	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011
Increased number of cases in population:	0.000025	0.0000068	0.0000015	0.0000029	0.000022	0.00000092	0.00000066	0.0000018
Strathfield								
Total Population in study area:	20335	20335	20335	20335	20335	20335	20335	20335
total change	-7.9	-7.9	-7.9	-7.9	-7.9	-7.9	-7.9	-7.9
Population weighted Δx ($\mu g/m^3$):	-0.00038849	-0.00038849	-0.00038849	-0.00038849	-0.00038849	-0.00038849	-0.00038849	-0.00038849
Increased number of cases in population:	-0.00028	-0.000076	-0.000017	-0.000033	-0.00025	-0.000010	-0.0000074	-0.000020
Burwood LGA								
Total Population in study area:	20986	20986	20986	20986	20986	20986	20986	20986
% population in assessment age-group:	60%	13%	13%	100%	60%	100%	100%	14%
Population weighted Δx ($\mu g/m^3$):	-0.00234919	-0.00234919	-0.00234919	-0.00234919	-0.00234919	-0.00234919	-0.00234919	-0.00234919
Baseline Incidence (per 100,000) (as per Table 4-5)	1026	9235	3978	555.6	412.0	138.0	49.4	1209.0
Baseline Incidence (per person)	0.01026	0.09235	0.03978	0.00556	0.00412	0.00138	0.00049	0.01209
Increased number of cases in population:	-0.0018	-0.00048	-0.00011	-0.00026	-0.0016	-0.000066	-0.000046	-0.00013
Risk:	-1.4E-07	-1.7E-07	-3.8E-08	-1.2E-08	-1.3E-07	-3.1E-09	-2.2E-09	-4.2E-08

	Primary Indicators			Secondary Indicators				
Health Endpoint:	**Mortality - All Causes, Long-term**	**Hospitalisations - Cardiovascular, Short-term**	**Hospitalisations - Respiratory, Short-term**	**Mortality - All Causes, Short-term**	**Mortality - Cardiopulmonary, Long-term**	**Mortality - Cardiovascular, Short-term**	**Mortality - Respiratory, Short-term**	**Morbidity - Asthma ED Admissions - Short-term**
Age Group:	≥ 30 years	≥ 65 years	≥ 65 years	All ages	≥ 30 years	All ages	All ages	1-14 years
β (change in effect per 1 μg/m^3 PM) (as per Table 6-22)	0.0058	0.0008	0.00041	0.00094	0.013	0.00097	0.0019	0.00148
Sydney Inner West LGA								
Total Population in study area:	180589	180589	180589	180589	180589	180589	180589	180589
% population in assessment age-group:	67%	10%	10%	100%	67%	100%	100%	15%
Population weighted Δx (μg/m^3):	-0.05300987	-0.05300987	-0.05300987	-0.05300987	-0.05300987	-0.05300987	-0.05300987	-0.05300987
Baseline Incidence (per 100,000) (as per Table 4-5)	1026	9235	3978	534.2	412.0	146.4	49.4	1209.0
Baseline Incidence (per person)	0.01026	0.09235	0.03978	0.00534	0.00412	0.00146	0.00049	0.01209
Increased number of cases in population:	-0.38	-0.072	-0.016	-0.048	-0.34	-0.014	-0.0090	-0.026
Risk:	-3.2E-06	-3.9E-06	-8.6E-07	-2.7E-07	-2.8E-06	-7.5E-08	-5.0E-08	-9.5E-07
Individual subrubs within LGA								
Ashfield								
Total Population in study area:	22769	22769	22769	22769	22769	22769	22769	22769
total change	-501.9	-501.9	-501.9	-501.9	-501.9	-501.9	-501.9	-501.9
Population weighted Δx (μg/m^3):	-0.02204313	-0.02204313	-0.02204313	-0.02204313	-0.02204313	-0.02204313	-0.02204313	-0.02204313
Increased number of cases in population:	-0.020	-0.0038	-0.00083	-0.0025	-0.018	-0.00071	-0.00047	-0.0013
Canterbury North-Ashbury								
Total Population in study area:	9390	9390	9390	9390	9390	9390	9390	9390
total change	-61	-61	-61	-61	-61	-61	-61	-61
Population weighted Δx (μg/m^3):	-0.00649627	-0.00649627	-0.00649627	-0.00649627	-0.00649627	-0.00649627	-0.00649627	-0.00649627
Increased number of cases in population:	-0.0024	-0.00046	-0.00010	-0.00031	-0.0022	-0.000087	-0.000057	-0.00016
Croyden Park								
Total Population in study area:	16360	16360	16360	16360	16360	16360	16360	16360
total change	-299.8	-299.8	-299.8	-299.8	-299.8	-299.8	-299.8	-299.8
Population weighted Δx (μg/m^3):	-0.01832518	-0.01832518	-0.01832518	-0.01832518	-0.01832518	-0.01832518	-0.01832518	-0.01832518
Increased number of cases in population:	-0.012	-0.0023	-0.00050	-0.0015	-0.011	-0.00043	-0.00028	-0.00080
Dulwich Hill								
Total Population in study area:	15862	15862	15862	15862	15862	15862	15862	15862
Population weighted Δx (μg/m^3):	-0.04385323	-0.04385323	-0.04385323	-0.04385323	-0.04385323	-0.04385323	-0.04385323	-0.04385323
Increased number of cases in population:	-0.028	-0.0052	-0.0012	-0.0035	-0.025	-0.0010	-0.00065	-0.0019
Haberfield								
Total Population in study area:	13245	13245	13245	13245	13245	13245	13245	13245
total change	-1249.7	-1249.7	-1249.7	-1249.7	-1249.7	-1249.7	-1249.7	-1249.7
Population weighted Δx (μg/m^3):	-0.09435259	-0.09435259	-0.09435259	-0.09435259	-0.09435259	-0.09435259	-0.09435259	-0.09435259
Increased number of cases in population:	-0.050	-0.0094	-0.0021	-0.0063	-0.045	-0.0018	-0.0012	-0.0033
Balmain								
Total Population in study area:	14794	14794	14794	14794	14794	14794	14794	14794
total change	-28.5	-28.5	-28.5	-28.5	-28.5	-28.5	-28.5	-28.5
Population weighted Δx (μg/m^3):	-0.00192646	-0.00192646	-0.00192646	-0.00192646	-0.00192646	-0.00192646	-0.00192646	-0.00192646
Increased number of cases in population:	-0.0011	-0.00021	-0.000047	-0.00014	-0.0010	-0.000040	-0.000027	-0.000076
Leichhardt								
Total Population in study area:	24443	24443	24443	24443	24443	24443	24443	24443
total change	-2334	-2334	-2334	-2334	-2334	-2334	-2334	-2334
Population weighted Δx (μg/m^3):	-0.09548746	-0.09548746	-0.09548746	-0.09548746	-0.09548746	-0.09548746	-0.09548746	-0.09548746
Increased number of cases in population:	-0.093	-0.018	-0.0039	-0.012	-0.084	-0.0033	-0.0022	-0.0062
Lilyfield								
Total Population in study area:	13073	13073	13073	13073	13073	13073	13073	13073
total change	-1477.6	-1477.6	-1477.6	-1477.6	-1477.6	-1477.6	-1477.6	-1477.6
Population weighted Δx (μg/m^3):	-0.11302685	-0.11302685	-0.11302685	-0.11302685	-0.11302685	-0.11302685	-0.11302685	-0.11302685
Increased number of cases in population:	-0.059	-0.011	-0.0025	-0.0074	-0.053	-0.0021	-0.0014	-0.0039
Marrickville								
Total Population in study area:	24632	24632	24632	24632	24632	24632	24632	24632
total change	-986.8	-986.8	-986.8	-986.8	-986.8	-986.8	-986.8	-986.8
Population weighted Δx (μg/m^3):	-0.04006171	-0.04006171	-0.04006171	-0.04006171	-0.04006171	-0.04006171	-0.04006171	-0.04006171
Increased number of cases in population:	-0.039	-0.0074	-0.0016	-0.0050	-0.036	-0.0014	-0.00093	-0.0026
Petersham								
Total Population in study area:	18817	18817	18817	18817	18817	18817	18817	18817
total change	-1923.1	-1923.1	-1923.1	-1923.1	-1923.1	-1923.1	-1923.1	-1923.1
Population weighted Δx (μg/m^3):	-0.10220014	-0.10220014	-0.10220014	-0.10220014	-0.10220014	-0.10220014	-0.10220014	-0.10220014
Increased number of cases in population:	-0.077	-0.014	-0.0032	-0.0097	-0.069	-0.0027	-0.0018	-0.0051
Sydenham								
Total Population in study area:	7204	7204	7204	7204	7204	7204	7204	7204
total change	-15.1	-15.1	-15.1	-15.1	-15.1	-15.1	-15.1	-15.1
Population weighted Δx (μg/m^3):	-0.00209606	-0.00209606	-0.00209606	-0.00209606	-0.00209606	-0.00209606	-0.00209606	-0.00209606
Increased number of cases in population:	-0.00060	-0.00011	-0.000025	-0.000076	-0.00054	-0.000021	-0.000014	-0.000040

	Primary Indicators			Secondary Indicators				
Health Endpoint:	**Mortality - All Causes, Long-term**	**Hospitalisations - Cardiovascular, Short-term**	**Hospitalisations - Respiratory, Short-term**	**Mortality - All Causes, Short-term**	**Mortality - Cardiopulmonary, Long-term**	**Mortality - Cardiovascular, Short-term**	**Mortality - Respiratory, Short-term**	**Morbidity - Asthma ED Admissions - Short-term**
Age Group:	≥ 30 years	≥ 65 years	≥ 65 years	All ages	≥ 30 years	All ages	All ages	1-14 years
β (change in effect per 1 μg/m^3 PM) (as per Table 6-22)	0.0058	0.0008	0.00041	0.00094	0.013	0.00097	0.0019	0.00148
Sydney LGA								
Total Population in study area:	125509	125509	125509	125509	125509	125509	125509	125509
% population in assessment age-group:	59%	8%	8%	100%	59%	100%	100%	6%
Population weighted Δx (μg/m^3):	-0.00102542	-0.00102542	-0.00102542	-0.00102542	-0.00102542	-0.00102542	-0.00102542	-0.00102542
Baseline Incidence (per 100,000) (as per Table 4-5)	1026	9235	3978	508.0	412.0	138.9	49.4	1209.0
Baseline Incidence (per person)	0.01026	0.09235	0.03978	0.00508	0.00412	0.00139	0.00049	0.01209
Increased number of cases in population:	-0.0045	-0.00074	-0.00016	-0.00061	-0.0041	-0.00017	-0.00012	-0.00014
Risk:	-6.1E-08	-7.6E-08	-1.7E-08	-4.9E-09	-5.5E-08	-1.4E-09	-9.6E-10	-1.8E-08
Individual subrubs within LGA								
Erskinville								
Total Population in study area:	13908	13908	13908	13908	13908	13908	13908	13908
total change	-442	-442	-442	-442	-442	-442	-442	-442
Population weighted Δx (μg/m^3):	-0.03178027	-0.03178027	-0.03178027	-0.03178027	-0.03178027	-0.03178027	-0.03178027	-0.03178027
Increased number of cases in population:	-0.016	-0.0025	-0.00056	-0.0021	-0.014	-0.00060	-0.00041	-0.00049
Glebe								
Total Population in study area:	16595	16595	16595	16595	16595	16595	16595	16595
total change	-479.8	-479.8	-479.8	-479.8	-479.8	-479.8	-479.8	-479.8
Population weighted Δx (μg/m^3):	-0.02891232	-0.02891232	-0.02891232	-0.02891232	-0.02891232	-0.02891232	-0.02891232	-0.02891232
Increased number of cases in population:	-0.017	-0.0028	-0.00061	-0.0023	-0.015	-0.00065	-0.00045	-0.00053
Newtown								
Total Population in study area:	21480	21480	21480	21480	21480	21480	21480	21480
total change	-826.3	-826.3	-826.3	-826.3	-826.3	-826.3	-826.3	-826.3
Population weighted Δx (μg/m^3):	-0.03846834	-0.03846834	-0.03846834	-0.03846834	-0.03846834	-0.03846834	-0.03846834	-0.03846834
Increased number of cases in population:	-0.029	-0.0048	-0.0011	-0.0039	-0.026	-0.0011	-0.00078	-0.00092
Pyrmont								
Total Population in study area:	18720	18720	18720	18720	18720	18720	18720	18720
total change	2179.7	2179.7	2179.7	2179.7	2179.7	2179.7	2179.7	2179.7
Population weighted Δx (μg/m^3):	0.11643697	0.11643697	0.11643697	0.11643697	0.11643697	0.11643697	0.11643697	0.11643697
Increased number of cases in population:	0.077	0.013	0.0028	0.010	0.069	0.0029	0.0020	0.0024
Redfern								
Total Population in study area:	12628	12628	12628	12628	12628	12628	12628	12628
total change	-756	-756	-756	-756	-756	-756	-756	-756
Population weighted Δx (μg/m^3):	-0.05986696	-0.05986696	-0.05986696	-0.05986696	-0.05986696	-0.05986696	-0.05986696	-0.05986696
Increased number of cases in population:	-0.027	-0.0044	-0.0010	-0.0036	-0.024	-0.0010	-0.00071	-0.00084
Surry Hills								
Total Population in study area:	4190	4190	4190	4190	4190	4190	4190	4190
total change	-11.9	-11.9	-11.9	-11.9	-11.9	-11.9	-11.9	-11.9
Population weighted Δx (μg/m^3):	-0.00284010	-0.00284010	-0.00284010	-0.00284010	-0.00284010	-0.00284010	-0.00284010	-0.00284010
Increased number of cases in population:	-0.00042	-0.000069	-0.000015	-0.000057	-0.00038	-0.000016	-0.000011	-0.000013
Sydney								
Total Population in study area:	21726	21726	21726	21726	21726	21726	21726	21726
total change	401.5	401.5	401.5	401.5	401.5	401.5	401.5	401.5
Population weighted Δx (μg/m^3):	0.01848016	0.01848016	0.01848016	0.01848016	0.01848016	0.01848016	0.01848016	0.01848016
Increased number of cases in population:	0.014	0.0023	0.00051	0.0019	0.013	0.00054	0.00038	0.00045
Waterloo								
Total Population in study area:	11306	11306	11306	11306	11306	11306	11306	11306
total change	-203.2	-203.2	-203.2	-203.2	-203.2	-203.2	-203.2	-203.2
Population weighted Δx (μg/m^3):	-0.01797276	-0.01797276	-0.01797276	-0.01797276	-0.01797276	-0.01797276	-0.01797276	-0.01797276
Increased number of cases in population:	-0.0071	-0.0012	-0.00026	-0.0010	-0.0064	-0.00027	-0.00019	-0.00023
Crows Nest								
Total Population in study area:	50	50	50	50	50	50	50	50
total change	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1
Population weighted Δx (μg/m^3):	-0.0020	-0.0020	-0.0020	-0.0020	-0.0020	-0.0020	-0.0020	-0.0020
Increased number of cases in population:	-0.0000035	-0.00000058	-0.00000013	-0.00000048	-0.0000032	-0.00000013	-0.000000094	-0.00000011
North Sydney								
Total Population in study area:	4906	4906	4906	4906	4906	4906	4906	4906
total change	12.4	12.4	12.4	12.4	12.4	12.4	12.4	12.4
Population weighted Δx (μg/m^3):	0.00252752	0.00252752	0.00252752	0.00252752	0.00252752	0.00252752	0.00252752	0.00252752
Increased number of cases in population:	0.00044	0.000071	0.000016	0.000059	0.00039	0.000017	0.000012	0.000014

	Primary Indicators			Secondary Indicators				
Health Endpoint:	**Mortality - All Causes, Long-term**	**Hospitalisations - Cardiovascular, Short-term**	**Hospitalisations - Respiratory, Short-term**	**Mortality - All Causes, Short-term**	**Mortality - Cardiopulmonary, Long-term**	**Mortality - Cardiovascular, Short-term**	**Mortality - Respiratory, Short-term**	**Morbidity - Asthma ED Admissions - Short-term**
Age Group:	≥ 30 years	≥ 65 years	≥ 65 years	All ages	≥ 30 years	All ages	All ages	1-14 years
β (change in effect per 1 μg/m^3 PM) (as per Table 6-22)	0.0058	0.0008	0.00041	0.00094	0.013	0.00097	0.0019	0.00148
Botany LGA								
Total Population in study area:	25700	25700	25700	25700	25700	25700	25700	25700
% population in assessment age-group:	62%	14%	14%	100%	62%	100%	100%	17%
Population weighted Δx (μg/m^3):	0.07677432	0.07677432	0.07677432	0.07677432	0.07677432	0.07677432	0.07677432	0.07677432
Baseline Incidence (per 100,000) (as per Table 4-5)	1026	9235	3978	523.8	412.0	150.0	49.4	1209.0
Baseline Incidence (per person)	0.01026	0.09235	0.03978	0.00524	0.00412	0.00150	0.00049	0.01209
Increased number of cases in population:	0.072	0.021	0.0046	0.0097	0.065	0.0029	0.0019	0.0059
Risk:	4.6E-06	5.7E-06	1.3E-06	3.8E-07	4.1E-06	1.1E-07	7.2E-08	1.4E-06
Individual subrubs within LGA								
Botany								
Total Population in study area:	8915	8915	8915	8915	8915	8915	8915	8915
total change	47.9	47.9	47.9	47.9	47.9	47.9	47.9	47.9
Population weighted Δx (μg/m^3):	0.00537297	0.00537297	0.00537297	0.00537297	0.00537297	0.00537297	0.00537297	0.00537297
Increased number of cases in population:	0.0018	0.00051	0.00011	0.00024	0.0016	0.000070	0.000045	0.00014
Mascot								
Total Population in study area:	16215	16215	16215	16215	16215	16215	16215	16215
total change	1903.5	1903.5	1903.5	1903.5	1903.5	1903.5	1903.5	1903.5
Population weighted Δx (μg/m^3):	0.11739130	0.11739130	0.11739130	0.11739130	0.11739130	0.11739130	0.11739130	0.11739130
Increased number of cases in population:	0.070	0.0202	0.0045	0.0094	0.0628	0.0028	0.0018	0.0057
Pagewood								
Total Population in study area:	567	567	567	567	567	567	567	567
total change	21.4	21.4	21.4	21.4	21.4	21.4	21.4	21.4
Population weighted Δx (μg/m^3):	0.03774250	0.03774250	0.03774250	0.03774250	0.03774250	0.03774250	0.03774250	0.03774250
Increased number of cases in population:	0.00078	0.000228	0.000050	0.00011	0.00071	0.000031	0.000020	0.000064

	Primary Indicators			Secondary Indicators				
Health Endpoint:	**Mortality - All Causes, Long-term**	**Hospitalisations - Cardiovascular, Short-term**	**Hospitalisations - Respiratory, Short-term**	**Mortality - All Causes, Short-term**	**Mortality - Cardiopulmonary, Long-term**	**Mortality - Cardiovascular, Short-term**	**Mortality - Respiratory, Short-term**	**Morbidity - Asthma ED Admissions - Short-term**
Age Group:	≥ 30 years	≥ 65 years	≥ 65 years	All ages	≥ 30 years	All ages	All ages	1-14 years
β (change in effect per 1 μg/m^3 PM) (as per Table 6-22)	0.0058	0.0008	0.00041	0.00094	0.013	0.00097	0.0019	0.00148
Rockdale LGA								
Total Population in study area:	82293	82293	82293	82293	82293	82293	82293	82293
% population in assessment age-group:	62%	15%	15%	100%	62%	100%	100%	16%
Population weighted Δx (μg/m^3):	-0.02082534	-0.02082534	-0.02082534	-0.02082534	-0.02082534	-0.02082534	-0.02082534	-0.02082534
Baseline Incidence (per 100,000) (as per Table 4-5)	1026	9235	3978	534.5	412.0	150.0	49.4	1209.0
Baseline Incidence (per person)	0.01026	0.09235	0.03978	0.00535	0.00412	0.00150	0.00049	0.01209
Increased number of cases in population:	-0.063	-0.019	-0.0041	-0.0086	-0.057	-0.0025	-0.0016	-0.0049
Risk:	-1.2E-06	-1.5E-06	-3.4E-07	-1.0E-07	-1.1E-06	-3.0E-08	-2.0E-08	-3.7E-07
Individual subrubs within LGA								
Arncliffe								
Total Population in study area:	14669	14669	14669	14669	14669	14669	14669	14669
total change	-297.5	-297.5	-297.5	-297.5	-297.5	-297.5	-297.5	-297.5
Population weighted Δx (μg/m^3):	-0.02028086	-0.02028086	-0.02028086	-0.02028086	-0.02028086	-0.02028086	-0.02028086	-0.02028086
Increased number of cases in population:	-0.0109	-0.0033	-0.0007	-0.0015	-0.0098	-0.0004	-0.0003	-0.0009
Bexley								
Total Population in study area:	25123	25123	25123	25123	25123	25123	25123	25123
total change	-236.3	-236.3	-236.3	-236.3	-236.3	-236.3	-236.3	-236.3
Population weighted Δx (μg/m^3):	-0.00940572	-0.00940572	-0.00940572	-0.00940572	-0.00940572	-0.00940572	-0.00940572	-0.00940572
Increased number of cases in population:	-0.0087	-0.0026	-0.0006	-0.0012	-0.0078	-0.0003	-0.0002	-0.0007
Kingsgrove - South								
Total Population in study area:	11981	11981	11981	11981	11981	11981	11981	11981
total change	-442.6	-442.6	-442.6	-442.6	-442.6	-442.6	-442.6	-442.6
Population weighted Δx (μg/m^3):	-0.03694182	-0.03694182	-0.03694182	-0.03694182	-0.03694182	-0.03694182	-0.03694182	-0.03694182
Increased number of cases in population:	-0.0163	-0.0048	-0.0011	-0.0022	-0.0146	-0.0006	-0.0004	-0.0013
Monterey								
Total Population in study area:	12192	12192	12192	12192	12192	12192	12192	12192
total change	-246.3	-246.3	-246.3	-246.3	-246.3	-246.3	-246.3	-246.3
Population weighted Δx (μg/m^3):	-0.02020177	-0.02020177	-0.02020177	-0.02020177	-0.02020177	-0.02020177	-0.02020177	-0.02020177
Increased number of cases in population:	-0.0090	-0.0027	-0.0006	-0.0012	-0.0081	-0.0004	-0.0002	-0.0007
Rockdale								
Total Population in study area:	18328	18328	18328	18328	18328	18328	18328	18328
total change	-491.1	-491.1	-491.1	-491.1	-491.1	-491.1	-491.1	-491.1
Population weighted Δx (μg/m^3):	-0.02679507	-0.02679507	-0.02679507	-0.02679507	-0.02679507	-0.02679507	-0.02679507	-0.02679507
Increased number of cases in population:	-0.0180	-0.0054	-0.0012	-0.0025	-0.0162	-0.0007	-0.0005	-0.0014

	Primary Indicators			Secondary Indicators				
Health Endpoint:	**Mortality - All Causes, Long-term**	**Hospitalisations - Cardiovascular, Short-term**	**Hospitalisations - Respiratory, Short-term**	**Mortality - All Causes, Short-term**	**Mortality - Cardiopulmonary, Long-term**	**Mortality - Cardiovascular, Short-term**	**Mortality - Respiratory, Short-term**	**Morbidity - Asthma ED Admissions - Short-term**
Age Group:	≥ 30 years	≥ 65 years	≥ 65 years	All ages	≥ 30 years	All ages	All ages	1-14 years
β (change in effect per 1 μg/m^3 PM) (as per Table 6-22)	0.0058	0.0008	0.00041	0.00094	0.013	0.00097	0.0019	0.00148
Canterbury - Bankstown LGA								
Total Population in study area:	76834	76834	76834	76834	76834	76834	76834	76834
% population in assessment age-group:	58%	13%	13%	100%	58%	100%	100%	19%
Population weighted Δx (μg/m^3):	-0.01556733	-0.01556733	-0.01556733	-0.01556733	-0.01556733	-0.01556733	-0.01556733	-0.01556733
Baseline Incidence (per 100,000) (as per Table 4-5)	1026	9235	3978	490.6	412.0	139.2	49.4	1209.0
Baseline Incidence (per person)	0.01026	0.09235	0.03978	0.00491	0.00412	0.00139	0.00049	0.01209
Increased number of cases in population:	-0.041	-0.011	-0.0025	-0.0055	-0.037	-0.0016	-0.0011	-0.0041
Risk:	-9.3E-07	-1.2E-06	-2.5E-07	-7.2E-08	-8.3E-07	-2.1E-08	-1.5E-08	-2.8E-07
Individual subrubs within LGA								
Belmore								
Total Population in study area:	18330	18330	18330	18330	18330	18330	18330	18330
total change	-133.8	-133.8	-133.8	-133.8	-133.8	-133.8	-133.8	-133.8
Population weighted Δx (μg/m^3):	-0.00729951	-0.00729951	-0.00729951	-0.00729951	-0.00729951	-0.00729951	-0.00729951	-0.00729951
Increased number of cases in population:	-0.0046	-0.0013	-0.0003	-0.0006	-0.0042	-0.0002	-0.0001	-0.0005
Canterbury (South)								
Total Population in study area:	26841	26841	26841	26841	26841	26841	26841	26841
total change	-394.2	-394.2	-394.2	-394.2	-394.2	-394.2	-394.2	-394.2
Population weighted Δx (μg/m^3):	-0.01468649	-0.01468649	-0.01468649	-0.01468649	-0.01468649	-0.01468649	-0.01468649	-0.01468649
Increased number of cases in population:	-0.0137	-0.0038	-0.0008	-0.0018	-0.0123	-0.0005	-0.0004	-0.0014
Kinsgrove - North								
Total Population in study area:	22489	22489	22489	22489	22489	22489	22489	22489
total change	-648.3	-648.3	-648.3	-648.3	-648.3	-648.3	-648.3	-648.3
Population weighted Δx (μg/m^3):	-0.02882743	-0.02882743	-0.02882743	-0.02882743	-0.02882743	-0.02882743	-0.02882743	-0.02882743
Increased number of cases in population:	-0.0225	-0.0062	-0.0014	-0.0030	-0.0202	-0.0009	-0.0006	-0.0022
Lakemba								
Total Population in study area:	3643	3643	3643	3643	3643	3643	3643	3643
total change	-1.5	-1.5	-1.5	-1.5	-1.5	-1.5	-1.5	-1.5
Population weighted Δx (μg/m^3):	-0.00041175	-0.00041175	-0.00041175	-0.00041175	-0.00041175	-0.00041175	-0.00041175	-0.00041175
Increased number of cases in population:	-0.000052	-0.000014	-0.0000032	-0.0000069	-0.000047	-0.0000020	-0.0000014	-0.0000052
Roselands								
Total Population in study area:	5561	5561	5561	5561	5561	5561	5561	5561
total change	-18.3	-18.3	-18.3	-18.3	-18.3	-18.3	-18.3	-18.3
Population weighted Δx (μg/m^3):	-0.00329078	-0.00329078	-0.00329078	-0.00329078	-0.00329078	-0.00329078	-0.00329078	-0.00329078
Increased number of cases in population:	-0.0006	-0.00018	-0.000039	-0.000084	-0.00057	-0.000025	-0.000017	-0.000063

	Primary Indicators			Secondary Indicators				
Health Endpoint:	**Mortality - All Causes, Long-term**	**Hospitalisations - Cardiovascular, Short-term**	**Hospitalisations - Respiratory, Short-term**	**Mortality - All Causes, Short-term**	**Mortality - Cardiopulmonary, Long-term**	**Mortality - Cardiovascular, Short-term**	**Mortality - Respiratory, Short-term**	**Morbidity - Asthma ED Admissions - Short-term**
Age Group:	≥ 30 years	≥ 65 years	≥ 65 years	All ages	≥ 30 years	All ages	All ages	1-14 years
β (change in effect per 1 μg/m^3 PM) (as per Table 6-22)	0.0058	0.0008	0.00041	0.00094	0.013	0.00097	0.0019	0.00148
Georges River LGA								
Total Population in study area:	66896	66896	66896	66896	66896	66896	66896	66896
% population in assessment age-group:	61%	15%	15%	100%	61%	100%	100%	16%
Population weighted Δx (μg/m^3):	-0.00603325	-0.00603325	-0.00603325	-0.00603325	-0.00603325	-0.00603325	-0.00603325	-0.00603325
Baseline Incidence (per 100,000) (as per Table 4-5)	1026	9235	3978	465.5	412.0	131.3	49.4	1209.0
Baseline Incidence (per person)	0.01026	0.09235	0.03978	0.00466	0.00412	0.00131	0.00049	0.01209
Increased number of cases in population:	-0.015	-0.0046	-0.0010	-0.0018	-0.013	-0.00051	-0.00038	-0.0012
Risk:	-3.6E-07	-4.5E-07	-9.8E-08	-2.6E-08	-3.2E-07	-7.7E-09	-5.7E-09	-1.1E-07
Individual subrubs within LGA								
Hurstville								
Total Population in study area:	20164	20164	20164	20164	20164	20164	20164	20164
total change	-153.8	-153.8	-153.8	-153.8	-153.8	-153.8	-153.8	-153.8
Population weighted Δx (μg/m^3):	-0.00762745	-0.00762745	-0.00762745	-0.00762745	-0.00762745	-0.00762745	-0.00762745	-0.00762745
Increased number of cases in population:	-0.0056	-0.0017	-0.00039	-0.00067	-0.0050	-0.00020	-0.00014	-0.00045
Kogorah								
Total Population in study area:	9484	9484	9484	9484	9484	9484	9484	9484
total change	-91.5	-91.5	-91.5	-91.5	-91.5	-91.5	-91.5	-91.5
Population weighted Δx (μg/m^3):	-0.00964783	-0.00964783	-0.00964783	-0.00964783	-0.00964783	-0.00964783	-0.00964783	-0.00964783
Increased number of cases in population:	-0.0033	-0.0010	-0.00023	-0.00040	-0.0030	-0.000117	-0.000086	-0.00027
Kogorah Bay								
Total Population in study area:	9469	9469	9469	9469	9469	9469	9469	9469
total change	-42	-42	-42	-42	-42	-42	-42	-42
Population weighted Δx (μg/m^3):	-0.00443553	-0.00443553	-0.00443553	-0.00443553	-0.00443553	-0.00443553	-0.00443553	-0.00443553
Increased number of cases in population:	-0.0015	-0.00048	-0.00011	-0.00018	-0.0014	-0.000053	-0.000039	-0.00012
Mortdale								
Total Population in study area:	11002	11002	11002	11002	11002	11002	11002	11002
total change	-46.4	-46.4	-46.4	-46.4	-46.4	-46.4	-46.4	-46.4
Population weighted Δx (μg/m^3):	-0.00421742	-0.00421742	-0.00421742	-0.00421742	-0.00421742	-0.00421742	-0.00421742	-0.00421742
Increased number of cases in population:	-0.0017	-0.00053	-0.00012	-0.00020	-0.0015	-0.000059	-0.000044	-0.000136
Narwee								
Total Population in study area:	4884	4884	4884	4884	4884	4884	4884	4884
total change	-74.4	-74.4	-74.4	-74.4	-74.4	-74.4	-74.4	-74.4
Population weighted Δx (μg/m^3):	-0.01523342	-0.01523342	-0.01523342	-0.01523342	-0.01523342	-0.01523342	-0.01523342	-0.01523342
Increased number of cases in population:	-0.0027	-0.00085	-0.00019	-0.00033	-0.0024	-0.000095	-0.000070	-0.00022
Oatley								
Total Population in study area:	4322	4322	4322	4322	4322	4322	4322	4322
total change	18.7	18.7	18.7	18.7	18.7	18.7	18.7	18.7
Population weighted Δx (μg/m^3):	0.00432670	0.00432670	0.00432670	0.00432670	0.00432670	0.00432670	0.00432670	0.00432670
Increased number of cases in population:	0.00068	0.00021	0.000047	0.000082	0.00061	0.000024	0.000018	0.000055
South Hurstville								
Total Population in study area:	7571	7571	7571	7571	7571	7571	7571	7571
total change	-14.1	-14.1	-14.1	-14.1	-14.1	-14.1	-14.1	-14.1
Population weighted Δx (μg/m^3):	-0.00186237	-0.00186237	-0.00186237	-0.00186237	-0.00186237	-0.00186237	-0.00186237	-0.00186237
Increased number of cases in population:	-0.00051	-0.00016	-0.000035	-0.000062	-0.00046	-0.000018	-0.000013	-0.000041
Total population incidence - All Suburbs	**-0.4**	**-0.09**	**-0.02**	**-0.06**	**-0.4**	**-0.02**	**-0.01**	**-0.03**

Assessment of Increased Incidence - $PM_{2.5}$
M4-M5 Link: 2023 Cumulative

	Primary Indicators			Secondary Indicators				
Health Endpoint:	**Mortality - All Causes, Long-term**	**Hospitalisations - Cardiovascular, Short-term**	**Hospitalisations - Respiratory, Short-term**	**Mortality - All Causes, Short-term**	**Mortality - Cardiopulmonary, Long-term**	**Mortality - Cardiovascular, Short-term**	**Mortality - Respiratory, Short-term**	**Morbidity - Asthma ED Admissions - Short-term**
Age Group:	≥ 30 years	≥ 65 years	≥ 65 years	All ages	≥ 30 years	All ages	All ages	1-14 years
β (change in effect per 1 μg/m^3 PM) (as per Table 6-22)	0.0058	0.0008	0.00041	0.00094	0.013	0.00097	0.0019	0.00148
Canada Bay LGA								
Total Population in study area:	67644	67644	67644	67644	67644	67644	67644	67644
% population in assessment age-group:	63%	14%	14%	100%	63%	100%	100%	16%
Population weighted Δx (μg/m^3):	0.01160739	0.01160739	0.01160739	0.01160739	0.01160739	0.01160739	0.01160739	0.01160739
Baseline Incidence (per 100,000) (as per Table 4-5)	1026	9235	3978	403.3	412.0	113.4	49.4	1209.0
Baseline Incidence (per person)	0.01026	0.09235	0.03978	0.00403	0.00412	0.00113	0.00049	0.01209
Increased number of cases in population:	0.030	0.0081	0.0018	0.0030	0.027	0.00086	0.00074	0.0022
Risk:	6.9E-07	8.6E-07	1.9E-07	4.4E-08	6.2E-07	1.3E-08	1.1E-08	2.1E-07
Individual subrubs within LGA								
Concord - Mortlake - Cabarita								
Total Population in study area:	19204	19204	19204	19204	19204	19204	19204	19204
total change	200.1	200.1	200.1	200.1	200.1	200.1	200.1	200.1
Population weighted Δx (μg/m^3):	0.01041970	0.01041970	0.01041970	0.01041970	0.01041970	0.01041970	0.01041970	0.01041970
Attributable fraction (AF):	6.0E-05	8.3E-06	4.3E-06	9.8E-06	1.4E-04	1.0E-05	2.0E-05	1.5E-05
Increased number of cases in population:	0.0075	0.0021	0.0005	0.0008	0.0068	0.00022	0.00019	0.0006
Concord West								
Total Population in study area:	10692	10692	10692	10692	10692	10692	10692	10692
total change	159.7	159.7	159.7	159.7	159.7	159.7	159.7	159.7
Population weighted Δx (μg/m^3):	0.01493640	0.01493640	0.01493640	0.01493640	0.01493640	0.01493640	0.01493640	0.01493640
Increased number of cases in population:	0.0060	0.0017	0.0004	0.0006	0.0054	0.0002	0.00015	0.0004
Drummoyne - Rodd Pt								
Total Population in study area:	17456	17456	17456	17456	17456	17456	17456	17456
total change	509.8	509.8	509.8	509.8	509.8	509.8	509.8	509.8
Population weighted Δx (μg/m^3):	0.02920486	0.02920486	0.02920486	0.02920486	0.02920486	0.02920486	0.02920486	0.02920486
Increased number of cases in population:	0.019	0.0053	0.0012	0.0019	0.0173	0.0006	0.00048	0.0014
Five Dock								
Total Population in study area:	19111	19111	19111	19111	19111	19111	19111	19111
total change	-110	-110	-110	-110	-110	-110	-110	-110
Population weighted Δx (μg/m^3):	-0.00575585	-0.00575585	-0.00575585	-0.00575585	-0.00575585	-0.00575585	-0.00575585	-0.00575585
Increased number of cases in population:	-0.0042	-0.0011	-0.0003	-0.0004	-0.0037	-0.00012	-0.00010	-0.0003
Gladesville								
Total Population in study area:	590	590	590	590	590	590	590	590
total change	12.6	12.6	12.6	12.6	12.6	12.6	12.6	12.6
Population weighted Δx (μg/m^3):	0.02135593	0.02135593	0.02135593	0.02135593	0.02135593	0.02135593	0.02135593	0.02135593
Increased number of cases in population:	0.00048	0.00013	0.000029	0.000048	0.00043	0.000014	0.000012	0.000035
Hunters Hill								
Total Population in study area:	591	591	591	591	591	591	591	591
total change	13	13	13	13	13	13	13	13
Population weighted Δx (μg/m^3):	0.02199662	0.02199662	0.02199662	0.02199662	0.02199662	0.02199662	0.02199662	0.02199662
Increased number of cases in population:	0.00049	0.00013	0.000030	0.000049	0.00044	0.000014	0.000012	0.000036

	Primary Indicators			Secondary Indicators				
Health Endpoint:	**Mortality - All Causes, Long-term**	**Hospitalisations - Cardiovascular, Short-term**	**Hospitalisations - Respiratory, Short-term**	**Mortality - All Causes, Short-term**	**Mortality - Cardiopulmonary, Long-term**	**Mortality - Cardiovascular, Short-term**	**Mortality - Respiratory, Short-term**	**Morbidity - Asthma ED Admissions - Short-term**
Age Group:	≥ 30 years	≥ 65 years	≥ 65 years	All ages	≥ 30 years	All ages	All ages	1-14 years
β (change in effect per 1 μg/m^3 PM) (as per Table 6-22)	0.0058	0.0008	0.00041	0.00094	0.013	0.00097	0.0019	0.00148
Strathfield LGA								
Total Population in study area:	25473	25473	25473	25473	25473	25473	25473	25473
% population in assessment age-group:	60%	13%	13%	100%	60%	100%	100%	14%
Population weighted Δx (μg/m^3):	-0.00398069	-0.00398069	-0.00398069	-0.00398069	-0.00398069	-0.00398069	-0.00398069	-0.00398069
Baseline Incidence (per 100,000) (as per Table 4-5)	1026	9235	3978	443.1	412.0	135.2	49.4	1209.0
Baseline Incidence (per person)	0.01026	0.09235	0.03978	0.00443	0.00412	0.00135	0.00049	0.01209
Increased number of cases in population:	-0.0036	-0.0010	-0.00022	-0.00042	-0.0032	-0.00013	-0.00010	-0.00026
Risk:	-2.4E-07	-2.9E-07	-6.5E-08	-1.7E-08	-2.1E-07	-5.2E-09	-3.7E-09	-7.1E-08
Individual subrubs within LGA								
Homebush								
Total Population in study area:	5075	5075	5075	5075	5075	5075	5075	5075
total change	-25.3	-25.3	-25.3	-25.3	-25.3	-25.3	-25.3	-25.3
Population weighted Δx (μg/m^3):	-0.00498522	-0.00498522	-0.00498522	-0.00498522	-0.00498522	-0.00498522	-0.00498522	-0.00498522
Increased number of cases in population:	-0.0009	-0.00024	-0.000054	-0.000105	-0.00081	-0.000033	-0.0000237	-0.000065
Homebush Bay								
Total Population in study area:	63	63	63	63	63	63	63	63
total change	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4
Population weighted Δx (μg/m^3):	0.02222222	0.02222222	0.02222222	0.02222222	0.02222222	0.02222222	0.02222222	0.02222222
Increased number of cases in population:	0.000050	0.000014	0.0000030	0.0000058	0.000045	0.0000018	0.0000013	0.0000036
Strathfield								
Total Population in study area:	20335	20335	20335	20335	20335	20335	20335	20335
total change	-77.5	-77.5	-77.5	-77.5	-77.5	-77.5	-77.5	-77.5
Population weighted Δx (μg/m^3):	-0.00381116	-0.00381116	-0.00381116	-0.00381116	-0.00381116	-0.00381116	-0.00381116	-0.00381116
Increased number of cases in population:	-0.0028	-0.0008	-0.00017	-0.00032	-0.0025	-0.00010	-0.000073	-0.00020
Burwood LGA								
Total Population in study area:	20986	20986	20986	20986	20986	20986	20986	20986
% population in assessment age-group:	60%	13%	13%	100%	60%	100%	100%	14%
Population weighted Δx (μg/m^3):	-0.00176785	-0.00176785	-0.00176785	-0.00176785	-0.00176785	-0.00176785	-0.00176785	-0.00176785
Baseline Incidence (per 100,000) (as per Table 4-5)	1026	9235	3978	555.6	412.0	138.0	49.4	1209.0
Baseline Incidence (per person)	0.01026	0.09235	0.03978	0.00556	0.00412	0.00138	0.00049	0.01209
Increased number of cases in population:	-0.0013	-0.00036	-0.000079	-0.00019	-0.0012	-0.000050	-0.000035	-0.000095
Risk:	-1.1E-07	-1.3E-07	-2.9E-08	-9.2E-09	-9.5E-08	-2.4E-09	-1.7E-09	-3.2E-08

	Primary Indicators			Secondary Indicators				
Health Endpoint:	**Mortality - All Causes, Long-term**	**Hospitalisations - Cardiovascular, Short-term**	**Hospitalisations - Respiratory, Short-term**	**Mortality - All Causes, Short-term**	**Mortality - Cardiopulmonary, Long-term**	**Mortality - Cardiovascular, Short-term**	**Mortality - Respiratory, Short-term**	**Morbidity - Asthma ED Admissions - Short-term**
Age Group:	≥ 30 years	≥ 65 years	≥ 65 years	All ages	≥ 30 years	All ages	All ages	1-14 years
β (change in effect per 1 μg/m³ PM) (as per Table 6-22)	0.0058	0.0008	0.00041	0.00094	0.013	0.00097	0.0019	0.00148
Sydney Inner West LGA								
Total Population in study area:	180589	180589	180589	180589	180589	180589	180589	180589
% population in assessment age-group:	67%	10%	10%	100%	67%	100%	100%	15%
Population weighted Δx (μg/m³):	-0.04449108	-0.04449108	-0.04449108	-0.04449108	-0.04449108	-0.04449108	-0.04449108	-0.04449108
Baseline Incidence (per 100,000) (as per Table 4-5)	1026	9235	3978	534.2	412.0	146.4	49.4	1209.0
Baseline Incidence (per person)	0.01026	0.09235	0.03978	0.00534	0.00412	0.00146	0.00049	0.01209
Increased number of cases in population:	-0.32	-0.061	-0.013	-0.040	-0.29	-0.011	-0.0075	-0.021
Risk:	-2.6E-06	-3.3E-06	-7.3E-07	-2.2E-07	-2.4E-06	-6.3E-08	-4.2E-08	-8.0E-07
Individual subrubs within LGA								
Ashfield								
Total Population in study area:	22769	22769	22769	22769	22769	22769	22769	22769
total change	-379.4	-379.4	-379.4	-379.4	-379.4	-379.4	-379.4	-379.4
Population weighted Δx (μg/m³):	-0.01666301	-0.01666301	-0.01666301	-0.01666301	-0.01666301	-0.01666301	-0.01666301	-0.01666301
Increased number of cases in population:	-0.015	-0.0029	-0.0006	-0.0019	-0.0137	-0.00054	-0.00036	-0.0010
Canterbury North-Ashbury								
Total Population in study area:	9390	9390	9390	9390	9390	9390	9390	9390
total change	-113.8	-113.8	-113.8	-113.8	-113.8	-113.8	-113.8	-113.8
Population weighted Δx (μg/m³):	-0.01211928	-0.01211928	-0.01211928	-0.01211928	-0.01211928	-0.01211928	-0.01211928	-0.01211928
Increased number of cases in population:	-0.0046	-0.0009	-0.0002	-0.0006	-0.0041	-0.0002	-0.00011	-0.0003
Croyden Park								
Total Population in study area:	16360	16360	16360	16360	16360	16360	16360	16360
total change	-246	-246	-246	-246	-246	-246	-246	-246
Population weighted Δx (μg/m³):	-0.01503667	-0.01503667	-0.01503667	-0.01503667	-0.01503667	-0.01503667	-0.01503667	-0.01503667
Increased number of cases in population:	-0.0098	-0.0019	-0.0004	-0.0012	-0.0089	-0.0003	-0.0002	-0.0007
Dulwich Hill								
Total Population in study area:	15862	15862	15862	15862	15862	15862	15862	15862
Population weighted Δx (μg/m³):	-0.04342454	-0.04342454	-0.04342454	-0.04342454	-0.04342454	-0.04342454	-0.04342454	-0.04342454
Increased number of cases in population:	-0.028	-0.0052	-0.0011	-0.0035	-0.0248	-0.0010	-0.0006	-0.0018
Haberfield								
Total Population in study area:	13245	13245	13245	13245	13245	13245	13245	13245
total change	-1236.1	-1236.1	-1236.1	-1236.1	-1236.1	-1236.1	-1236.1	-1236.1
Population weighted Δx (μg/m³):	-0.09332578	-0.09332578	-0.09332578	-0.09332578	-0.09332578	-0.09332578	-0.09332578	-0.09332578
Increased number of cases in population:	-0.049	-0.0093	-0.0021	-0.0062	-0.0445	-0.0018	-0.0012	-0.0033
Balmain								
Total Population in study area:	14794	14794	14794	14794	14794	14794	14794	14794
total change	145.8	145.8	145.8	145.8	145.8	145.8	145.8	145.8
Population weighted Δx (μg/m³):	0.00985535	0.00985535	0.00985535	0.00985535	0.00985535	0.00985535	0.00985535	0.00985535
Increased number of cases in population:	0.0058	0.0011	0.0002	0.00073	0.0052	0.00021	0.00014	0.0004
Leichhardt								
Total Population in study area:	24443	24443	24443	24443	24443	24443	24443	24443
total change	-1957	-1957	-1957	-1957	-1957	-1957	-1957	-1957
Population weighted Δx (μg/m³):	-0.08006382	-0.08006382	-0.08006382	-0.08006382	-0.08006382	-0.08006382	-0.08006382	-0.08006382
Increased number of cases in population:	-0.078	-0.0147	-0.0033	-0.0098	-0.0705	-0.0028	-0.0018	-0.0052
Lilyfield								
Total Population in study area:	13073	13073	13073	13073	13073	13073	13073	13073
total change	-934.3	-934.3	-934.3	-934.3	-934.3	-934.3	-934.3	-934.3
Population weighted Δx (μg/m³):	-0.07146791	-0.07146791	-0.07146791	-0.07146791	-0.07146791	-0.07146791	-0.07146791	-0.07146791
Increased number of cases in population:	-0.037	-0.0070	-0.0016	-0.0047	-0.0336	-0.0013	-0.0009	-0.0025
Marrickville								
Total Population in study area:	24632	24632	24632	24632	24632	24632	24632	24632
total change	-898.1	-898.1	-898.1	-898.1	-898.1	-898.1	-898.1	-898.1
Population weighted Δx (μg/m³):	-0.03646070	-0.03646070	-0.03646070	-0.03646070	-0.03646070	-0.03646070	-0.03646070	-0.03646070
Increased number of cases in population:	-0.036	-0.0068	-0.0015	-0.0045	-0.0323	-0.0013	-0.0008	-0.0024
Petersham								
Total Population in study area:	18817	18817	18817	18817	18817	18817	18817	18817
total change	-1795.9	-1795.9	-1795.9	-1795.9	-1795.9	-1795.9	-1795.9	-1795.9
Population weighted Δx (μg/m³):	-0.09544029	-0.09544029	-0.09544029	-0.09544029	-0.09544029	-0.09544029	-0.09544029	-0.09544029
Increased number of cases in population:	-0.072	-0.0135	-0.0030	-0.0090	-0.0647	-0.0026	-0.0017	-0.0048
Sydenham								
Total Population in study area:	7204	7204	7204	7204	7204	7204	7204	7204
total change	69.1	69.1	69.1	69.1	69.1	69.1	69.1	69.1
Population weighted Δx (μg/m³):	0.00959189	0.00959189	0.00959189	0.00959189	0.00959189	0.00959189	0.00959189	0.00959189
Increased number of cases in population:	0.0028	0.0005	0.00011	0.0003	0.0025	0.000098	0.000065	0.0002

	Primary Indicators			Secondary Indicators				
Health Endpoint:	**Mortality - All Causes, Long-term**	**Hospitalisations - Cardiovascular, Short-term**	**Hospitalisations - Respiratory, Short-term**	**Mortality - All Causes, Short-term**	**Mortality - Cardiopulmonary, Long-term**	**Mortality - Cardiovascular, Short-term**	**Mortality - Respiratory, Short-term**	**Morbidity - Asthma ED Admissions - Short-term**
Age Group:	≥ 30 years	≥ 65 years	≥ 65 years	All ages	≥ 30 years	All ages	All ages	1-14 years
β (change in effect per 1 μg/m^3 PM) (as per Table 6-22)	0.0058	0.0008	0.00041	0.00094	0.013	0.00097	0.0019	0.00148
Sydney LGA								
Total Population in study area:	125509	125509	125509	125509	125509	125509	125509	125509
% population in assessment age-group:	59%	8%	8%	100%	59%	100%	100%	6%
Population weighted Δx (μg/m^3):	-0.01002398	-0.01002398	-0.01002398	-0.01002398	-0.01002398	-0.01002398	-0.01002398	-0.01002398
Baseline Incidence (per 100,000) (as per Table 4-5)	1026	9235	3978	508.0	412.0	138.9	49.4	1209.0
Baseline Incidence (per person)	0.01026	0.09235	0.03978	0.00508	0.00412	0.00139	0.00049	0.01209
Increased number of cases in population:	-0.044	-0.0073	-0.0016	-0.0060	-0.040	-0.0017	-0.0012	-0.0014
Risk:	-6.0E-07	-7.4E-07	-1.6E-07	-4.8E-08	-5.4E-07	-1.4E-08	-9.4E-09	-1.8E-07
Individual subrubs within LGA								
Erskinville								
Total Population in study area:	13908	13908	13908	13908	13908	13908	13908	13908
total change	-515.3	-515.3	-515.3	-515.3	-515.3	-515.3	-515.3	-515.3
Population weighted Δx (μg/m^3):	-0.03705062	-0.03705062	-0.03705062	-0.03705062	-0.03705062	-0.03705062	-0.03705062	-0.03705062
Increased number of cases in population:	-0.018	-0.0030	-0.0007	-0.0025	-0.0163	-0.0007	-0.0005	-0.0006
Glebe								
Total Population in study area:	16595	16595	16595	16595	16595	16595	16595	16595
total change	-232	-232	-232	-232	-232	-232	-232	-232
Population weighted Δx (μg/m^3):	-0.01398011	-0.01398011	-0.01398011	-0.01398011	-0.01398011	-0.01398011	-0.01398011	-0.01398011
Increased number of cases in population:	-0.0082	-0.0013	-0.0003	-0.0011	-0.0073	-0.0003	-0.0002	-0.0003
Newtown								
Total Population in study area:	21480	21480	21480	21480	21480	21480	21480	21480
total change	-557.5	-557.5	-557.5	-557.5	-557.5	-557.5	-557.5	-557.5
Population weighted Δx (μg/m^3):	-0.02595438	-0.02595438	-0.02595438	-0.02595438	-0.02595438	-0.02595438	-0.02595438	-0.02595438
Increased number of cases in population:	-0.020	-0.0032	-0.0007	-0.0027	-0.0177	-0.0008	-0.0005	-0.0006
Pyrmont								
Total Population in study area:	18720	18720	18720	18720	18720	18720	18720	18720
total change	892.8	892.8	892.8	892.8	892.8	892.8	892.8	892.8
Population weighted Δx (μg/m^3):	0.04769231	0.04769231	0.04769231	0.04769231	0.04769231	0.04769231	0.04769231	0.04769231
Increased number of cases in population:	0.031	0.0051	0.0011	0.0043	0.0283	0.0012	0.0008	0.0010
Redfern								
Total Population in study area:	12628	12628	12628	12628	12628	12628	12628	12628
total change	-558	-558	-558	-558	-558	-558	-558	-558
Population weighted Δx (μg/m^3):	-0.04418752	-0.04418752	-0.04418752	-0.04418752	-0.04418752	-0.04418752	-0.04418752	-0.04418752
Increased number of cases in population:	-0.020	-0.0032	-0.0007	-0.0027	-0.0177	-0.0008	-0.0005	-0.0006
Surry Hills								
Total Population in study area:	4190	4190	4190	4190	4190	4190	4190	4190
total change	-29.2	-29.2	-29.2	-29.2	-29.2	-29.2	-29.2	-29.2
Population weighted Δx (μg/m^3):	-0.00696897	-0.00696897	-0.00696897	-0.00696897	-0.00696897	-0.00696897	-0.00696897	-0.00696897
Increased number of cases in population:	-0.0010	-0.00017	-0.000037	-0.000139	-0.00092	-0.000039	-0.0000274	-0.0000324
Sydney								
Total Population in study area:	21726	21726	21726	21726	21726	21726	21726	21726
total change	-77.2	-77.2	-77.2	-77.2	-77.2	-77.2	-77.2	-77.2
Population weighted Δx (μg/m^3):	-0.00355335	-0.00355335	-0.00355335	-0.00355335	-0.00355335	-0.00355335	-0.00355335	-0.00355335
Increased number of cases in population:	-0.0027	-0.0004	-0.00010	-0.00037	-0.0024	-0.000104	-0.00007	-0.00009
Waterloo								
Total Population in study area:	11306	11306	11306	11306	11306	11306	11306	11306
total change	-198.8	-198.8	-198.8	-198.8	-198.8	-198.8	-198.8	-198.8
Population weighted Δx (μg/m^3):	-0.01758358	-0.01758358	-0.01758358	-0.01758358	-0.01758358	-0.01758358	-0.01758358	-0.01758358
Increased number of cases in population:	-0.0070	-0.0011	-0.0003	-0.0009	-0.0063	-0.0003	-0.0002	-0.0002
Crows Nest								
Total Population in study area:	50	50	50	50	50	50	50	50
total change	-0.3	-0.3	-0.3	-0.3	-0.3	-0.3	-0.3	-0.3
Population weighted Δx (μg/m^3):	-0.00600000	-0.00600000	-0.00600000	-0.00600000	-0.00600000	-0.00600000	-0.00600000	-0.00600000
Increased number of cases in population:	-0.000011	-0.0000017	-0.00000038	-0.0000014	-0.00000950	-0.00000040	-0.00000028	-0.00000033
North Sydney								
Total Population in study area:	4906	4906	4906	4906	4906	4906	4906	4906
total change	17.3	17.3	17.3	17.3	17.3	17.3	17.3	17.3
Population weighted Δx (μg/m^3):	0.00352629	0.00352629	0.00352629	0.00352629	0.00352629	0.00352629	0.00352629	0.00352629
Increased number of cases in population:	0.00061	0.000100	0.000022	0.000083	0.00055	0.000023	0.000016	0.000019

	Primary Indicators			Secondary Indicators				
Health Endpoint:	**Mortality - All Causes, Long-term**	**Hospitalisations - Cardiovascular, Short-term**	**Hospitalisations - Respiratory, Short-term**	**Mortality - All Causes, Short-term**	**Mortality - Cardiopulmonary, Long-term**	**Mortality - Cardiovascular, Short-term**	**Mortality - Respiratory, Short-term**	**Morbidity - Asthma ED Admissions - Short-term**
Age Group:	≥ 30 years	≥ 65 years	≥ 65 years	All ages	≥ 30 years	All ages	All ages	1-14 years
β (change in effect per 1 $\mu g/m^3$ PM) (as per Table 6-22)	0.0058	0.0008	0.00041	0.00094	0.013	0.00097	0.0019	0.00148
Botany LGA								
Total Population in study area:	25700	25700	25700	25700	25700	25700	25700	25700
% population in assessment age-group:	62%	14%	14%	100%	62%	100%	100%	17%
Population weighted Δx ($\mu g/m^3$):	-0.01624514	-0.01624514	-0.01624514	-0.01624514	-0.01624514	-0.01624514	-0.01624514	-0.01624514
Baseline Incidence (per 100,000) (as per Table 4-5)	1026	9235	3978	523.8	412.0	150.0	49.4	1209.0
Baseline Incidence (per person)	0.01026	0.09235	0.03978	0.00524	0.00412	0.00150	0.00049	0.01209
Increased number of cases in population:	-0.015	-0.0044	-0.0010	-0.0021	-0.014	-0.00061	-0.00039	-0.0013
Risk:	-9.7E-07	-1.2E-06	-2.6E-07	-8.0E-08	-8.7E-07	-2.4E-08	-1.5E-08	-2.9E-07
Individual subrubs within LGA								
Botany								
Total Population in study area:	8915	8915	8915	8915	8915	8915	8915	8915
total change	-31.6	-31.6	-31.6	-31.6	-31.6	-31.6	-31.6	-31.6
Population weighted Δx ($\mu g/m^3$):	-0.00354459	-0.00354459	-0.00354459	-0.00354459	-0.00354459	-0.00354459	-0.00354459	-0.00354459
Increased number of cases in population:	-0.0012	-0.0003	-0.000074	-0.00016	-0.0010	-0.000046	-0.000030	-0.000095
Mascot								
Total Population in study area:	16215	16215	16215	16215	16215	16215	16215	16215
total change	-383.4	-383.4	-383.4	-383.4	-383.4	-383.4	-383.4	-383.4
Population weighted Δx ($\mu g/m^3$):	-0.02364477	-0.02364477	-0.02364477	-0.02364477	-0.02364477	-0.02364477	-0.02364477	-0.02364477
Increased number of cases in population:	-0.014	-0.0041	-0.00090	-0.0019	-0.0127	-0.00056	-0.00036	-0.0012
Pagewood								
Total Population in study area:	567	567	567	567	567	567	567	567
total change	-2.9	-2.9	-2.9	-2.9	-2.9	-2.9	-2.9	-2.9
Population weighted Δx ($\mu g/m^3$):	-0.00511464	-0.00511464	-0.00511464	-0.00511464	-0.00511464	-0.00511464	-0.00511464	-0.00511464
Increased number of cases in population:	-0.00011	-0.000031	-0.0000068	-0.000014	-0.000096	-0.0000042	-0.00000272	-0.0000087

	Primary Indicators			Secondary Indicators				
Health Endpoint:	**Mortality - All Causes, Long-term**	**Hospitalisations - Cardiovascular, Short-term**	**Hospitalisations - Respiratory, Short-term**	**Mortality - All Causes, Short-term**	**Mortality - Cardiopulmonary, Long-term**	**Mortality - Cardiovascular, Short-term**	**Mortality - Respiratory, Short-term**	**Morbidity - Asthma ED Admissions - Short-term**
Age Group:	≥ 30 years	≥ 65 years	≥ 65 years	All ages	≥ 30 years	All ages	All ages	1-14 years
β (change in effect per 1 μg/m^3 PM) (as per Table 6-22)	0.0058	0.0008	0.00041	0.00094	0.013	0.00097	0.0019	0.00148
Rockdale LGA								
Total Population in study area:	82293	82293	82293	82293	82293	82293	82293	82293
% population in assessment age-group:	62%	15%	15%	100%	62%	100%	100%	16%
Population weighted Δx (μg/m^3):	-0.02343334	-0.02343334	-0.02343334	-0.02343334	-0.02343334	-0.02343334	-0.02343334	-0.02343334
Baseline Incidence (per 100,000) (as per Table 4-5)	1026	9235	3978	534.5	412.0	150.0	49.4	1209.0
Baseline Incidence (per person)	0.01026	0.09235	0.03978	0.00535	0.00412	0.00150	0.00049	0.01209
Increased number of cases in population:	-0.071	-0.021	-0.0047	-0.0097	-0.064	-0.0028	-0.0018	-0.0055
Risk:	-1.4E-06	-1.7E-06	-3.8E-07	-1.2E-07	-1.3E-06	-3.4E-08	-2.2E-08	-4.2E-07
Individual subrubs within LGA								
Arncliffe								
Total Population in study area:	14669	14669	14669	14669	14669	14669	14669	14669
total change	-644.5	-644.5	-644.5	-644.5	-644.5	-644.5	-644.5	-644.5
Population weighted Δx (μg/m^3):	-0.043936	-0.04393619	-0.04393619	-0.04393619	-0.04393619	-0.04393619	-0.04393619	-0.04393619
Increased number of cases in population:	-0.024	-0.0070	-0.0016	-0.0032	-0.0213	-0.0009	-0.0006	-0.0018
Bexley								
Total Population in study area:	25123	25123	25123	25123	25123	25123	25123	25123
total change	-341.8	-341.8	-341.8	-341.8	-341.8	-341.8	-341.8	-341.8
Population weighted Δx (μg/m^3):	-0.01360506	-0.01360506	-0.01360506	-0.01360506	-0.01360506	-0.01360506	-0.01360506	-0.01360506
Increased number of cases in population:	-0.013	-0.0037	-0.0008	-0.0017	-0.0113	-0.0005	-0.0003	-0.0010
Kingsgrove - South								
Total Population in study area:	11981	11981	11981	11981	11981	11981	11981	11981
total change	-653.3	-653.3	-653.3	-653.3	-653.3	-653.3	-653.3	-653.3
Population weighted Δx (μg/m^3):	-0.05452800	-0.05452800	-0.05452800	-0.05452800	-0.05452800	-0.05452800	-0.05452800	-0.05452800
Increased number of cases in population:	-0.024	-0.0071	-0.0016	-0.0033	-0.0216	-0.0010	-0.0006	-0.0019
Monterey								
Total Population in study area:	12192	12192	12192	12192	12192	12192	12192	12192
total change	-75.5	-75.5	-75.5	-75.5	-75.5	-75.5	-75.5	-75.5
Population weighted Δx (μg/m^3):	-0.00619259	-0.00619259	-0.00619259	-0.00619259	-0.00619259	-0.00619259	-0.00619259	-0.00619259
Increased number of cases in population:	-0.0028	-0.00083	-0.00018	-0.00038	-0.0025	-0.000110	-0.000071	-0.00022
Rockdale								
Total Population in study area:	18328	18328	18328	18328	18328	18328	18328	18328
total change	-213.3	-213.3	-213.3	-213.3	-213.3	-213.3	-213.3	-213.3
Population weighted Δx (μg/m^3):	-0.01163793	-0.01163793	-0.01163793	-0.01163793	-0.01163793	-0.01163793	-0.01163793	-0.01163793
Increased number of cases in population:	-0.0078	-0.0023	-0.0005	-0.0011	-0.0070	-0.0003	-0.0002	-0.0006

	Primary Indicators			Secondary Indicators				
Health Endpoint:	**Mortality - All Causes, Long-term**	**Hospitalisations - Cardiovascular, Short-term**	**Hospitalisations - Respiratory, Short-term**	**Mortality - All Causes, Short-term**	**Mortality - Cardiopulmonary, Long-term**	**Mortality - Cardiovascular, Short-term**	**Mortality - Respiratory, Short-term**	**Morbidity - Asthma ED Admissions - Short-term**
Age Group:	≥ 30 years	≥ 65 years	≥ 65 years	All ages	≥ 30 years	All ages	All ages	1-14 years
β (change in effect per 1 μg/m^3 PM) (as per Table 6-22)	0.0058	0.0008	0.00041	0.00094	0.013	0.00097	0.0019	0.00148
Canterbury - Bankstown LGA								
Total Population in study area:	76834	76834	76834	76834	76834	76834	76834	76834
% population in assessment age-group:	58%	13%	13%	100%	58%	100%	100%	19%
Population weighted Δx (μg/m^3):	-0.02034906	-0.02034906	-0.02034906	-0.02034906	-0.02034906	-0.02034906	-0.02034906	-0.02034906
Baseline Incidence (per 100,000) (as per Table 4-5)	1026	9235	3978	490.6	412.0	139.2	49.4	1209.0
Baseline Incidence (per person)	0.01026	0.09235	0.03978	0.00491	0.00412	0.00139	0.00049	0.01209
Increased number of cases in population:	-0.054	-0.015	-0.0033	-0.0072	-0.049	-0.0021	-0.0015	-0.0054
Risk:	-1.2E-06	-1.5E-06	-3.3E-07	-9.4E-08	-1.1E-06	-2.7E-08	-1.9E-08	-3.6E-07
Individual subrubs within LGA								
Belmore								
Total Population in study area:	18330	18330	18330	18330	18330	18330	18330	18330
total change	-242.7	-242.7	-242.7	-242.7	-242.7	-242.7	-242.7	-242.7
Population weighted Δx (μg/m^3):	-0.01324059	-0.01324059	-0.01324059	-0.01324059	-0.01324059	-0.01324059	-0.01324059	-0.01324059
Increased number of cases in population:	-0.0084	-0.0023	-0.0005	-0.0011	-0.0076	-0.0003	-0.0002	-0.0008
Canterbury (South)								
Total Population in study area:	26841	26841	26841	26841	26841	26841	26841	26841
total change	-599.6	-599.6	-599.6	-599.6	-599.6	-599.6	-599.6	-599.6
Population weighted Δx (μg/m^3):	-0.02233896	-0.02233896	-0.02233896	-0.02233896	-0.02233896	-0.02233896	-0.02233896	-0.02233896
Increased number of cases in population:	-0.021	-0.0058	-0.0013	-0.0028	-0.0187	-0.0008	-0.0006	-0.0021
Kinsgrove - North								
Total Population in study area:	22489	22489	22489	22489	22489	22489	22489	22489
total change	-702.5	-702.5	-702.5	-702.5	-702.5	-702.5	-702.5	-702.5
Population weighted Δx (μg/m^3):	-0.03123749	-0.03123749	-0.03123749	-0.03123749	-0.03123749	-0.03123749	-0.03123749	-0.03123749
Increased number of cases in population:	-0.024	-0.0067	-0.0015	-0.0032	-0.0219	-0.0009	-0.0007	-0.0024
Lakemba								
Total Population in study area:	3643	3643	3643	3643	3643	3643	3643	3643
total change	-2.7	-2.7	-2.7	-2.7	-2.7	-2.7	-2.7	-2.7
Population weighted Δx (μg/m^3):	-0.00074115	-0.00074115	-0.00074115	-0.00074115	-0.00074115	-0.00074115	-0.00074115	-0.00074115
Increased number of cases in population:	-0.000094	-0.000026	-0.0000057	-0.000012	-0.000084	-0.0000036	-0.0000025	-0.0000093
Roselands								
Total Population in study area:	5531	5531	5531	5531	5531	5531	5531	5531
total change	-16	-16	-16	-16	-16	-16	-16	-16
Population weighted Δx (μg/m^3):	-0.00289279	-0.00289279	-0.00289279	-0.00289279	-0.00289279	-0.00289279	-0.00289279	-0.00289279
Increased number of cases in population:	-0.00055	-0.0002	-0.000034	-0.000074	-0.00050	-0.000022	-0.000015	-0.000055

	Primary Indicators			Secondary Indicators				
Health Endpoint:	**Mortality - All Causes, Long-term**	**Hospitalisations - Cardiovascular, Short-term**	**Hospitalisations - Respiratory, Short-term**	**Mortality - All Causes, Short-term**	**Mortality - Cardiopulmonary, Long-term**	**Mortality - Cardiovascular, Short-term**	**Mortality - Respiratory, Short-term**	**Morbidity - Asthma ED Admissions - Short-term**
Age Group:	≥ 30 years	≥ 65 years	≥ 65 years	All ages	≥ 30 years	All ages	All ages	1-14 years
β (change in effect per 1 μg/m^3 PM) (as per Table 6-22)	0.0058	0.0008	0.00041	0.00094	0.013	0.00097	0.0019	0.00148
Georges River LGA								
Total Population in study area:	66896	66896	66896	66896	66896	66896	66896	66896
% population in assessment age-group:	61%	15%	15%	100%	61%	100%	100%	16%
Population weighted Δx (μg/m^3):	-0.01062096	-0.01062096	-0.01062096	-0.01062096	-0.01062096	-0.01062096	-0.01062096	-0.01062096
Baseline Incidence (per 100,000) (as per Table 4-5)	1026	9235	3978	465.5	412.0	131.3	49.4	1209.0
Baseline Incidence (per person)	0.01026	0.09235	0.03978	0.00466	0.00412	0.00131	0.00049	0.01209
Increased number of cases in population:	-0.026	-0.0081	-0.0018	-0.0031	-0.023	-0.00090	-0.00067	-0.0021
Risk:	-6.3E-07	-7.8E-07	-1.7E-07	-4.6E-08	-5.7E-07	-1.4E-08	-1.0E-08	-1.9E-07
Individual subrubs within LGA								
Hurstville								
Total Population in study area:	20164	20164	20164	20164	20164	20164	20164	20164
total change	-231.3	-231.3	-231.3	-231.3	-231.3	-231.3	-231.3	-231.3
Population weighted Δx (μg/m^3):	-0.01147094	-0.01147094	-0.01147094	-0.01147094	-0.01147094	-0.01147094	-0.01147094	-0.01147094
Increased number of cases in population:	-0.0084	-0.0026	-0.0006	-0.0010	-0.0076	-0.0003	-0.0002	-0.0007
Kogorah								
Total Population in study area:	9484	9484	9484	9484	9484	9484	9484	9484
total change	-22	-22	-22	-22	-22	-22	-22	-22
Population weighted Δx (μg/m^3):	-0.00231970	-0.00231970	-0.00231970	-0.00231970	-0.00231970	-0.00231970	-0.00231970	-0.00231970
Increased number of cases in population:	-0.00080	-0.0003	-0.00006	-0.000096	-0.0007	-0.000028	-0.000021	-0.00006
Kogorah Bay								
Total Population in study area:	9469	9469	9469	9469	9469	9469	9469	9469
total change	-62.8	-62.8	-62.8	-62.8	-62.8	-62.8	-62.8	-62.8
Population weighted Δx (μg/m^3):	-0.00663217	-0.00663217	-0.00663217	-0.00663217	-0.00663217	-0.00663217	-0.00663217	-0.00663217
Increased number of cases in population:	-0.0023	-0.0007	-0.0002	-0.0003	-0.0021	-0.00008	-0.00006	-0.0002
Mortdale								
Total Population in study area:	11002	11002	11002	11002	11002	11002	11002	11002
total change	-101.2	-101.2	-101.2	-101.2	-101.2	-101.2	-101.2	-101.2
Population weighted Δx (μg/m^3):	-0.00919833	-0.00919833	-0.00919833	-0.00919833	-0.00919833	-0.00919833	-0.00919833	-0.00919833
Increased number of cases in population:	-0.0037	-0.0012	-0.0003	-0.0004	-0.0033	-0.00013	-0.000095	-0.0003
Narwee								
Total Population in study area:	4884	4884	4884	4884	4884	4884	4884	4884
total change	-244.5	-244.5	-244.5	-244.5	-244.5	-244.5	-244.5	-244.5
Population weighted Δx (μg/m^3):	-0.05006143	-0.05006143	-0.05006143	-0.05006143	-0.05006143	-0.05006143	-0.05006143	-0.05006143
Increased number of cases in population:	-0.0089	-0.0028	-0.0006	-0.0011	-0.0080	-0.0003	-0.0002	-0.0007
Oatley								
Total Population in study area:	4322	4322	4322	4322	4322	4322	4322	4322
total change	-11.7	-11.7	-11.7	-11.7	-11.7	-11.7	-11.7	-11.7
Population weighted Δx (μg/m^3):	-0.00270708	-0.00270708	-0.00270708	-0.00270708	-0.00270708	-0.00270708	-0.00270708	-0.00270708
Increased number of cases in population:	-0.00043	-0.00013	-0.000029	-0.000051	-0.0004	-0.000015	-0.000011	-0.000034
South Hurstville								
Total Population in study area:	7571	7571	7571	7571	7571	7571	7571	7571
total change	-37	-37	-37	-37	-37	-37	-37	-37
Population weighted Δx (μg/m^3):	-0.00488707	-0.00488707	-0.00488707	-0.00488707	-0.00488707	-0.00488707	-0.00488707	-0.00488707
Increased number of cases in population:	-0.0013	-0.0004	-0.000093	-0.00016	-0.00121	-0.000047	-0.000035	-0.00011
Total population incidence - All Suburbs	**-0.5**	**-0.1**	**-0.02**	**-0.07**	**-0.5**	**-0.02**	**-0.01**	**-0.04**

Assessment of Increased Incidence - $PM_{2.5}$
M4-M5 Link: 2033

	Primary Indicators			Secondary Indicators				
Health Endpoint:	**Mortality - All Causes, Long-term**	**Hospitalisations - Cardiovascular, Short-term**	**Hospitalisations - Respiratory, Short-term**	**Mortality - All Causes, Short-term**	**Mortality - Cardiopulmonary, Long-term**	**Mortality - Cardiovascular, Short-term**	**Mortality - Respiratory, Short-term**	**Morbidity - Asthma ED Admissions - Short-term**
Age Group:	≥ 30 years	≥ 65 years	≥ 65 years	All ages	≥ 30 years	All ages	All ages	1-14 years
β (change in effect per 1 μg/m³ PM) (as per Table 6-22)	0.0058	0.0008	0.00041	0.00094	0.013	0.00097	0.0019	0.00148
Canada Bay LGA								
Total Population in study area:	67644	67644	67644	67644	67644	67644	67644	67644
% population in assessment age-group:	63%	14%	14%	100%	63%	100%	100%	16%
Population weighted Δx (μg/m³):	0.00061173	0.00061173	0.00061173	0.00061173	0.00061173	0.00061173	0.00061173	0.00061173
Baseline Incidence (per 100,000) (as per Table 4-5)	1026	9235	3978	403.3	412.0	113.4	49.4	1209.0
Baseline Incidence (per person)	0.01026	0.09235	0.03978	0.00403	0.00412	0.00113	0.00049	0.01209
Increased number of cases in population:	0.0016	0.00043	0.000094	0.00016	0.0014	0.000046	0.000039	0.00011
Risk:	3.6E-08	4.5E-08	1.0E-08	2.3E-09	3.3E-08	6.7E-10	5.7E-10	1.1E-08
Individual subrubs within LGA								
Concord - Mortlake - Cabarita								
Total Population in study area:	19204	19204	19204	19204	19204	19204	19204	19204
total change	84.5	84.5	84.5	84.5	84.5	84.5	84.5	84.5
Population weighted Δx (μg/m³):	0.00440012	0.00440012	0.00440012	0.00440012	0.00440012	0.00440012	0.00440012	0.00440012
Attributable fraction (AF):	2.6E-05	3.5E-06	1.8E-06	4.1E-06	5.7E-05	4.3E-06	8.4E-06	6.5E-06
Increased number of cases in population:	0.003188	0.0009	0.0002	0.0003	0.0029	0.000093	0.000079	0.0002
Concord West								
Total Population in study area:	10692	10692	10692	10692	10692	10692	10692	10692
total change	191.8	191.8	191.8	191.8	191.8	191.8	191.8	191.8
Population weighted Δx (μg/m³):	0.01793865	0.01793865	0.01793865	0.01793865	0.01793865	0.01793865	0.01793865	0.01793865
Increased number of cases in population:	0.007236	0.0020	0.0004	0.0007	0.0065	0.0002	0.0002	0.0005
Drummoyne - Rodd Pt								
Total Population in study area:	17456	17456	17456	17456	17456	17456	17456	17456
total change	-60.1	-60.1	-60.1	-60.1	-60.1	-60.1	-60.1	-60.1
Population weighted Δx (μg/m³):	-0.00344294	-0.00344294	-0.00344294	-0.00344294	-0.00344294	-0.00344294	-0.00344294	-0.00344294
Increased number of cases in population:	-0.002267	-0.0006	-0.00014	-0.00023	-0.0020	-0.000066	-0.000056	-0.0002
Five Dock								
Total Population in study area:	19111	19111	19111	19111	19111	19111	19111	19111
total change	-170.8	-170.8	-170.8	-170.8	-170.8	-170.8	-170.8	-170.8
Population weighted Δx (μg/m³):	-0.00893726	-0.00893726	-0.00893726	-0.00893726	-0.00893726	-0.00893726	-0.00893726	-0.00893726
Increased number of cases in population:	-0.006444	-0.0018	-0.0004	-0.0006	-0.0058	-0.0002	-0.0002	-0.0005
Gladesville								
Total Population in study area:	590	590	590	590	590	590	590	590
total change	-2.6	-2.6	-2.6	-2.6	-2.6	-2.6	-2.6	-2.6
Population weighted Δx (μg/m³):	-0.00440678	-0.00440678	-0.00440678	-0.00440678	-0.00440678	-0.00440678	-0.00440678	-0.00440678
Increased number of cases in population:	-0.000098	-0.000027	-0.0000059	-0.0000099	-0.000088	-0.0000029	-0.0000024	-0.000007
Hunters Hill								
Total Population in study area:	591	591	591	591	591	591	591	591
total change	-1.4	-1.4	-1.4	-1.4	-1.4	-1.4	-1.4	-1.4
Population weighted Δx (μg/m³):	-0.00236887	-0.00236887	-0.00236887	-0.00236887	-0.00236887	-0.00236887	-0.00236887	-0.00236887
Increased number of cases in population:	-0.000053	-0.0000145	-0.0000032	-0.0000053	-0.0000475	-0.0000015	-0.0000013	-0.0000039

	Primary Indicators			Secondary Indicators				
Health Endpoint:	**Mortality - All Causes, Long-term**	**Hospitalisations - Cardiovascular, Short-term**	**Hospitalisations - Respiratory, Short-term**	**Mortality - All Causes, Short-term**	**Mortality - Cardiopulmonary, Long-term**	**Mortality - Cardiovascular, Short-term**	**Mortality - Respiratory, Short-term**	**Morbidity - Asthma ED Admissions - Short-term**
Age Group:	≥ 30 years	≥ 65 years	≥ 65 years	All ages	≥ 30 years	All ages	All ages	1-14 years
β (change in effect per 1 μg/m^3 PM) (as per Table 6-22)	0.0058	0.0008	0.00041	0.00094	0.013	0.00097	0.0019	0.00148
Strathfield LGA								
Total Population in study area:	25473	25473	25473	25473	25473	25473	25473	25473
% population in assessment age-group:	60%	13%	13%	100%	60%	100%	100%	14%
Population weighted Δx (μg/m^3):	-0.00246143	-0.00246143	-0.00246143	-0.00246143	-0.00246143	-0.00246143	-0.00246143	-0.00246143
Baseline Incidence (per 100,000) (as per Table 4-5)	1026	9235	3978	443.1	412.0	135.2	49.4	1209.0
Baseline Incidence (per person)	0.01026	0.09235	0.03978	0.00443	0.00412	0.00135	0.00049	0.01209
Increased number of cases in population:	-0.0022	-0.00061	-0.00013	-0.00026	-0.0020	-0.000082	-0.000059	-0.00016
Risk:	-1.5E-07	-1.8E-07	-4.0E-08	-1.0E-08	-1.3E-07	-3.2E-09	-2.3E-09	-4.4E-08
Individual subrubs within LGA								
Homebush								
Total Population in study area:	25473	25473	25473	25473	25473	25473	25473	25473
total change	-62.7	-62.7	-62.7	-62.7	-62.7	-62.7	-62.7	-62.7
Population weighted Δx (μg/m^3):	-0.00246143	-0.00246143	-0.00246143	-0.00246143	-0.00246143	-0.00246143	-0.00246143	-0.00246143
Increased number of cases in population:	-0.0022	-0.00061	-0.00013	-0.00026	-0.00201	-0.000082	-0.000059	-0.00016
Homebush Bay								
Total Population in study area:	63	63	63	63	63	63	63	63
total change	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6
Population weighted Δx (μg/m^3):	0.02539683	0.02539683	0.02539683	0.02539683	0.02539683	0.02539683	0.02539683	0.02539683
Increased number of cases in population:	0.000057	0.000015	0.0000034	0.0000067	0.0000512	0.0000021	0.0000015	0.0000041
Strathfield								
Total Population in study area:	20335	20335	20335	20335	20335	20335	20335	20335
total change	-204.3	-204.3	-204.3	-204.3	-204.3	-204.3	-204.3	-204.3
Population weighted Δx (μg/m^3):	-0.01004672	-0.01004672	-0.01004672	-0.01004672	-0.01004672	-0.01004672	-0.01004672	-0.01004672
Increased number of cases in population:	-0.0073	-0.0020	-0.0004	-0.0009	-0.0065	-0.0003	-0.0002	-0.0005
Burwood LGA								
Total Population in study area:	20986	20986	20986	20986	20986	20986	20986	20986
% population in assessment age-group:	60%	13%	13%	100%	60%	100%	100%	14%
Population weighted Δx (μg/m^3):	-0.00125798	-0.00125798	-0.00125798	-0.00125798	-0.00125798	-0.00125798	-0.00125798	-0.00125798
Baseline Incidence (per 100,000) (as per Table 4-5)	1026	9235	3978	555.6	412.0	138.0	49.4	1209.0
Baseline Incidence (per person)	0.01026	0.09235	0.03978	0.00556	0.00412	0.00138	0.00049	0.01209
Increased number of cases in population:	-0.00094	-0.00026	-0.000056	-0.00014	-0.00085	-0.000035	-0.000025	-0.000068
Risk:	-7.5E-08	-9.3E-08	-2.1E-08	-6.6E-09	-6.7E-08	-1.7E-09	-1.2E-09	-2.3E-08

	Primary Indicators			Secondary Indicators				
Health Endpoint:	**Mortality - All Causes, Long-term**	**Hospitalisations - Cardiovascular, Short-term**	**Hospitalisations - Respiratory, Short-term**	**Mortality - All Causes, Short-term**	**Mortality - Cardiopulmonary, Long-term**	**Mortality - Cardiovascular, Short-term**	**Mortality - Respiratory, Short-term**	**Morbidity - Asthma ED Admissions - Short-term**
Age Group:	≥ 30 years	≥ 65 years	≥ 65 years	All ages	≥ 30 years	All ages	All ages	1-14 years
β (change in effect per 1 μg/m^3 PM) (as per Table 6-22)	0.0058	0.0008	0.00041	0.00094	0.013	0.00097	0.0019	0.00148
Sydney Inner West LGA								
Total Population in study area:	180589	180589	180589	180589	180589	180589	180589	180589
% population in assessment age-group:	67%	10%	10%	100%	67%	100%	100%	15%
Population weighted Δx (μg/m^3):	-0.04736723	-0.04736723	-0.04736723	-0.04736723	-0.04736723	-0.04736723	-0.04736723	-0.04736723
Baseline Incidence (per 100,000) (as per Table 4-5)	1026	9235	3978	534.2	412.0	146.4	49.4	1209.0
Baseline Incidence (per person)	0.01026	0.09235	0.03978	0.00534	0.00412	0.00146	0.00049	0.01209
Increased number of cases in population:	-0.34	-0.064	-0.014	-0.043	-0.31	-0.012	-0.0080	-0.023
Risk:	-2.8E-06	-3.5E-06	-7.7E-07	-2.4E-07	-2.5E-06	-6.7E-08	-4.4E-08	-8.5E-07
Individual subrubs within LGA								
Ashfield								
Total Population in study area:	22769	22769	22769	22769	22769	22769	22769	22769
total change	-452.1	-452.1	-452.1	-452.1	-452.1	-452.1	-452.1	-452.1
Population weighted Δx (μg/m^3):	-0.01985594	-0.01985594	-0.01985594	-0.01985594	-0.01985594	-0.01985594	-0.01985594	-0.01985594
Increased number of cases in population:	-0.0181	-0.0034	-0.0008	-0.0023	-0.0163	-0.0006	-0.0004	-0.0012
Canterbury North-Ashbury								
Total Population in study area:	9390	9390	9390	9390	9390	9390	9390	9390
total change	-192.9	-192.9	-192.9	-192.9	-192.9	-192.9	-192.9	-192.9
Population weighted Δx (μg/m^3):	-0.02054313	-0.02054313	-0.02054313	-0.02054313	-0.02054313	-0.02054313	-0.02054313	-0.02054313
Increased number of cases in population:	-0.0077	-0.0015	-0.0003	-0.0010	-0.0069	-0.0003	-0.0002	-0.0005
Croyden Park								
Total Population in study area:	16360	16360	16360	16360	16360	16360	16360	16360
total change	-186	-186	-186	-186	-186	-186	-186	-186
Population weighted Δx (μg/m^3):	-0.01136919	-0.01136919	-0.01136919	-0.01136919	-0.01136919	-0.01136919	-0.01136919	-0.01136919
Increased number of cases in population:	-0.0074	-0.0014	-0.0003	-0.0009	-0.0067	-0.0003	-0.0002	-0.0005
Dulwich Hill								
Total Population in study area:	15862	15862	15862	15862	15862	15862	15862	15862
Population weighted Δx (μg/m^3):	-0.05603959	-0.05603959	-0.05603959	-0.05603959	-0.05603959	-0.05603959	-0.05603959	-0.05603959
Increased number of cases in population:	-0.0356	-0.0067	-0.0015	-0.0045	-0.0320	-0.0013	-0.0008	-0.0024
Haberfield								
Total Population in study area:	13245	13245	13245	13245	13245	13245	13245	13245
total change	-1075.8	-1075.8	-1075.8	-1075.8	-1075.8	-1075.8	-1075.8	-1075.8
Population weighted Δx (μg/m^3):	-0.08122310	-0.08122310	-0.08122310	-0.08122310	-0.08122310	-0.08122310	-0.08122310	-0.08122310
Increased number of cases in population:	-0.0430	-0.0081	-0.0018	-0.0054	-0.0387	-0.0015	-0.0010	-0.0029
Balmain								
Total Population in study area:	14794	14794	14794	14794	14794	14794	14794	14794
total change	36	36	36	36	36	36	36	36
Population weighted Δx (μg/m^3):	0.00243342	0.00243342	0.00243342	0.00243342	0.00243342	0.00243342	0.00243342	0.00243342
Increased number of cases in population:	0.0014	0.00027	0.000060	0.00018	0.0013	0.000051	0.000034	0.00010
Leichhardt								
Total Population in study area:	24443	24443	24443	24443	24443	24443	24443	24443
total change	-1880.2	-1880.2	-1880.2	-1880.2	-1880.2	-1880.2	-1880.2	-1880.2
Population weighted Δx (μg/m^3):	-0.07692182	-0.07692182	-0.07692182	-0.07692182	-0.07692182	-0.07692182	-0.07692182	-0.07692182
Increased number of cases in population:	-0.0752	-0.0142	-0.0031	-0.0094	-0.0677	-0.0027	-0.0018	-0.0050
Lilyfield								
Total Population in study area:	13073	13073	13073	13073	13073	13073	13073	13073
total change	-1235.8	-1235.8	-1235.8	-1235.8	-1235.8	-1235.8	-1235.8	-1235.8
Population weighted Δx (μg/m^3):	-0.09453071	-0.09453071	-0.09453071	-0.09453071	-0.09453071	-0.09453071	-0.09453071	-0.09453071
Increased number of cases in population:	-0.0494	-0.0093	-0.0021	-0.0062	-0.0445	-0.0018	-0.0012	-0.0033
Marrickville								
Total Population in study area:	24632	24632	24632	24632	24632	24632	24632	24632
total change	-1000.9	-1000.9	-1000.9	-1000.9	-1000.9	-1000.9	-1000.9	-1000.9
Population weighted Δx (μg/m^3):	-0.04063413	-0.04063413	-0.04063413	-0.04063413	-0.04063413	-0.04063413	-0.04063413	-0.04063413
Increased number of cases in population:	-0.0400	-0.0075	-0.0017	-0.0050	-0.0360	-0.0014	-0.0009	-0.0027
Petersham								
Total Population in study area:	18817	18817	18817	18817	18817	18817	18817	18817
total change	-8554	-8554	-8554	-8554	-8554	-8554	-8554	-8554
Population weighted Δx (μg/m^3):	-0.45458894	-0.45458894	-0.45458894	-0.45458894	-0.45458894	-0.45458894	-0.45458894	-0.45458894
Increased number of cases in population:	-0.3425	-0.0645	-0.0142	-0.0430	-0.3088	-0.0122	-0.0080	-0.0228
Sydenham								
Total Population in study area:	7204	7204	7204	7204	7204	7204	7204	7204
total change	131.7	131.7	131.7	131.7	131.7	131.7	131.7	131.7
Population weighted Δx (μg/m^3):	0.01828151	0.01828151	0.01828151	0.01828151	0.01828151	0.01828151	0.01828151	0.01828151
Increased number of cases in population:	0.0053	0.0010	0.0002	0.0007	0.0047	0.0002	0.00012	0.0004

	Primary Indicators			Secondary Indicators				
Health Endpoint:	**Mortality - All Causes, Long-term**	**Hospitalisations - Cardiovascular, Short-term**	**Hospitalisations - Respiratory, Short-term**	**Mortality - All Causes, Short-term**	**Mortality - Cardiopulmonary, Long-term**	**Mortality - Cardiovascular, Short-term**	**Mortality - Respiratory, Short-term**	**Morbidity - Asthma ED Admissions - Short-term**
Age Group:	≥ 30 years	≥ 65 years	≥ 65 years	All ages	≥ 30 years	All ages	All ages	1-14 years
β (change in effect per 1 μg/m^3 PM) (as per Table 6-22)	0.0058	0.0008	0.00041	0.00094	0.013	0.00097	0.0019	0.00148
Sydney LGA								
Total Population in study area:	125509	125509	125509	125509	125509	125509	125509	125509
% population in assessment age-group:	59%	8%	8%	100%	59%	100%	100%	6%
Population weighted Δx (μg/m^3):	0.00470564	0.00470564	0.00470564	0.00470564	0.00470564	0.00470564	0.00470564	0.00470564
Baseline Incidence (per 100,000) (as per Table 4-5)	1026	9235	3978	508.0	412.0	138.9	49.4	1209.0
Baseline Incidence (per person)	0.01026	0.09235	0.03978	0.00508	0.00412	0.00139	0.00049	0.01209
Increased number of cases in population:	0.021	0.0034	0.00075	0.0028	0.019	0.00080	0.00055	0.00066
Risk:	2.8E-07	3.5E-07	7.7E-08	2.2E-08	2.5E-07	6.3E-09	4.4E-09	8.4E-08
Individual subrubs within LGA								
Erskinville								
Total Population in study area:	13908	13908	13908	13908	13908	13908	13908	13908
total change	-344.2	-344.2	-344.2	-344.2	-344.2	-344.2	-344.2	-344.2
Population weighted Δx (μg/m^3):	-0.02474835	-0.02474835	-0.02474835	-0.02474835	-0.02474835	-0.02474835	-0.02474835	-0.02474835
Increased number of cases in population:	-0.0121	-0.0020	-0.0004	-0.0016	-0.0109	-0.0005	-0.0003	-0.0004
Glebe								
Total Population in study area:	16595	16595	16595	16595	16595	16595	16595	16595
total change	-474.9	-474.9	-474.9	-474.9	-474.9	-474.9	-474.9	-474.9
Population weighted Δx (μg/m^3):	-0.02861705	-0.02861705	-0.02861705	-0.02861705	-0.02861705	-0.02861705	-0.02861705	-0.02861705
Increased number of cases in population:	-0.0167	-0.0027	-0.0006	-0.0023	-0.0150	-0.0006	-0.0004	-0.0005
Newtown								
Total Population in study area:	21480	21480	21480	21480	21480	21480	21480	21480
total change	-835.8	-835.8	-835.8	-835.8	-835.8	-835.8	-835.8	-835.8
Population weighted Δx (μg/m^3):	-0.03891061	-0.03891061	-0.03891061	-0.03891061	-0.03891061	-0.03891061	-0.03891061	-0.03891061
Increased number of cases in population:	-0.0294	-0.0048	-0.0011	-0.0040	-0.0265	-0.0011	-0.0008	-0.0009
Pyrmont								
Total Population in study area:	18720	18720	18720	18720	18720	18720	18720	18720
total change	1759.8	1759.8	1759.8	1759.8	1759.8	1759.8	1759.8	1759.8
Population weighted Δx (μg/m^3):	0.09400641	0.09400641	0.09400641	0.09400641	0.09400641	0.09400641	0.09400641	0.09400641
Increased number of cases in population:	0.0619	0.0101	0.0022	0.0084	0.0557	0.0024	0.0017	0.0020
Redfern								
Total Population in study area:	12628	12628	12628	12628	12628	12628	12628	12628
total change	-582.2	-582.2	-582.2	-582.2	-582.2	-582.2	-582.2	-582.2
Population weighted Δx (μg/m^3):	-0.04610390	-0.04610390	-0.04610390	-0.04610390	-0.04610390	-0.04610390	-0.04610390	-0.04610390
Increased number of cases in population:	-0.0205	-0.0034	-0.0007	-0.0028	-0.0184	-0.0008	-0.0005	-0.0006
Surry Hills								
Total Population in study area:	4190	4190	4190	4190	4190	4190	4190	4190
total change	-17.5	-17.5	-17.5	-17.5	-17.5	-17.5	-17.5	-17.5
Population weighted Δx (μg/m^3):	-0.00417661	-0.00417661	-0.00417661	-0.00417661	-0.00417661	-0.00417661	-0.00417661	-0.00417661
Increased number of cases in population:	-0.0006	-0.00010	-0.000022	-0.000084	-0.000554	-0.000024	-0.000016	-0.000019
Sydney								
Total Population in study area:	21726	21726	21726	21726	21726	21726	21726	21726
total change	1060.2	1060.2	1060.2	1060.2	1060.2	1060.2	1060.2	1060.2
Population weighted Δx (μg/m^3):	0.04879867	0.04879867	0.04879867	0.04879867	0.04879867	0.04879867	0.04879867	0.04879867
Increased number of cases in population:	0.0373	0.0061	0.0013	0.0051	0.0335	0.0014	0.0010	0.0012
Waterloo								
Total Population in study area:	11306	11306	11306	11306	11306	11306	11306	11306
total change	5.3	5.3	5.3	5.3	5.3	5.3	5.3	5.3
Population weighted Δx (μg/m^3):	0.00046878	0.00046878	0.00046878	0.00046878	0.00046878	0.00046878	0.00046878	0.00046878
Increased number of cases in population:	0.0002	0.000031	0.0000067	0.000025	0.00017	0.0000071	0.00000497	0.0000059
Crows Nest								
Total Population in study area:	50	50	50	50	50	50	50	50
total change	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
Population weighted Δx (μg/m^3):	0.00800000	0.00800000	0.00800000	0.00800000	0.00800000	0.00800000	0.00800000	0.00800000
Increased number of cases in population:	0.000014	0.0000023	0.0000005	0.0000019	0.0000127	0.0000005	0.00000038	0.00000044
North Sydney								
Total Population in study area:	4906	4906	4906	4906	4906	4906	4906	4906
total change	19.3	19.3	19.3	19.3	19.3	19.3	19.3	19.3
Population weighted Δx (μg/m^3):	0.00393396	0.00393396	0.00393396	0.00393396	0.00393396	0.00393396	0.00393396	0.00393396
Increased number of cases in population:	0.0007	0.00011	0.000025	0.000092	0.00061	0.000026	0.000018	0.000021

	Primary Indicators			Secondary Indicators				
Health Endpoint:	**Mortality - All Causes, Long-term**	**Hospitalisations - Cardiovascular, Short-term**	**Hospitalisations - Respiratory, Short-term**	**Mortality - All Causes, Short-term**	**Mortality - Cardiopulmonary, Long-term**	**Mortality - Cardiovascular, Short-term**	**Mortality - Respiratory, Short-term**	**Morbidity - Asthma ED Admissions - Short-term**
Age Group:	≥ 30 years	≥ 65 years	≥ 65 years	All ages	≥ 30 years	All ages	All ages	1-14 years
β (change in effect per 1 μg/m^3 PM) (as per Table 6-22)	0.0058	0.0008	0.00041	0.00094	0.013	0.00097	0.0019	0.00148
Botany LGA								
Total Population in study area:	25700	25700	25700	25700	25700	25700	25700	25700
% population in assessment age-group:	62%	14%	14%	100%	62%	100%	100%	17%
Population weighted Δx (μg/m^3):	0.08917899	0.08917899	0.08917899	0.08917899	0.08917899	0.08917899	0.08917899	0.08917899
Baseline Incidence (per 100,000) (as per Table 4-5)	1026	9235	3978	523.8	412.0	150.0	49.4	1209.0
Baseline Incidence (per person)	0.01026	0.09235	0.03978	0.00524	0.00412	0.00150	0.00049	0.01209
Increased number of cases in population:	0.084	0.024	0.0054	0.011	0.076	0.0033	0.0022	0.0069
Risk:	5.3E-06	6.6E-06	1.5E-06	4.4E-07	4.8E-06	1.3E-07	8.4E-08	1.6E-06
Individual subrubs within LGA								
Botany								
Total Population in study area:	8915	8915	8915	8915	8915	8915	8915	8915
total change	91.4	91.4	91.4	91.4	91.4	91.4	91.4	91.4
Population weighted Δx (μg/m^3):	0.01025238	0.01025238	0.01025238	0.01025238	0.01025238	0.01025238	0.01025238	0.01025238
Increased number of cases in population:	0.0034	0.0010	0.00021	0.00045	0.0030	0.000133	0.000086	0.00027
Mascot								
Total Population in study area:	16215	16215	16215	16215	16215	16215	16215	16215
total change	2179.7	2179.7	2179.7	2179.7	2179.7	2179.7	2179.7	2179.7
Population weighted Δx (μg/m^3):	0.13442492	0.13442492	0.13442492	0.13442492	0.13442492	0.13442492	0.13442492	0.13442492
Increased number of cases in population:	0.0799	0.0232	0.0051	0.0107	0.0719	0.0032	0.0020	0.0066
Pagewood								
Total Population in study area:	567	567	567	567	567	567	567	567
total change	20.7	20.7	20.7	20.7	20.7	20.7	20.7	20.7
Population weighted Δx (μg/m^3):	0.03650794	0.03650794	0.03650794	0.03650794	0.03650794	0.03650794	0.03650794	0.03650794
Increased number of cases in population:	0.0008	0.00022	0.000049	0.000102	0.00068	0.000030	0.000019	0.000062

	Primary Indicators			Secondary Indicators				
Health Endpoint:	**Mortality - All Causes, Long-term**	**Hospitalisations - Cardiovascular, Short-term**	**Hospitalisations - Respiratory, Short-term**	**Mortality - All Causes, Short-term**	**Mortality - Cardiopulmonary, Long-term**	**Mortality - Cardiovascular, Short-term**	**Mortality - Respiratory, Short-term**	**Morbidity - Asthma ED Admissions - Short-term**
Age Group:	≥ 30 years	≥ 65 years	≥ 65 years	All ages	≥ 30 years	All ages	All ages	1-14 years
β (change in effect per 1 $\mu g/m^3$ PM) (as per Table 6-22)	0.0058	0.0008	0.00041	0.00094	0.013	0.00097	0.0019	0.00148
Rockdale LGA								
Total Population in study area:	82293	82293	82293	82293	82293	82293	82293	82293
% population in assessment age-group:	62%	15%	15%	100%	62%	100%	100%	16%
Population weighted Δx ($\mu g/m^3$):	-0.02306393	-0.02306393	-0.02306393	-0.02306393	-0.02306393	-0.02306393	-0.02306393	-0.02306393
Baseline Incidence (per 100,000) (as per Table 4-5)	1026	9235	3978	534.5	412.0	150.0	49.4	1209.0
Baseline Incidence (per person)	0.01026	0.09235	0.03978	0.00535	0.00412	0.00150	0.00049	0.01209
Increased number of cases in population:	-0.070	-0.021	-0.0046	-0.0095	-0.063	-0.0028	-0.0018	-0.0054
Risk:	-1.4E-06	-1.7E-06	-3.8E-07	-1.2E-07	-1.2E-06	-3.4E-08	-2.2E-08	-4.1E-07
Individual subrubs within LGA								
Arncliffe								
Total Population in study area:	14669	14669	14669	14669	14669	14669	14669	14669
total change	-181.6	-181.6	-181.6	-181.6	-181.6	-181.6	-181.6	-181.6
Population weighted Δx ($\mu g/m^3$):	-0.01237985	-0.01237985	-0.01237985	-0.01237985	-0.01237985	-0.01237985	-0.01237985	-0.01237985
Increased number of cases in population:	-0.0067	-0.0020	-0.0004	-0.0009	-0.0060	-0.00026	-0.00017	-0.0005
Bexley								
Total Population in study area:	25123	25123	25123	25123	25123	25123	25123	25123
total change	-343.9	-343.9	-343.9	-343.9	-343.9	-343.9	-343.9	-343.9
Population weighted Δx ($\mu g/m^3$):	-0.01368865	-0.01368865	-0.01368865	-0.01368865	-0.01368865	-0.01368865	-0.01368865	-0.01368865
Increased number of cases in population:	-0.0126	-0.0038	-0.0008	-0.0017	-0.0114	-0.0005	-0.0003	-0.0010
Kingsgrove - South								
Total Population in study area:	11981	11981	11981	11981	11981	11981	11981	11981
total change	-495.5	-495.5	-495.5	-495.5	-495.5	-495.5	-495.5	-495.5
Population weighted Δx ($\mu g/m^3$):	-0.04135715	-0.04135715	-0.04135715	-0.04135715	-0.04135715	-0.04135715	-0.04135715	-0.04135715
Increased number of cases in population:	-0.0182	-0.0054	-0.0012	-0.0025	-0.0164	-0.0007	-0.0005	-0.0014
Monterey								
Total Population in study area:	12192	12192	12192	12192	12192	12192	12192	12192
total change	-283.2	-283.2	-283.2	-283.2	-283.2	-283.2	-283.2	-283.2
Population weighted Δx ($\mu g/m^3$):	-0.02322835	-0.02322835	-0.02322835	-0.02322835	-0.02322835	-0.02322835	-0.02322835	-0.02322835
Increased number of cases in population:	-0.0104	-0.0031	-0.0007	-0.0014	-0.0094	-0.0004	-0.0003	-0.0008
Rockdale								
Total Population in study area:	18328	18328	18328	18328	18328	18328	18328	18328
total change	-593.8	-593.8	-593.8	-593.8	-593.8	-593.8	-593.8	-593.8
Population weighted Δx ($\mu g/m^3$):	-0.03239852	-0.03239852	-0.03239852	-0.03239852	-0.03239852	-0.03239852	-0.03239852	-0.03239852
Increased number of cases in population:	-0.0218	-0.0065	-0.0014	-0.0030	-0.0196	-0.0009	-0.0006	-0.0017

	Primary Indicators			Secondary Indicators				
Health Endpoint:	**Mortality - All Causes, Long-term**	**Hospitalisations - Cardiovascular, Short-term**	**Hospitalisations - Respiratory, Short-term**	**Mortality - All Causes, Short-term**	**Mortality - Cardiopulmonary, Long-term**	**Mortality - Cardiovascular, Short-term**	**Mortality - Respiratory, Short-term**	**Morbidity - Asthma ED Admissions - Short-term**
Age Group:	≥ 30 years	≥ 65 years	≥ 65 years	All ages	≥ 30 years	All ages	All ages	1-14 years
β (change in effect per 1 μg/m³ PM) (as per Table 6-22)	0.0058	0.0008	0.00041	0.00094	0.013	0.00097	0.0019	0.00148
Canterbury - Bankstown LGA								
Total Population in study area:	76834	76834	76834	76834	76834	76834	76834	76834
% population in assessment age-group:	58%	13%	13%	100%	58%	100%	100%	19%
Population weighted Δx (μg/m³):	-0.01249317	-0.01249317	-0.01249317	-0.01249317	-0.01249317	-0.01249317	-0.01249317	-0.01249317
Baseline Incidence (per 100,000) (as per Table 4-5)	1026	9235	3978	490.6	412.0	139.2	49.4	1209.0
Baseline Incidence (per person)	0.01026	0.09235	0.03978	0.00491	0.00412	0.00139	0.00049	0.01209
Increased number of cases in population:	-0.033	-0.0092	-0.0020	-0.0044	-0.030	-0.0013	-0.00090	-0.0033
Risk:	-7.4E-07	-9.2E-07	-2.0E-07	-5.8E-08	-6.7E-07	-1.7E-08	-1.2E-08	-2.2E-07
Individual subrubs within LGA								
Belmore								
Total Population in study area:	18330	18330	18330	18330	18330	18330	18330	18330
total change	-178.8	-178.8	-178.8	-178.8	-178.8	-178.8	-178.8	-178.8
Population weighted Δx (μg/m³):	-0.00975450	-0.00975450	-0.00975450	-0.00975450	-0.00975450	-0.00975450	-0.00975450	-0.00975450
Increased number of cases in population:	-0.0062	-0.0017	-0.0004	-0.0008	-0.0056	-0.00024	-0.00017	-0.0006
Canterbury (South)								
Total Population in study area:	26841	26841	26841	26841	26841	26841	26841	26841
total change	-337.8	-337.8	-337.8	-337.8	-337.8	-337.8	-337.8	-337.8
Population weighted Δx (μg/m³):	-0.01258522	-0.01258522	-0.01258522	-0.01258522	-0.01258522	-0.01258522	-0.01258522	-0.01258522
Increased number of cases in population:	-0.0117	-0.0032	-0.0007	-0.0016	-0.0105	-0.0005	-0.00032	-0.0012
Kinsgrove - North								
Total Population in study area:	22489	22489	22489	22489	22489	22489	22489	22489
total change	-407.4	-407.4	-407.4	-407.4	-407.4	-407.4	-407.4	-407.4
Population weighted Δx (μg/m³):	-0.01811552	-0.01811552	-0.01811552	-0.01811552	-0.01811552	-0.01811552	-0.01811552	-0.01811552
Increased number of cases in population:	-0.0141	-0.0039	-0.0009	-0.0019	-0.0127	-0.0006	-0.0004	-0.0014
Lakemba								
Total Population in study area:	3643	3643	3643	3643	3643	3643	3643	3643
total change	-6.3	-6.3	-6.3	-6.3	-6.3	-6.3	-6.3	-6.3
Population weighted Δx (μg/m³):	-0.00172934	-0.00172934	-0.00172934	-0.00172934	-0.00172934	-0.00172934	-0.00172934	-0.00172934
Increased number of cases in population:	-0.0002	-0.000061	-0.000013	-0.000029	-0.00020	-0.0000085	-0.0000059	-0.0000216
Roselands								
Total Population in study area:	5531	5531	5531	5531	5531	5531	5531	5531
total change	-29.6	-29.6	-29.6	-29.6	-29.6	-29.6	-29.6	-29.6
Population weighted Δx (μg/m³):	-0.00535165	-0.00535165	-0.00535165	-0.00535165	-0.00535165	-0.00535165	-0.00535165	-0.00535165
Increased number of cases in population:	-0.0010	-0.00028	-0.000063	-0.000137	-0.00092	-0.000040	-0.000028	-0.000102

	Primary Indicators			Secondary Indicators				
Health Endpoint:	**Mortality - All Causes, Long-term**	**Hospitalisations - Cardiovascular, Short-term**	**Hospitalisations - Respiratory, Short-term**	**Mortality - All Causes, Short-term**	**Mortality - Cardiopulmonary, Long-term**	**Mortality - Cardiovascular, Short-term**	**Mortality - Respiratory, Short-term**	**Morbidity - Asthma ED Admissions - Short-term**
Age Group:	≥ 30 years	≥ 65 years	≥ 65 years	All ages	≥ 30 years	All ages	All ages	1-14 years
β (change in effect per 1 μg/m^3 PM) (as per Table 6-22)	0.0058	0.0008	0.00041	0.00094	0.013	0.00097	0.0019	0.00148
Georges River LGA								
Total Population in study area:	66896	66896	66896	66896	66896	66896	66896	66896
% population in assessment age-group:	61%	15%	15%	100%	61%	100%	100%	16%
Population weighted Δx (μg/m^3):	-0.00959101	-0.00959101	-0.00959101	-0.00959101	-0.00959101	-0.00959101	-0.00959101	-0.00959101
Baseline Incidence (per 100,000) (as per Table 4-5)	1026	9235	3978	465.5	412.0	131.3	49.4	1209.0
Baseline Incidence (per person)	0.01026	0.09235	0.03978	0.00466	0.00412	0.00131	0.00049	0.01209
Increased number of cases in population:	-0.023	-0.0073	-0.0016	-0.0028	-0.021	-0.00082	-0.00060	-0.0019
Risk:	-5.7E-07	-7.1E-07	-1.6E-07	-4.2E-08	-5.1E-07	-1.2E-08	-9.0E-09	-1.7E-07
Individual subrubs within LGA								
Hurstville								
Total Population in study area:	20164	20164	20164	20164	20164	20164	20164	20164
total change	-237.2	-237.2	-237.2	-237.2	-237.2	-237.2	-237.2	-237.2
Population weighted Δx (μg/m^3):	-0.01176354	-0.01176354	-0.01176354	-0.01176354	-0.01176354	-0.01176354	-0.01176354	-0.01176354
Increased number of cases in population:	-0.0086	-0.0027	-0.0006	-0.0010	-0.0078	-0.00030	-0.00022	-0.0007
Kogorah								
Total Population in study area:	9484	9484	9484	9484	9484	9484	9484	9484
total change	-159.9	-159.9	-159.9	-159.9	-159.9	-159.9	-159.9	-159.9
Population weighted Δx (μg/m^3):	-0.01685997	-0.01685997	-0.01685997	-0.01685997	-0.01685997	-0.01685997	-0.01685997	-0.01685997
Increased number of cases in population:	-0.0058	-0.0018	-0.0004	-0.0007	-0.0052	-0.00020	-0.00015	-0.00047
Kogorah Bay								
Total Population in study area:	9469	9469	9469	9469	9469	9469	9469	9469
total change	-30	-30	-30	-30	-30	-30	-30	-30
Population weighted Δx (μg/m^3):	-0.00316823	-0.00316823	-0.00316823	-0.00316823	-0.00316823	-0.00316823	-0.00316823	-0.00316823
Increased number of cases in population:	-0.0011	-0.0003	-0.000075	-0.00013	-0.0010	-0.000038	-0.000028	-0.000088
Mortdale								
Total Population in study area:	11002	11002	11002	11002	11002	11002	11002	11002
total change	-43	-43	-43	-43	-43	-43	-43	-43
Population weighted Δx (μg/m^3):	-0.00390838	-0.00390838	-0.00390838	-0.00390838	-0.00390838	-0.00390838	-0.00390838	-0.00390838
Increased number of cases in population:	-0.0016	-0.0005	-0.00011	-0.0002	-0.0014	-0.000055	-0.000040	-0.00013
Narwee								
Total Population in study area:	4884	4884	4884	4884	4884	4884	4884	4884
total change	-144.9	-144.9	-144.9	-144.9	-144.9	-144.9	-144.9	-144.9
Population weighted Δx (μg/m^3):	-0.02966830	-0.02966830	-0.02966830	-0.02966830	-0.02966830	-0.02966830	-0.02966830	-0.02966830
Increased number of cases in population:	-0.0053	-0.0016	-0.0004	-0.0006	-0.0048	-0.00018	-0.00014	-0.0004
Oatley								
Total Population in study area:	4322	4322	4322	4322	4322	4322	4322	4322
total change	-5	-5	-5	-5	-5	-5	-5	-5
Population weighted Δx (μg/m^3):	-0.00115687	-0.00115687	-0.00115687	-0.00115687	-0.00115687	-0.00115687	-0.00115687	-0.00115687
Increased number of cases in population:	-0.0002	-0.000057	-0.000013	-0.000022	-0.00016	-0.000006	-0.000005	-0.000015
South Hurstville								
Total Population in study area:	7571	7571	7571	7571	7571	7571	7571	7571
total change	-21.6	-21.6	-21.6	-21.6	-21.6	-21.6	-21.6	-21.6
Population weighted Δx (μg/m^3):	-0.00285299	-0.00285299	-0.00285299	-0.00285299	-0.00285299	-0.00285299	-0.00285299	-0.00285299
Increased number of cases in population:	-0.0008	-0.0002	-0.000054	-0.000095	-0.0007	-0.000028	-0.000020	-0.000063
Total population incidence - All Suburbs	**-0.4**	**-0.07**	**-0.02**	**-0.05**	**-0.3**	**-0.01**	**-0.009**	**-0.03**

Assessment of Increased Incidence - $PM_{2.5}$
M4-M5 Link: 2033 Cumulative

	Primary Indicators			Secondary Indicators				
Health Endpoint:	**Mortality - All Causes, Long-term**	**Hospitalisations - Cardiovascular, Short-term**	**Hospitalisations - Respiratory, Short-term**	**Mortality - All Causes, Short-term**	**Mortality - Cardiopulmonary, Long-term**	**Mortality - Cardiovascular, Short-term**	**Mortality - Respiratory, Short-term**	**Morbidity - Asthma ED Admissions - Short-term**
Age Group:	≥ 30 years	≥ 65 years	≥ 65 years	All ages	≥ 30 years	All ages	All ages	1-14 years
β (change in effect per 1 μg/m^3 PM) (as per Table 6-22)	0.0058	0.0008	0.00041	0.00094	0.013	0.00097	0.0019	0.00148
Canada Bay LGA								
Total Population in study area:	67644	67644	67644	67644	67644	67644	67644	67644
% population in assessment age-group:	63%	14%	14%	100%	63%	100%	100%	16%
Population weighted Δx (μg/m^3):	0.01285849	0.01285849	0.01285849	0.01285849	0.01285849	0.01285849	0.01285849	0.01285849
Baseline Incidence (per 100,000) (as per Table 4-5)	1026	9235	3978	403.3	412.0	113.4	49.4	1209.0
Baseline Incidence (per person)	0.01026	0.09235	0.03978	0.00403	0.00412	0.00113	0.00049	0.01209
Increased number of cases in population:	0.033	0.0090	0.0020	0.0033	0.030	0.0010	0.00082	0.0024
Risk:	7.7E-07	9.5E-07	2.1E-07	4.9E-08	6.9E-07	1.4E-08	1.2E-08	2.3E-07
Individual subrubs within LGA								
Concord - Mortlake - Cabarita								
Total Population in study area:	19204	19204	19204	19204	19204	19204	19204	19204
total change	283.7	283.7	283.7	283.7	283.7	283.7	283.7	283.7
Population weighted Δx (μg/m^3):	0.01477296	0.01477296	0.01477296	0.01477296	0.01477296	0.01477296	0.01477296	0.01477296
Attributable fraction (AF):	8.6E-05	1.2E-05	6.1E-06	1.4E-05	1.9E-04	1.4E-05	2.8E-05	2.2E-05
Increased number of cases in population:	0.010703	0.0029	0.0006	0.0011	0.0096	0.0003	0.0003	0.0008
Concord West								
Total Population in study area:	10692	10692	10692	10692	10692	10692	10692	10692
total change	320.8	320.8	320.8	320.8	320.8	320.8	320.8	320.8
Population weighted Δx (μg/m^3):	0.03000374	0.03000374	0.03000374	0.03000374	0.03000374	0.03000374	0.03000374	0.03000374
Increased number of cases in population:	0.012102	0.0033	0.0007	0.0012	0.0109	0.00035	0.00030	0.00089
Drummoyne - Rodd Pt								
Total Population in study area:	17456	17456	17456	17456	17456	17456	17456	17456
total change	292.3	292.3	292.3	292.3	292.3	292.3	292.3	292.3
Population weighted Δx (μg/m^3):	0.01674496	0.01674496	0.01674496	0.01674496	0.01674496	0.01674496	0.01674496	0.01674496
Increased number of cases in population:	0.011027	0.0030	0.0007	0.0011	0.0099	0.00032	0.00027	0.00081
Five Dock								
Total Population in study area:	19111	19111	19111	19111	19111	19111	19111	19111
total change	-40.4	-40.4	-40.4	-40.4	-40.4	-40.4	-40.4	-40.4
Population weighted Δx (μg/m^3):	-0.00211397	-0.00211397	-0.00211397	-0.00211397	-0.00211397	-0.00211397	-0.00211397	-0.00211397
Increased number of cases in population:	-0.001524	-0.00042	-0.000092	-0.000153	-0.00137	-0.000044	-0.000038	-0.000112
Gladesville								
Total Population in study area:	590	590	590	590	590	590	590	590
total change	8.2	8.2	8.2	8.2	8.2	8.2	8.2	8.2
Population weighted Δx (μg/m^3):	0.01389831	0.01389831	0.01389831	0.01389831	0.01389831	0.01389831	0.01389831	0.01389831
Increased number of cases in population:	0.000309	0.000085	0.000019	0.000031	0.00028	0.0000090	0.0000077	0.000023
Hunters Hill								
Total Population in study area:	591	591	591	591	591	591	591	591
total change	5.1	5.1	5.1	5.1	5.1	5.1	5.1	5.1
Population weighted Δx (μg/m^3):	0.00862944	0.00862944	0.00862944	0.00862944	0.00862944	0.00862944	0.00862944	0.00862944
Increased number of cases in population:	0.000192	0.000053	0.000012	0.000019	0.00017	0.0000056	0.0000048	0.000014

	Primary Indicators			Secondary Indicators				
Health Endpoint:	**Mortality - All Causes, Long-term**	**Hospitalisations - Cardiovascular, Short-term**	**Hospitalisations - Respiratory, Short-term**	**Mortality - All Causes, Short-term**	**Mortality - Cardiopulmonary, Long-term**	**Mortality - Cardiovascular, Short-term**	**Mortality - Respiratory, Short-term**	**Morbidity - Asthma ED Admissions - Short-term**
Age Group:	≥ 30 years	≥ 65 years	≥ 65 years	All ages	≥ 30 years	All ages	All ages	1-14 years
β (change in effect per 1 $\mu g/m^3$ PM) (as per Table 6-22)	0.0058	0.0008	0.00041	0.00094	0.013	0.00097	0.0019	0.00148
Strathfield LGA								
Total Population in study area:	25473	25473	25473	25473	25473	25473	25473	25473
% population in assessment age-group:	60%	13%	13%	100%	60%	100%	100%	14%
Population weighted Δx ($\mu g/m^3$):	-0.00069093	-0.00069093	-0.00069093	-0.00069093	-0.00069093	-0.00069093	-0.00069093	-0.00069093
Baseline Incidence (per 100,000) (as per Table 4-5)	1026	9235	3978	443.1	412.0	135.2	49.4	1209.0
Baseline Incidence (per person)	0.01026	0.09235	0.03978	0.00443	0.00412	0.00135	0.00049	0.01209
Increased number of cases in population:	-0.00063	-0.00017	-0.000038	-0.000073	-0.00056	-0.000023	-0.000017	-0.000045
Risk:	-4.1E-08	-5.1E-08	-1.1E-08	-2.9E-09	-3.7E-08	-9.1E-10	-6.5E-10	-1.2E-08
Individual subrubs within LGA								
Homebush								
Total Population in study area:	5075	5075	5075	5075	5075	5075	5075	5075
total change	57.7	57.7	57.7	57.7	57.7	57.7	57.7	57.7
Population weighted Δx ($\mu g/m^3$):	0.01136946	0.01136946	0.01136946	0.01136946	0.01136946	0.01136946	0.01136946	0.01136946
Increased number of cases in population:	0.0021	0.00056	0.000123	0.00024	0.00185	0.000076	0.000054	0.000148
Homebush Bay								
Total Population in study area:	63	63	63	63	63	63	63	63
total change	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.3
Population weighted Δx ($\mu g/m^3$):	0.03650794	0.03650794	0.03650794	0.03650794	0.03650794	0.03650794	0.03650794	0.03650794
Increased number of cases in population:	0.000082	0.0000223	0.0000049	0.0000096	0.000074	0.0000030	0.0000022	0.0000059
Strathfield								
Total Population in study area:	20335	20335	20335	20335	20335	20335	20335	20335
total change	-77.6	-77.6	-77.6	-77.6	-77.6	-77.6	-77.6	-77.6
Population weighted Δx ($\mu g/m^3$):	-0.00381608	-0.00381608	-0.00381608	-0.00381608	-0.00381608	-0.00381608	-0.00381608	-0.00381608
Increased number of cases in population:	-0.0028	-0.0008	-0.00017	-0.00032	-0.00249	-0.000102	-0.000073	-0.00020
Burwood LGA								
Total Population in study area:	20986	20986	20986	20986	20986	20986	20986	20986
% population in assessment age-group:	60%	13%	13%	100%	60%	100%	100%	14%
Population weighted Δx ($\mu g/m^3$):	0.00891547	0.00891547	0.00891547	0.00891547	0.00891547	0.00891547	0.00891547	0.00891547
Baseline Incidence (per 100,000) (as per Table 4-5)	1026	9235	3978	555.6	412.0	138.0	49.4	1209.0
Baseline Incidence (per person)	0.01026	0.09235	0.03978	0.00556	0.00412	0.00138	0.00049	0.01209
Increased number of cases in population:	0.0067	0.0018	0.00040	0.0010	0.0060	0.00025	0.00018	0.00048
Risk:	5.3E-07	6.6E-07	1.5E-07	4.7E-08	4.8E-07	1.2E-08	8.4E-09	1.6E-07

	Primary Indicators			Secondary Indicators				
Health Endpoint:	**Mortality - All Causes, Long-term**	**Hospitalisations - Cardiovascular, Short-term**	**Hospitalisations - Respiratory, Short-term**	**Mortality - All Causes, Short-term**	**Mortality - Cardiopulmonary, Long-term**	**Mortality - Cardiovascular, Short-term**	**Mortality - Respiratory, Short-term**	**Morbidity - Asthma ED Admissions - Short-term**
Age Group:	≥ 30 years	≥ 65 years	≥ 65 years	All ages	≥ 30 years	All ages	All ages	1-14 years
β (change in effect per 1 μg/m^3 PM) (as per Table 6-22)	0.0058	0.0008	0.00041	0.00094	0.013	0.00097	0.0019	0.00148
Sydney Inner West LGA								
Total Population in study area:	180589	180589	180589	180589	180589	180589	180589	180589
% population in assessment age-group:	67%	10%	10%	100%	67%	100%	100%	15%
Population weighted Δx (μg/m^3):	-0.03301419	-0.03301419	-0.03301419	-0.03301419	-0.03301419	-0.03301419	-0.03301419	-0.03301419
Baseline Incidence (per 100,000) (as per Table 4-5)	1026	9235	3978	534.2	412.0	146.4	49.4	1209.0
Baseline Incidence (per person)	0.01026	0.09235	0.03978	0.00534	0.00412	0.00146	0.00049	0.01209
Increased number of cases in population:	-0.24	-0.045	-0.0099	-0.030	-0.21	-0.0085	-0.0056	-0.016
Risk:	-2.0E-06	-2.4E-06	-5.4E-07	-1.7E-07	-1.8E-06	-4.7E-08	-3.1E-08	-5.9E-07
Individual subrubs within LGA								
Ashfield								
Total Population in study area:	22769	22769	22769	22769	22769	22769	22769	22769
total change	-97.8	-97.8	-97.8	-97.8	-97.8	-97.8	-97.8	-97.8
Population weighted Δx (μg/m^3):	-0.00429531	-0.00429531	-0.00429531	-0.00429531	-0.00429531	-0.00429531	-0.00429531	-0.00429531
Increased number of cases in population:	-0.0039	-0.0007	-0.0002	-0.0005	-0.0035	-0.0001	-0.0001	-0.0003
Canterbury North-Ashbury								
Total Population in study area:	9390	9390	9390	9390	9390	9390	9390	9390
total change	-209.5	-209.5	-209.5	-209.5	-209.5	-209.5	-209.5	-209.5
Population weighted Δx (μg/m^3):	-0.02231097	-0.02231097	-0.02231097	-0.02231097	-0.02231097	-0.02231097	-0.02231097	-0.02231097
Increased number of cases in population:	-0.0084	-0.0016	-0.0003	-0.0011	-0.0075	-0.0003	-0.0002	-0.0006
Croyden Park								
Total Population in study area:	16360	16360	16360	16360	16360	16360	16360	16360
total change	-245.7	-245.7	-245.7	-245.7	-245.7	-245.7	-245.7	-245.7
Population weighted Δx (μg/m^3):	-0.01501834	-0.01501834	-0.01501834	-0.01501834	-0.01501834	-0.01501834	-0.01501834	-0.01501834
Increased number of cases in population:	-0.0098	-0.0019	-0.0004	-0.0012	-0.0088	-0.0003	-0.0002	-0.0007
Dulwich Hill								
Total Population in study area:	15862	15862	15862	15862	15862	15862	15862	15862
Population weighted Δx (μg/m^3):	-0.04477367	-0.04477367	-0.04477367	-0.04477367	-0.04477367	-0.04477367	-0.04477367	-0.04477367
Increased number of cases in population:	-0.0284	-0.0054	-0.0012	-0.0036	-0.0256	-0.0010	-0.0007	-0.0019
Haberfield								
Total Population in study area:	13245	13245	13245	13245	13245	13245	13245	13245
total change	-867.8	-867.8	-867.8	-867.8	-867.8	-867.8	-867.8	-867.8
Population weighted Δx (μg/m^3):	-0.06551906	-0.06551906	-0.06551906	-0.06551906	-0.06551906	-0.06551906	-0.06551906	-0.06551906
Increased number of cases in population:	-0.0347	-0.0065	-0.0014	-0.0044	-0.0312	-0.0012	-0.0008	-0.0023
Balmain								
Total Population in study area:	14794	14794	14794	14794	14794	14794	14794	14794
total change	250.5	250.5	250.5	250.5	250.5	250.5	250.5	250.5
Population weighted Δx (μg/m^3):	0.01693254	0.01693254	0.01693254	0.01693254	0.01693254	0.01693254	0.01693254	0.01693254
Increased number of cases in population:	0.0100	0.0019	0.0004	0.0013	0.0090	0.0004	0.0002	0.0007
Leichhardt								
Total Population in study area:	24443	24443	24443	24443	24443	24443	24443	24443
total change	-1283.3	-1283.3	-1283.3	-1283.3	-1283.3	-1283.3	-1283.3	-1283.3
Population weighted Δx (μg/m^3):	-0.05250174	-0.05250174	-0.05250174	-0.05250174	-0.05250174	-0.05250174	-0.05250174	-0.05250174
Increased number of cases in population:	-0.0513	-0.0097	-0.0021	-0.0064	-0.0462	-0.0018	-0.0012	-0.0034
Lilyfield								
Total Population in study area:	13073	13073	13073	13073	13073	13073	13073	13073
total change	-582.4	-582.4	-582.4	-582.4	-582.4	-582.4	-582.4	-582.4
Population weighted Δx (μg/m^3):	-0.04454984	-0.04454984	-0.04454984	-0.04454984	-0.04454984	-0.04454984	-0.04454984	-0.04454984
Increased number of cases in population:	-0.0233	-0.0044	-0.0010	-0.0029	-0.0210	-0.0008	-0.0005	-0.0016
Marrickville								
Total Population in study area:	24632	24632	24632	24632	24632	24632	24632	24632
total change	-621.3	-621.3	-621.3	-621.3	-621.3	-621.3	-621.3	-621.3
Population weighted Δx (μg/m^3):	-0.02522329	-0.02522329	-0.02522329	-0.02522329	-0.02522329	-0.02522329	-0.02522329	-0.02522329
Increased number of cases in population:	-0.0248	-0.0047	-0.0010	-0.0031	-0.0224	-0.0009	-0.0006	-0.0017
Petersham								
Total Population in study area:	18817	18817	18817	18817	18817	18817	18817	18817
total change	-1592.1	-1592.1	-1592.1	-1592.1	-1592.1	-1592.1	-1592.1	-1592.1
Population weighted Δx (μg/m^3):	-0.08460966	-0.08460966	-0.08460966	-0.08460966	-0.08460966	-0.08460966	-0.08460966	-0.08460966
Increased number of cases in population:	-0.0637	-0.0120	-0.0026	-0.0080	-0.0573	-0.0023	-0.0015	-0.0042
Sydenham								
Total Population in study area:	7204	7204	7204	7204	7204	7204	7204	7204
total change	-2.4	-2.4	-2.4	-2.4	-2.4	-2.4	-2.4	-2.4
Population weighted Δx (μg/m^3):	-0.00033315	-0.00033315	-0.00033315	-0.00033315	-0.00033315	-0.00033315	-0.00033315	-0.00033315
Increased number of cases in population:	-0.000096	-0.000018	-0.0000040	-0.0000121	-0.000086	-0.0000034	-0.0000023	-0.0000064

	Primary Indicators			Secondary Indicators				
Health Endpoint:	**Mortality - All Causes, Long-term**	**Hospitalisations - Cardiovascular, Short-term**	**Hospitalisations - Respiratory, Short-term**	**Mortality - All Causes, Short-term**	**Mortality - Cardiopulmonary, Long-term**	**Mortality - Cardiovascular, Short-term**	**Mortality - Respiratory, Short-term**	**Morbidity - Asthma ED Admissions - Short-term**
Age Group:	≥ 30 years	≥ 65 years	≥ 65 years	All ages	≥ 30 years	All ages	All ages	1-14 years
β (change in effect per 1 μg/m^3 PM) (as per Table 6-22)	0.0058	0.0008	0.00041	0.00094	0.013	0.00097	0.0019	0.00148
Sydney LGA								
Total Population in study area:	125509	125509	125509	125509	125509	125509	125509	125509
% population in assessment age-group:	59%	8%	8%	100%	59%	100%	100%	6%
Population weighted Δx (μg/m^3):	-0.00942004	-0.00942004	-0.00942004	-0.00942004	-0.00942004	-0.00942004	-0.00942004	-0.00942004
Baseline Incidence (per 100,000) (as per Table 4-5)	1026	9235	3978	508.0	412.0	138.9	49.4	1209.0
Baseline Incidence (per person)	0.01026	0.09235	0.03978	0.00508	0.00412	0.00139	0.00049	0.01209
Increased number of cases in population:	-0.042	-0.0068	-0.0015	-0.0056	-0.037	-0.0016	-0.0011	-0.0013
Risk:	-5.6E-07	-7.0E-07	-1.5E-07	-4.5E-08	-5.0E-07	-1.3E-08	-8.8E-09	-1.7E-07
Individual subrubs within LGA								
Erskinville								
Total Population in study area:	13908	13908	13908	13908	13908	13908	13908	13908
total change	-355.7	-355.7	-355.7	-355.7	-355.7	-355.7	-355.7	-355.7
Population weighted Δx (μg/m^3):	-0.02557521	-0.02557521	-0.02557521	-0.02557521	-0.02557521	-0.02557521	-0.02557521	-0.02557521
Increased number of cases in population:	-0.0125	-0.0020	-0.0005	-0.0017	-0.0113	-0.0005	-0.0003	-0.0004
Glebe								
Total Population in study area:	16595	16595	16595	16595	16595	16595	16595	16595
total change	-375.6	-375.6	-375.6	-375.6	-375.6	-375.6	-375.6	-375.6
Population weighted Δx (μg/m^3):	-0.02263332	-0.02263332	-0.02263332	-0.02263332	-0.02263332	-0.02263332	-0.02263332	-0.02263332
Increased number of cases in population:	-0.0132	-0.0022	-0.0005	-0.0018	-0.0119	-0.0005	-0.0004	-0.0004
Newtown								
Total Population in study area:	21480	21480	21480	21480	21480	21480	21480	21480
total change	-599.7	-599.7	-599.7	-599.7	-599.7	-599.7	-599.7	-599.7
Population weighted Δx (μg/m^3):	-0.02791899	-0.02791899	-0.02791899	-0.02791899	-0.02791899	-0.02791899	-0.02791899	-0.02791899
Increased number of cases in population:	-0.0211	-0.0035	-0.0008	-0.0029	-0.0190	-0.0008	-0.0006	-0.0007
Pyrmont								
Total Population in study area:	18720	18720	18720	18720	18720	18720	18720	18720
total change	764	764	764	764	764	764	764	764
Population weighted Δx (μg/m^3):	0.04081197	0.04081197	0.04081197	0.04081197	0.04081197	0.04081197	0.04081197	0.04081197
Increased number of cases in population:	0.0269	0.0044	0.0010	0.0036	0.0242	0.0010	0.0007	0.0008
Redfern								
Total Population in study area:	12628	12628	12628	12628	12628	12628	12628	12628
total change	-554.8	-554.8	-554.8	-554.8	-554.8	-554.8	-554.8	-554.8
Population weighted Δx (μg/m^3):	-0.04393411	-0.04393411	-0.04393411	-0.04393411	-0.04393411	-0.04393411	-0.04393411	-0.04393411
Increased number of cases in population:	-0.0195	-0.0032	-0.0007	-0.0026	-0.0176	-0.0007	-0.0005	-0.0006
Surry Hills								
Total Population in study area:	4190	4190	4190	4190	4190	4190	4190	4190
total change	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Population weighted Δx (μg/m^3):	0.00002387	0.00002387	0.00002387	0.00002387	0.00002387	0.00002387	0.00002387	0.00002387
Increased number of cases in population:	0.00000352	0.00000058	0.00000013	0.00000048	0.00000317	0.00000013	0.00000009	0.00000011
Sydney								
Total Population in study area:	21726	21726	21726	21726	21726	21726	21726	21726
total change	15.8	15.8	15.8	15.8	15.8	15.8	15.8	15.8
Population weighted Δx (μg/m^3):	0.00072724	0.00072724	0.00072724	0.00072724	0.00072724	0.00072724	0.00072724	0.00072724
Increased number of cases in population:	0.00056	0.000091	0.000020	0.000075	0.00050	0.000021	0.000015	0.000018
Waterloo								
Total Population in study area:	11306	11306	11306	11306	11306	11306	11306	11306
total change	-110.8	-110.8	-110.8	-110.8	-110.8	-110.8	-110.8	-110.8
Population weighted Δx (μg/m^3):	-0.00980011	-0.00980011	-0.00980011	-0.00980011	-0.00980011	-0.00980011	-0.00980011	-0.00980011
Increased number of cases in population:	-0.0039	-0.0006	-0.000141	-0.00053	-0.0035	-0.000149	-0.000104	-0.000123
Crows Nest								
Total Population in study area:	50	50	50	50	50	50	50	50
total change	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Population weighted Δx (μg/m^3):	0.01000000	0.01000000	0.01000000	0.01000000	0.01000000	0.01000000	0.01000000	0.01000000
Increased number of cases in population:	0.000018	0.0000029	0.00000064	0.0000024	0.0000158	0.00000067	0.00000047	0.00000055
North Sydney								
Total Population in study area:	4906	4906	4906	4906	4906	4906	4906	4906
total change	33.8	33.8	33.8	33.8	33.8	33.8	33.8	33.8
Population weighted Δx (μg/m^3):	0.00688952	0.00688952	0.00688952	0.00688952	0.00688952	0.00688952	0.00688952	0.00688952
Increased number of cases in population:	0.0012	0.00019	0.000043	0.00016	0.00107	0.000046	0.000032	0.000037

	Primary Indicators			Secondary Indicators				
Health Endpoint:	**Mortality - All Causes, Long-term**	**Hospitalisations - Cardiovascular, Short-term**	**Hospitalisations - Respiratory, Short-term**	**Mortality - All Causes, Short-term**	**Mortality - Cardiopulmonary, Long-term**	**Mortality - Cardiovascular, Short-term**	**Mortality - Respiratory, Short-term**	**Morbidity - Asthma ED Admissions - Short-term**
Age Group:	≥ 30 years	≥ 65 years	≥ 65 years	All ages	≥ 30 years	All ages	All ages	1-14 years
β (change in effect per 1 μg/m^3 PM) (as per Table 6-22)	0.0058	0.0008	0.00041	0.00094	0.013	0.00097	0.0019	0.00148
Botany LGA								
Total Population in study area:	25700	25700	25700	25700	25700	25700	25700	25700
% population in assessment age-group:	62%	14%	14%	100%	62%	100%	100%	17%
Population weighted Δx (μg/m^3):	-0.01260311	-0.01260311	-0.01260311	-0.01260311	-0.01260311	-0.01260311	-0.01260311	-0.01260311
Baseline Incidence (per 100,000) (as per Table 4-5)	1026	9235	3978	523.8	412.0	150.0	49.4	1209.0
Baseline Incidence (per person)	0.01026	0.09235	0.03978	0.00524	0.00412	0.00150	0.00049	0.01209
Increased number of cases in population:	-0.012	-0.0034	-0.00076	-0.0016	-0.011	-0.00047	-0.00030	-0.0010
Risk:	-7.5E-07	-9.3E-07	-2.1E-07	-6.2E-08	-6.8E-07	-1.8E-08	-1.2E-08	-2.3E-07
Individual subrubs within LGA								
Botany								
Total Population in study area:	8915	8915	8915	8915	8915	8915	8915	8915
total change	60.4	60.4	60.4	60.4	60.4	60.4	60.4	60.4
Population weighted Δx (μg/m^3):	0.00677510	0.00677510	0.00677510	0.00677510	0.00677510	0.00677510	0.00677510	0.00677510
Increased number of cases in population:	0.0022	0.00064	0.00014	0.0003	0.0020	0.000088	0.000057	0.00018
Mascot								
Total Population in study area:	16215	16215	16215	16215	16215	16215	16215	16215
total change	-346.6	-346.6	-346.6	-346.6	-346.6	-346.6	-346.6	-346.6
Population weighted Δx (μg/m^3):	-0.02137527	-0.02137527	-0.02137527	-0.02137527	-0.02137527	-0.02137527	-0.02137527	-0.02137527
Increased number of cases in population:	-0.0127	-0.0037	-0.00081	-0.0017	-0.0114	-0.00050	-0.00033	-0.0010
Pagewood								
Total Population in study area:	567	567	567	567	567	567	567	567
total change	-37.6	-37.6	-37.6	-37.6	-37.6	-37.6	-37.6	-37.6
Population weighted Δx (μg/m^3):	-0.06631393	-0.06631393	-0.06631393	-0.06631393	-0.06631393	-0.06631393	-0.06631393	-0.06631393
Increased number of cases in population:	-0.00138	-0.00040	-0.000088	-0.00019	-0.00124	-0.000055	-0.000035	-0.00011

	Primary Indicators			Secondary Indicators				
Health Endpoint:	**Mortality - All Causes, Long-term**	**Hospitalisations - Cardiovascular, Short-term**	**Hospitalisations - Respiratory, Short-term**	**Mortality - All Causes, Short-term**	**Mortality - Cardiopulmonary, Long-term**	**Mortality - Cardiovascular, Short-term**	**Mortality - Respiratory, Short-term**	**Morbidity - Asthma ED Admissions - Short-term**
Age Group:	≥ 30 years	≥ 65 years	≥ 65 years	All ages	≥ 30 years	All ages	All ages	1-14 years
β (change in effect per 1 $\mu g/m^3$ PM) (as per Table 6-22)	0.0058	0.0008	0.00041	0.00094	0.013	0.00097	0.0019	0.00148
Rockdale LGA								
Total Population in study area:	82293	82293	82293	82293	82293	82293	82293	82293
% population in assessment age-group:	62%	15%	15%	100%	62%	100%	100%	16%
Population weighted Δx ($\mu g/m^3$):	-0.02658428	-0.02658428	-0.02658428	-0.02658428	-0.02658428	-0.02658428	-0.02658428	-0.02658428
Baseline Incidence (per 100,000) (as per Table 4-5)	1026	9235	3978	534.5	412.0	150.0	49.4	1209.0
Baseline Incidence (per person)	0.01026	0.09235	0.03978	0.00535	0.00412	0.00150	0.00049	0.01209
Increased number of cases in population:	-0.080	-0.024	-0.0053	-0.011	-0.072	-0.0032	-0.0021	-0.0063
Risk:	-1.6E-06	-2.0E-06	-4.3E-07	-1.3E-07	-1.4E-06	-3.9E-08	-2.5E-08	-4.8E-07
Individual subrubs within LGA								
Arncliffe								
Total Population in study area:	14669	14669	14669	14669	14669	14669	14669	14669
total change	-788.4	-788.4	-788.4	-788.4	-788.4	-788.4	-788.4	-788.4
Population weighted Δx ($\mu g/m^3$):	-0.05374599	-0.05374599	-0.05374599	-0.05374599	-0.05374599	-0.05374599	-0.05374599	-0.05374599
Increased number of cases in population:	-0.0290	-0.0086	-0.0019	-0.0040	-0.0261	-0.0011	-0.0007	-0.0023
Bexley								
Total Population in study area:	25123	25123	25123	25123	25123	25123	25123	25123
total change	-259.7	-259.7	-259.7	-259.7	-259.7	-259.7	-259.7	-259.7
Population weighted Δx ($\mu g/m^3$):	-0.01033714	-0.01033714	-0.01033714	-0.01033714	-0.01033714	-0.01033714	-0.01033714	-0.01033714
Increased number of cases in population:	-0.0095	-0.0028	-0.00063	-0.0013	-0.0086	-0.00038	-0.00024	-0.00074
Kingsgrove - South								
Total Population in study area:	11981	11981	11981	11981	11981	11981	11981	11981
total change	-747.4	-747.4	-747.4	-747.4	-747.4	-747.4	-747.4	-747.4
Population weighted Δx ($\mu g/m^3$):	-0.06238210	-0.06238210	-0.06238210	-0.06238210	-0.06238210	-0.06238210	-0.06238210	-0.06238210
Increased number of cases in population:	-0.0274	-0.0082	-0.0018	-0.0038	-0.0247	-0.0011	-0.00070	-0.0021
Monterey								
Total Population in study area:	12192	12192	12192	12192	12192	12192	12192	12192
total change	21.3	21.3	21.3	21.3	21.3	21.3	21.3	21.3
Population weighted Δx ($\mu g/m^3$):	0.00174705	0.00174705	0.00174705	0.00174705	0.00174705	0.00174705	0.00174705	0.00174705
Increased number of cases in population:	0.00078	0.00023	0.000051	0.00011	0.00070	0.000031	0.000020	0.000061
Rockdale								
Total Population in study area:	18328	18328	18328	18328	18328	18328	18328	18328
total change	-413.6	-413.6	-413.6	-413.6	-413.6	-413.6	-413.6	-413.6
Population weighted Δx ($\mu g/m^3$):	-0.02256656	-0.02256656	-0.02256656	-0.02256656	-0.02256656	-0.02256656	-0.02256656	-0.02256656
Increased number of cases in population:	-0.0152	-0.0045	-0.0010	-0.0021	-0.0137	-0.00060	-0.00039	-0.0012

	Primary Indicators			Secondary Indicators				
Health Endpoint:	**Mortality - All Causes, Long-term**	**Hospitalisations - Cardiovascular, Short-term**	**Hospitalisations - Respiratory, Short-term**	**Mortality - All Causes, Short-term**	**Mortality - Cardiopulmonary, Long-term**	**Mortality - Cardiovascular, Short-term**	**Mortality - Respiratory, Short-term**	**Morbidity - Asthma ED Admissions - Short-term**
Age Group:	≥ 30 years	≥ 65 years	≥ 65 years	All ages	≥ 30 years	All ages	All ages	1-14 years
β (change in effect per 1 μg/m³ PM) (as per Table 6-22)	0.0058	0.0008	0.00041	0.00094	0.013	0.00097	0.0019	0.00148
Canterbury - Bankstown LGA								
Total Population in study area:	76834	76834	76834	76834	76834	76834	76834	76834
% population in assessment age-group:	58%	13%	13%	100%	58%	100%	100%	19%
Population weighted Δx (μg/m³):	-0.02199417	-0.02199417	-0.02199417	-0.02199417	-0.02199417	-0.02199417	-0.02199417	-0.02199417
Baseline Incidence (per 100,000) (as per Table 4-5)	1026	9235	3978	490.6	412.0	139.2	49.4	1209.0
Baseline Incidence (per person)	0.01026	0.09235	0.03978	0.00491	0.00412	0.00139	0.00049	0.01209
Increased number of cases in population:	-0.059	-0.016	-0.0036	-0.0078	-0.053	-0.0023	-0.0016	-0.0058
Risk:	-1.3E-06	-1.6E-06	-3.6E-07	-1.0E-07	-1.2E-06	-3.0E-08	-2.1E-08	-3.9E-07
Individual subrubs within LGA								
Belmore								
Total Population in study area:	18330	18330	18330	18330	18330	18330	18330	18330
total change	-198.7	-198.7	-198.7	-198.7	-198.7	-198.7	-198.7	-198.7
Population weighted Δx (μg/m³):	-0.01084015	-0.01084015	-0.01084015	-0.01084015	-0.01084015	-0.01084015	-0.01084015	-0.01084015
Increased number of cases in population:	-0.0069	-0.0019	-0.0004	-0.00092	-0.0062	-0.00027	-0.00019	-0.00068
Canterbury (South)								
Total Population in study area:	26841	26841	26841	26841	26841	26841	26841	26841
total change	-686.8	-686.8	-686.8	-686.8	-686.8	-686.8	-686.8	-686.8
Population weighted Δx (μg/m³):	-0.02558772	-0.02558772	-0.02558772	-0.02558772	-0.02558772	-0.02558772	-0.02558772	-0.02558772
Increased number of cases in population:	-0.0238	-0.0066	-0.0015	-0.0032	-0.0214	-0.00093	-0.00064	-0.0024
Kinsgrove - North								
Total Population in study area:	22489	22489	22489	22489	22489	22489	22489	22489
total change	-701.1	-701.1	-701.1	-701.1	-701.1	-701.1	-701.1	-701.1
Population weighted Δx (μg/m³):	-0.03117524	-0.03117524	-0.03117524	-0.03117524	-0.03117524	-0.03117524	-0.03117524	-0.03117524
Increased number of cases in population:	-0.0243	-0.0067	-0.0015	-0.0032	-0.0219	-0.00095	-0.00066	-0.0024
Lakemba								
Total Population in study area:	3643	3643	3643	3643	3643	3643	3643	3643
total change	-22.6	-22.6	-22.6	-22.6	-22.6	-22.6	-22.6	-22.6
Population weighted Δx (μg/m³):	-0.00620368	-0.00620368	-0.00620368	-0.00620368	-0.00620368	-0.00620368	-0.00620368	-0.00620368
Increased number of cases in population:	-0.00078	-0.00022	-0.000048	-0.00010	-0.00070	-0.000031	-0.000021	-0.000078
Roselands								
Total Population in study area:	5531	5531	5531	5531	5531	5531	5531	5531
total change	-80.7	-80.7	-80.7	-80.7	-80.7	-80.7	-80.7	-80.7
Population weighted Δx (μg/m³):	-0.01459049	-0.01459049	-0.01459049	-0.01459049	-0.01459049	-0.01459049	-0.01459049	-0.01459049
Increased number of cases in population:	-0.0028	-0.00078	-0.00017	-0.00037	-0.0025	-0.00011	-0.000076	-0.00028

	Primary Indicators			Secondary Indicators				
Health Endpoint:	**Mortality - All Causes, Long-term**	**Hospitalisations - Cardiovascular, Short-term**	**Hospitalisations - Respiratory, Short-term**	**Mortality - All Causes, Short-term**	**Mortality - Cardiopulmonary, Long-term**	**Mortality - Cardiovascular, Short-term**	**Mortality - Respiratory, Short-term**	**Morbidity - Asthma ED Admissions - Short-term**
Age Group:	≥ 30 years	≥ 65 years	≥ 65 years	All ages	≥ 30 years	All ages	All ages	1-14 years
β (change in effect per 1 μg/m^3 PM) (as per Table 6-22)	0.0058	0.0008	0.00041	0.00094	0.013	0.00097	0.0019	0.00148
Georges River LGA								
Total Population in study area:	66896	66896	66896	66896	66896	66896	66896	66896
% population in assessment age-group:	61%	15%	15%	100%	61%	100%	100%	16%
Population weighted Δx (μg/m^3):	-0.00592711	-0.00592711	-0.00592711	-0.00592711	-0.00592711	-0.00592711	-0.00592711	-0.00592711
Baseline Incidence (per 100,000) (as per Table 4-5)	1026	9235	3978	465.5	412.0	131.3	49.4	1209.0
Baseline Incidence (per person)	0.01026	0.09235	0.03978	0.00466	0.00412	0.00131	0.00049	0.01209
Increased number of cases in population:	-0.014	-0.0045	-0.0010	-0.0017	-0.013	-0.00050	-0.00037	-0.0012
Risk:	-3.5E-07	-4.4E-07	-9.7E-08	-2.6E-08	-3.2E-07	-7.5E-09	-5.6E-09	-1.1E-07
Individual subrubs within LGA								
Hurstville								
Total Population in study area:	20164	20164	20164	20164	20164	20164	20164	20164
total change	-340.1	-340.1	-340.1	-340.1	-340.1	-340.1	-340.1	-340.1
Population weighted Δx (μg/m^3):	-0.01686669	-0.01686669	-0.01686669	-0.01686669	-0.01686669	-0.01686669	-0.01686669	-0.01686669
Increased number of cases in population:	-0.0124	-0.0039	-0.00085	-0.0015	-0.0111	-0.00043	-0.00032	-0.0010
Kogorah								
Total Population in study area:	9484	9484	9484	9484	9484	9484	9484	9484
total change	224.5	224.5	224.5	224.5	224.5	224.5	224.5	224.5
Population weighted Δx (μg/m^3):	0.02367145	0.02367145	0.02367145	0.02367145	0.02367145	0.02367145	0.02367145	0.02367145
Increased number of cases in population:	0.0082	0.0026	0.00056	0.0010	0.0074	0.00029	0.00021	0.00066
Kogorah Bay								
Total Population in study area:	9469	9469	9469	9469	9469	9469	9469	9469
total change	13.2	13.2	13.2	13.2	13.2	13.2	13.2	13.2
Population weighted Δx (μg/m^3):	0.00139402	0.00139402	0.00139402	0.00139402	0.00139402	0.00139402	0.00139402	0.00139402
Increased number of cases in population:	0.00048	0.00015	0.000033	0.000058	0.00043	0.000017	0.000012	0.000039
Mortdale								
Total Population in study area:	11002	11002	11002	11002	11002	11002	11002	11002
total change	-43.6	-43.6	-43.6	-43.6	-43.6	-43.6	-43.6	-43.6
Population weighted Δx (μg/m^3):	-0.00396292	-0.00396292	-0.00396292	-0.00396292	-0.00396292	-0.00396292	-0.00396292	-0.00396292
Increased number of cases in population:	-0.0016	-0.00050	-0.00011	-0.00019	-0.00143	-0.000056	-0.000041	-0.00013
Narwee								
Total Population in study area:	4884	4884	4884	4884	4884	4884	4884	4884
total change	-203.4	-203.4	-203.4	-203.4	-203.4	-203.4	-203.4	-203.4
Population weighted Δx (μg/m^3):	-0.04164619	-0.04164619	-0.04164619	-0.04164619	-0.04164619	-0.04164619	-0.04164619	-0.04164619
Increased number of cases in population:	-0.0074	-0.0023	-0.00051	-0.00089	-0.0067	-0.00026	-0.00019	-0.00060
Oatley								
Total Population in study area:	4322	4322	4322	4322	4322	4322	4322	4322
total change	-19.1	-19.1	-19.1	-19.1	-19.1	-19.1	-19.1	-19.1
Population weighted Δx (μg/m^3):	-0.00441925	-0.00441925	-0.00441925	-0.00441925	-0.00441925	-0.00441925	-0.00441925	-0.00441925
Increased number of cases in population:	-0.00070	-0.00022	-0.000048	-0.000084	-0.00063	-0.000024	-0.000018	-0.000056
South Hurstville								
Total Population in study area:	7571	7571	7571	7571	7571	7571	7571	7571
total change	-48.1	-48.1	-48.1	-48.1	-48.1	-48.1	-48.1	-48.1
Population weighted Δx (μg/m^3):	-0.00635319	-0.00635319	-0.00635319	-0.00635319	-0.00635319	-0.00635319	-0.00635319	-0.00635319
Increased number of cases in population:	-0.0018	-0.00055	-0.00012	-0.00021	-0.00158	-0.000061	-0.000045	-0.00014
Total population incidence - All Suburbs	**-0.4**	**-0.09**	**-0.02**	**-0.05**	**-0.4**	**-0.02**	**-0.01**	**-0.03**

Annexure H – Risk calculations: Particulate matter exposures for elevated receptors

Quantification of Effects - $PM_{2.5}$ and PM_{10}
M4-M5 Link: 2033 - Cumulative

Air quality indicator:	$PM_{2.5}$	$PM_{2.5}$	$PM_{2.5}$	$PM_{2.5}$	$PM_{2.5}$	$PM_{2.5}$	$PM_{2.5}$	$PM_{2.5}$	DPM
Endpoint:	Mortality - All Causes	Hospitalisations - Cardiovascular	Hospitalisations - Respiratory	Mortality - All Causes	Mortality - Cardiopulmonary	Mortality - Cardiovascular	Mortality - Respiratory	Morbidity - Asthma ED Admissions	Increased risk - lung cancer
Effect Exposure Duration:	Long-term	Short-term	Short-term	Short-Term	Long-term	Short-Term	Short-Term	Short-Term	Based on WHO
Age Group:	≥ 30 years	≥ 65 years	≥ 65 years	All ages	≥ 30 years	All ages	All ages	1-14 years	inhalation unit risk
β (change in effect per 1 μg/m^3) (as per Table 6-22)	0.0058	0.0008	0.00041	0.00094	0.013	0.00097	0.0019	0.00148	3.40E-05
Annual Baseline Incidence (as per Table 4-5)									(ug/m3)-1
Annual baseline incidence (per 100,000)	1026	9235	3978	493	412	134.7	49.4	1209	
Baseline Incidence (per person per year)	0.01026	0.09235	0.03978	0.00493	0.00412	0.001347	0.000494	0.01209	

Sensitive Receptors		Change in Annual Average PM2.5 Concentration (μg/m^3)	Risk	Risk	Risk	Risk	Risk	Risk	Risk	Risk	Risk
Impacts from tunnel ventilation outlets											
Maximum impact: 10 m height		0.79	5E-05	6E-05	1E-05	4E-06	4E-05	1E-06	7E-07	1E-05	3E-05
Maximum impact: 30m height		5.60	3E-04	4E-04	9E-05	3E-05	3E-04	7E-06	5E-06	1E-04	2E-04
Maximum impact, existing residential: 30m height		1.44	9E-05	1E-04	2E-05	7E-06	8E-05	2E-06	1E-06	3E-05	5E-05

Annexure I – Noise catchment areas

Figure I-1 **Site Plan and NCA Boundary Map (western section)**

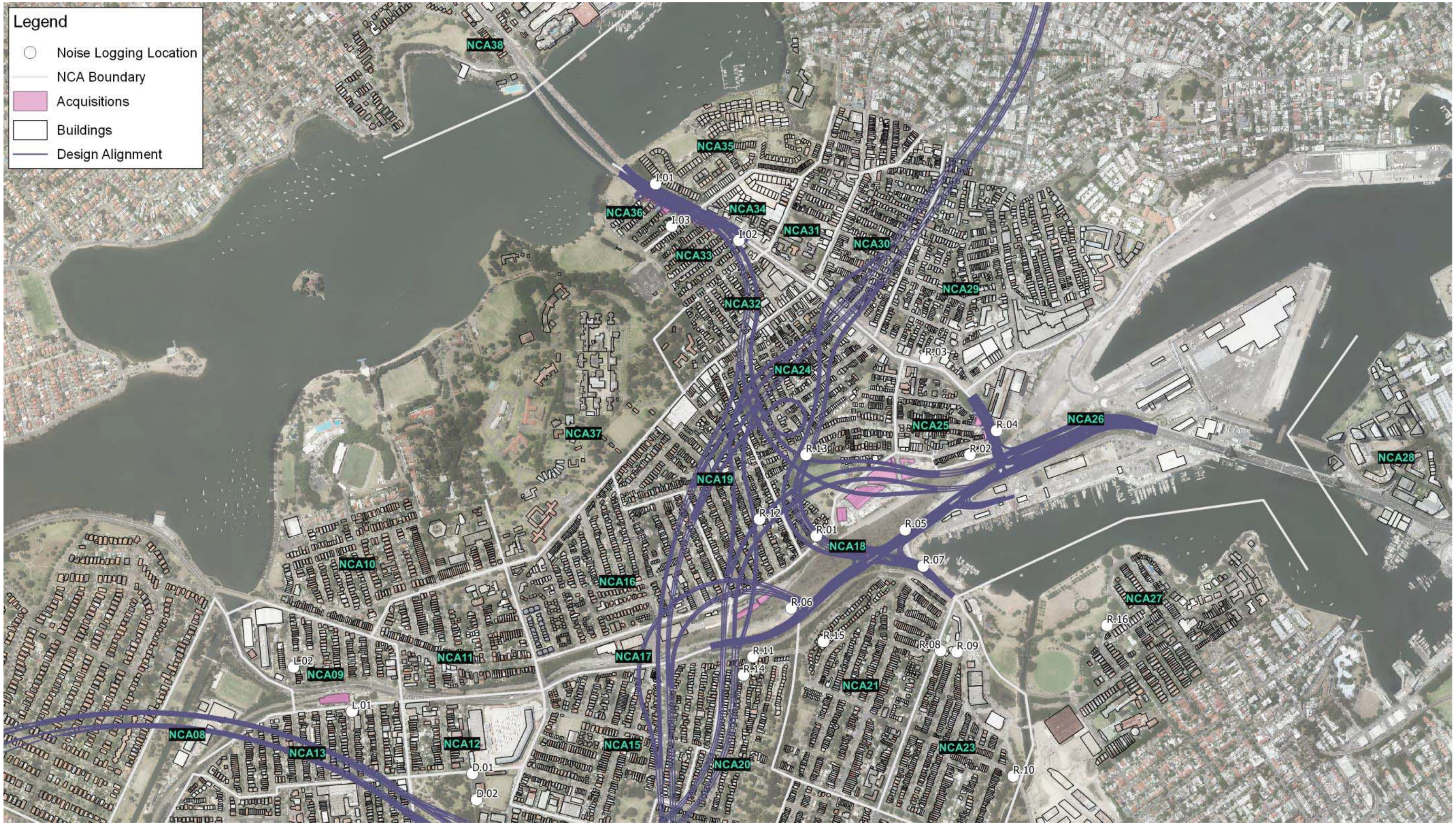


Figure I-2 Site Plan and NCA Boundary Map (northern section)

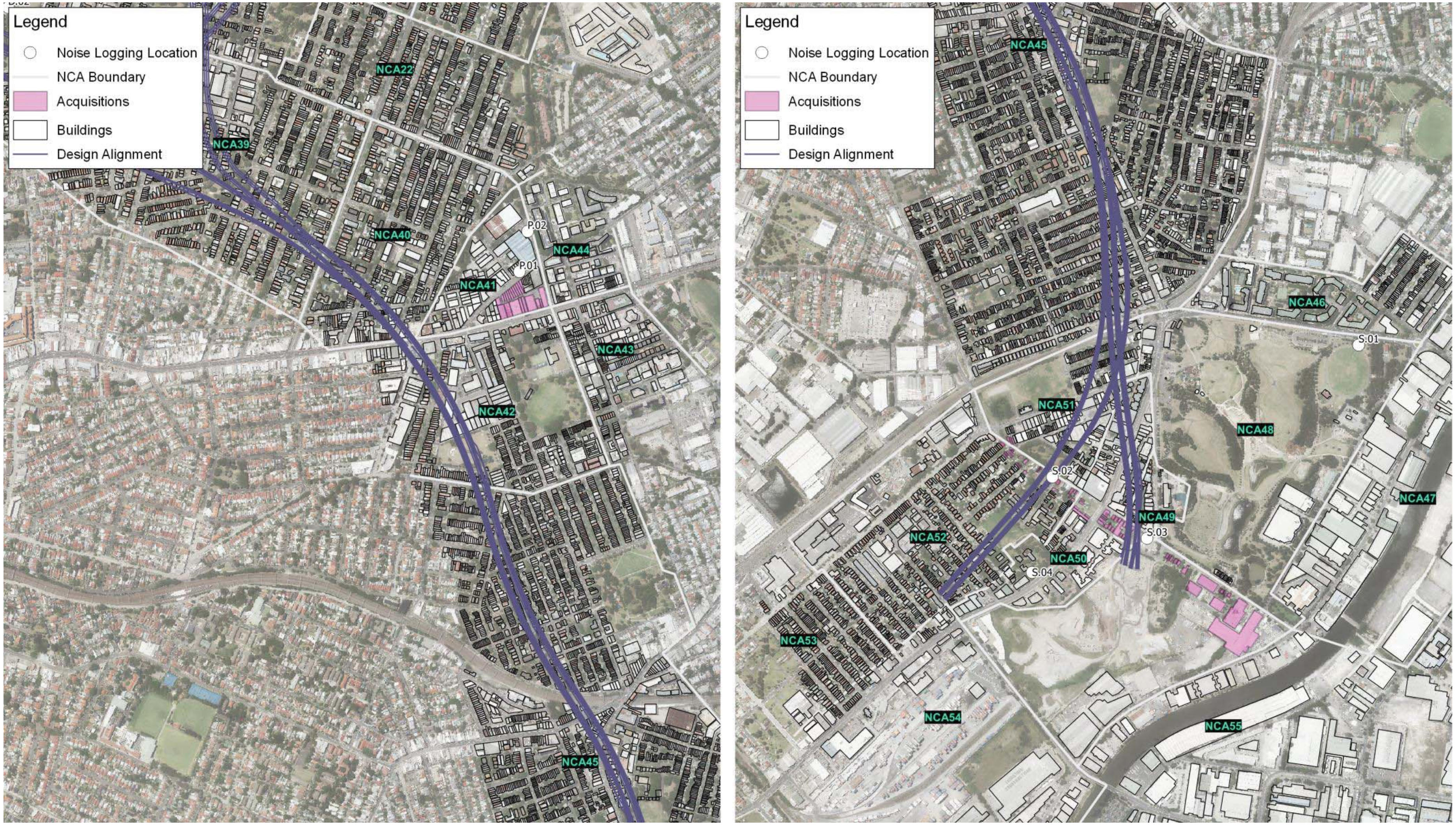


Figure I-3 **Site Plan and NCA Boundary Map (southern section)**

Table I-1 Noise catchment areas and surrounding land uses

NCA description		
Reference	**Min. distance (m)[1]**	**Description**
Haberfield		
NCA00	40	South of Parramatta Road between Bland Street and Orpington Street. Land use consists of residential receptors.
NCA01	<5	South of Parramatta Road between Iron Cove Creek and Bland Street. Land use comprises of a mix of residential receptors, special use facilities, active and passive recreation areas and commercial receptors fronting Parramatta Road.
NCA02	<5	North of Parramatta Road between Henley Marine Drive and Walker Avenue. Land use comprises of a mix of residential and commercial receptors, a place of worship and a child care facility.
NCA03	20	Catchment adjoins either side of Wattle Street between Ash Lane and Ramsay Street. Land use consists of residential receptors.
NCA04	30	Catchment area adjoins Ramsay Street and the western side of Wattle Street. Land use consists of residential receptors, isolated commercial receptors and a passive recreational area
NCA05	n/a[2]	South of Dobroyd Parade between Hawthorne Parade and Martin Street. Land use consists of residential receptors with isolated commercial receptors and educational facilities
NCA06	<5	North of Parramatta Road between Walker Avenue and Alt Street residences. Land use consists of residential and commercial receptors and an educational facility on Ramsay Street
NCA07	<5	North of Parramatta Road between Dalhousie Street and Bland Street residences. Land use comprises of a mix of residential and commercial facilities, other sensitives and active and passive recreation areas.
Darley Road, Leichhardt		
NCA08	120	South of City West Link between Hawthorne Parade and Darley Road. Land use comprises of commercial receptors and active and passive recreation areas
NCA09	45	North of City West Link between Norton Street and Lilyfield Road. Land use comprises of a mix of residential and commercial receptors and two child care facilities
NCA10	200	North of Perry Street between Lilyfield Road and Wharf Road. Land use comprises of a mix of residential receptors, isolated commercial receptors and special use facilities.
NCA11	100	North of City West Link between Norton Street, Balmain Road and Perry Street. Land use comprises of a mix of residential receptors, isolated commercial receptors and special use facilities.
NCA12	100	South of City West Link between Norton Street, Balmain Road and William Street. Land use comprises of a mix of residential and commercial receptors, a place of worship and the Sydney Buses Leichhardt depot.
NCA13	15	South of Darley Road between Norton Street and William Street. Land use consists of residential receptors and isolated commercial receptors.
NCA14	n/a[2]	South of William Street between Darley Road and Norton Street. Land use comprises of a mix of residential receptors, isolated commercial receptors and special use facilities.

NCA description		
Reference	**Min. distance (m)[1]**	**Description**
Rozelle, Lilyfield, Annandale, Glebe and Pyrmont		
NCA15	30	South of City West Link between Balmain Road, Moore Street and Starling Street/Paling Street. Land use comprises of a mix of residential receptors, isolated commercial receptors, a child care centre and passive recreation area.
NCA16	35	North of Lilyfield Road between Balmain Road, Lamb Street and O'Neill Street. Land use comprises of a mix of residential receptors, isolated commercial receptors and a medical centre.
NCA17	30	North of City West Link between Lilyfield Road, Balmain Road and the boundary of the project in the Rozelle Rail Yard. Land use consists of commercial receptors and the Sydney Light Rail Lilyfield Depot.
NCA18	<5	North of City West Link between Lilyfield Road, Victoria Road and the Sydney Light Rail Lilyfield Depot. Land use consists of commercial receptors and the Rozelle Rail Yard, which will become the project site.
NCA19	25	North of Lilyfield Road between Lamb Street, Foucart Street and Balmain Road. Land use comprises of a mix of residential receptors, isolated commercial receptors and a child care centre.
NCA20	45	South of City West Link between Whites Creek, Moore Street and Starling Street/Paling Street. Land use comprises of a mix of residential receptors, isolated commercial receptors and passive recreation areas.
NCA21	20	West of Johnston Street between Piper Street, Railway Parade and Whites Creek. Land use comprises of a mix of residential receptors, isolated commercial receptors and an educational facility.
NCA23	90	East of Johnston Street between The Crescent, Piper Street and Johnstons Creek, including commercial premises on the east side of The Crescent. Land use comprises of a mix of residential receptors, commercial receptors, an educational facility and a passive recreation area.
NCA24	20	North of Lilyfield Road between Foucart Street, Gordon Street, Victoria Road and Darling Street. Land use comprises of a mix of residential and commercial receptors, special use facilities and active and passive recreation areas.
NCA25	<5	West of Victoria Road between Gordon Street and Lilyfield Road, including residences on the south side of Lilyfield Road. Land use comprises of a mix of residential receptors, isolated commercial receptors and special use facilities.
NCA26	<5	Catchment area adjoins either side of the western approach to Anzac Bridge, between Victoria Road, Robert Street, White Bay, Johnstons Bay and Rozelle Bay. Land use consists of a mix of commercial and industrial receptors including port facilities.
NCA27	90	East of The Crescent between Rozelle Bay and Blackwattle Bay. Land use comprises of a mix of residential receptors, isolated commercial receptors, special use facilities and active and passive recreation areas.
NCA28	400	Catchment area adjoins either side of the eastern approach to Anzac Bridge, between Johnstons Bay and Blackwattle Bay. Land use comprises of a mix of residential and commercial receptors.
NCA29	50	North of Victoria Road between Robert Street and Evans Street. Land use comprises of a mix of residential and commercial receptors and special use facilities.
NCA39	n/a[2]	South of Moore Street/Booth Street between Norton Street and Johnston Street. Land use comprises of a mix of residential receptors and commercial receptors, special use facilities and a passive recreation area.

NCA description		
Reference	Min. distance (m)[1]	Description
Iron Cove		
NCA30	200	North of Victoria Road between Evans Street and Darling Street. Land use comprises of a mix of residential and commercial receptors and special use facilities.
NCA31	20	North of Victoria Road between Darling Street and Wellington Street. Land use comprises of a mix of residential and commercial receptors, special use facilities and an active recreation area.
NCA32	10	South of Victoria Road between Darling Street and Moodie Street residences. Land use comprises of a mix of residential and commercial receptors and special use facilities.
NCA33	<5	South of Victoria Road between Moodie Street residences and Toelle Street. Land use comprises of a mix of residential and commercial receptors.
NCA34	<5	North of Victoria Road between Wellington Street and Terry Street. Land use comprises of a mix of residential and commercial receptors.
NCA35	10	North of Victoria Road between Terry Street and Parramatta River. Land use comprises of a mix of residential receptors, isolated commercial receptors, an educational facility and active and passive recreation areas.
NCA36	<5	South of Victoria Road between Toelle Street and Parramatta River. Land use comprises of a mix of residential receptors, isolated commercial receptors and active and passive recreation areas.
NCA37	300	North of Balmain Road between Wharf Street, Manning Street and Parramatta River. Land use comprises of a mix of special use facilities and active and passive recreation areas.
NCA38	400	Catchment area adjoins either side of Victoria Road, north of Parramatta River. Land use comprises of a mix of residential and commercial receptors, special use facilities and active and passive recreation areas.
Pyrmont Bridge Road		
NCA22	300	Catchment area adjoins either side of Johnston Street, between Piper Street, Booth Street, Whites Creek Valley Park and Johnstons Creek. Land use comprises of a mix of residential receptors, isolated commercial receptors and passive recreation areas.
NCA40	160	East of Johnston Street between Booth Street, Johnstons Creek and Parramatta Road. Land use comprises of a mix of residential and commercial receptors and special use facilities.
NCA41	<5	North of Parramatta Road between Booth Street/Mallett Street and Johnstons Creek. Land use comprises of a mix of residential and commercial receptors and a place of worship.
NCA42	25	South of Parramatta Road between Mallett Street and Salisbury Road. Land use comprises of a mix of residential and commercial receptors, special use facilities and active and passive recreation areas.
NCA43	35	South of Parramatta Road, east of Mallett Street. Land use comprises of a mix of residential and commercial receptors and special use facilities.
NCA44	20	North of Parramatta Road, east of Booth Street. Land use comprises of a mix of residential and commercial receptors.

NCA description		
Reference	**Min. distance (m)[1]**	**Description**
NCA45	n/a[2]	Catchment area extends from Salisbury Road in the north to the Illawarra Rail Line/St Peters Rail Station in the south. Land use comprises of a mix of residential and commercial receptors and special use facilities.
St Peters		
NCA46	750	North of Sydney Park Road between Concord Street, Coulson Street and Maddox Street. Land use comprises of a mix of residential receptors and isolated commercial receptors.
NCA47	150	East of Euston Road, between Maddox Street and Campbell Road. Land use consists of commercial receptors.
NCA48	50	South of Sydney Park Road between Barwon Park Road, Campbell Road and Euston Road. Land use comprises of a passive recreation area and isolated commercial receptors.
NCA49	75	Catchment area adjoins either side of Barwon Park Road, between Campbell Road and Crown Street. Land use comprises of a mix of residential and commercial receptors.
NCA50	<5	Catchment area adjoins either side of Princes Highway, between Mary Street, Church Street/Applebee Street and May Street. Land use comprises of a mix of residential and commercial receptors, an educational facility and an active recreation area.
NCA51	225	North of Campbell Street between Applebee Street and the Illawarra Rail Line/St Peters Rail Station. Land use comprises of a mix of residential and commercial receptors and active and passive recreation areas.
NCA52	225	South of the Illawarra Rail Line between Campbell Street, Sutherland Street and Princes Highway premises. Land use comprises of a mix of residential and commercial receptors, an educational facility and active and passive recreation areas.
NCA53	n/a[2]	West of Princes Highway, south of Sutherland Street. Land use comprises of a mix of residential and commercial receptors.
NCA54	n/a[2]	East of Princes Highway between Canal Street and Alexandra Canal. Land use comprises of a mix of residential and commercial receptors.
NCA55	190	East of Burrows Road. Land use comprises of a mix of residential and commercial receptors.

Note 1: *Approximate minimum horizontal offset distance from the nearest receptor building facade (receptor of any type) to the nearest point that construction works are occurring.*

Note 2: *No surface works are proposed in this NCA. Receptors in this catchment would therefore only be potentially affected by impacts from tunnelling works during construction.*