9 Air quality

This chapter describes the methodology used to assess the impacts of the project on regional, local and in-tunnel air quality, the results of that assessment, proposed mitigation measures to avoid or reduce the impacts and how the desired performance outcomes have been met. **Appendix E** (Air quality technical report) provides greater detail on the monitoring and modelling methodologies and results. **Table 9-1** sets out the SEARs relevant to air quality and identifies where the requirements have been addressed in this EIS.

Table 9-1 SEARs - Air quality

Assessment requirements	Where addressed in this EIS
1. The Proponent must undertake an air quality impact assessment (AQIA) addressing local and regional air quality impacts for construction and operation of the project in accordance with the current guidelines.	The full AQIA is reported in Appendix E (Air quality technical report).
2. The Proponent must ensure the AQIA also includes the following: (a) demonstrated ability to comply with the relevant regulatory framework, specifically the Protection of the Environment Operations Act 1997 and the Protection of the Environment Operations (Clean Air) Regulation 2010;	Section 9.5 and section 9.6 and Appendix E (Air quality technical report).
(b) the identification of all potential sources of air pollution including details of the location, configuration and design of all potential emission sources including ventilation systems and tunnel portals;	Section 9.5 and section 9.6 and Appendix E (Air quality technical report).
(c) a review of vehicle emission trends and an assessment that uses or sources best available information on vehicle emission factors;	Section 9.4.3, Appendix E and Annexure K (Ventilation report) of Appendix E (Air quality technical report).
(d) an assessment of impacts (including human health impacts) from potential emissions of PM10, $PM_{2.5}$, CO, NO_2 and other nitrogen oxides and volatile organic compounds (e.g. BTEX) including consideration of short and long-term exposure periods;	Section 9.5 and section 9.6 and Appendix E (Air quality technical report). Refer to Appendix F (Human health technical report) for human health impacts.
(e) consider the impacts from the dispersal of these air pollutants on the ambient air quality along the proposal route, proposed ventilation outlets and portals, surface roads, ramps and interchanges and the alternative surface road routes;	Section 9.5 and section 9.6 and Appendix E (Air quality technical report).
(f) a qualitative assessment of the redistribution of ambient air quality impacts compared with existing conditions, due to the predicted changes in traffic volumes;	Section 9.6.7
(g) assessment of worst case scenarios for in-tunnel and ambient air quality, including a range of potential ventilation scenarios and range of traffic scenarios, including worst case design maximum traffic flow scenario (variable speed) and worst case breakdown scenario, and discussion of the likely occurrence of each;	Section 9.6 and Annexure K (Ventilation report) of Appendix E (Air quality technical report).
(h) details of the proposed tunnel design and mitigation measures to address in-tunnel air quality and the air quality in the vicinity of portals and any mechanical ventilation systems (i.e. ventilation outlets and air inlets) including details of proposed air quality monitoring (including frequency and criteria);	Chapter 5 (Project development and alternatives), Chapter 6 (Project description) and Appendix E (Air quality technical report).

Assessment requirements	Where addressed in this EIS
(i) a demonstration of how the project and ventilation design ensures that concentrations of air emissions meet NSW, national and international best practice for in-tunnel and ambient air quality, and taking into consideration the approved criteria for the New M5 project and the In-Tunnel Air Quality (Nitrogen Dioxide) Policy;	Section 9.6 and Appendix E (Air quality technical report).
(j) details of any emergency ventilation systems, such as air intake/ exhaust outlets, including protocols for the operation of these systems in emergency situations, potential emission of air pollutants and their dispersal, and safety procedures;	The ventilation facilities, including emergency systems and their operation, are described in Chapter 6 (Project description).
(k) details of in-tunnel air quality control measures considered, including air filtration, and justification of the proposed measures or for the exclusion of other measures;	The in-tunnel air quality control measures and their justification are described in section 9.7 and Appendix E (Air quality technical report).
(l) a description and assessment of the impacts of potential emissions sources relating to construction, including details of the proposed mitigation measures to prevent the generation and emission of dust (particulate matter and TSP) and air pollutants (including odours) during the construction of the project, particularly in relation to ancillary facilities (such as concrete batching plants), tunnel spoil handling and cut and cover earthworks, the use of mobile plant, stockpiles and the processing and movement of spoil; and	Section 9.5
(m) a cumulative assessment of the in-tunnel, local and regional air quality impacts from the operation of the project and due to the operation of and potential continuous travel through existing and committed future motorway tunnels and surface roads.	Section 9.6.8 and Appendix E (Air quality technical report). An analysis of the potential cumulative impacts is provided in section 9.6.10.

9.1 Background

9.1.1 Terminology

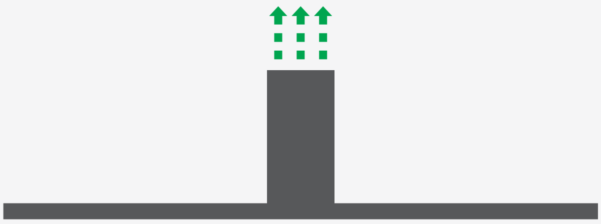
The concentration of a pollutant at a given location includes contributions from various sources.

Figure 9-1 shows the terms used in this assessment to describe the concentration of a pollutant at a specific location or receptor.

Concentration of a pollutant at a specific location or receptor

Background concentration describes all contributing sources of a pollutant concentration other than road traffic. For example, contributions from natural sources, industry and domestic activity

Surface road concentration describes the contribution of pollutants from the surface road network. It includes not only the contribution of the nearest road at the receptor, but also the net contribution of the rest of the modelled road network at the receptor



Ventilation outlet concentration describes the contribution of pollutants from tunnel ventilation outlets

Total concentration = background concentration + surface road concentration + ventilation outlet concentration.
It may relate to conditions with or without the project under assessment

The change in concentration due to the project = total concentration with the project - total concentration without the project.

This may be either an increase or a decrease, depending on factors such as the redistribution of traffic on the network as a result of the project.

Figure 9-1 Common terms used in this air quality assessment

9.1.2 In-tunnel air quality

This section outlines the various air filtration and ventilation options for in-tunnel air quality, and outlines the approach adopted for the project and therefore used in this assessment.

Filtration

There are several in-tunnel air filtration options, these include the electrostatic precipitator, filtering, denitrification and biofiltration, agglomeration and scrubbing. These are described in **Table 9-2** and discussed in more detail in **Appendix E** (Air quality technical report). No in-tunnel filtration system is proposed for the project, this is discussed below.

Table 9-2 In-tunnel air quality filtration options

Filtration type	Description
Electrostatic precipitator	In a typical electrostatic precipitator, the air flow is initially passed through an ionising chamber containing wires or plates maintained at several thousand volts. These produce a corona that releases electrons into the air-stream. The electrons attach to particles in the air flow, and give them a net negative charge. The particles then pass through a collector chamber or passageway which contains multiple parallel collecting plates. The collecting plates are grounded and attract the charged dust particles.
Denitrification systems	Denitrification refers to systems or processes that are designed to remove nitrogen dioxide (NO_2), and other oxides of nitrogen, from tunnel air. A number of alternative systems are available. Nitrogen oxides (NO_X) removal by catalytic and biological processes has been tested in Austria, Germany and Japan in the early 1990s. Due to their weak performance in Nitric oxide (NO) removal efficiency, these tests were stopped. Subsequent developments have concentrated on pilot systems for NO_2 removal. No significant progress in robust NO treatment has been reported.
Bio-filtration	Bio-filtration is a general term used to describe processes in which contaminated air is passed over or through some medium containing micro-organisms capable of consuming, converting or otherwise removing some or all of the harmful pollutants present. The application of bio-filtration processes to emission treatment in road tunnels involves a conflict between the need to move large volumes of air relatively quickly and the need for air to have relatively long exposures or residence times for the biological processes to be effective. Bio-filtration remains an emission treatment option of potential interest, but still an emerging or developing option in respect of road tunnel applications.
Agglomeration	Agglomeration is an electrostatic process whereby opposite electrical charges are applied to very fine airborne particles, causing them to combine or agglomerate into larger particles, which can then be more easily and effectively removed by other processes, or by gravity. Some electrostatic precipitation technologies include the principle of agglomeration in their basic designs. From a road tunnel viewpoint, agglomeration remains an emerging or developing technology, but would appear to have the potential to enhance the effectiveness of other particulate matter removal systems.
Scrubbing	Scrubbing describes a range of processes in which contaminated air is passed through a wash liquid, and pollutants are either entrained or dissolved in the liquid. Scrubbing is a well-established treatment technology in a number of industrial process applications, but generally in applications involving more heavily contaminated or polluted air streams than are experienced in road tunnels. Scrubbing has a potential application in the treatment of road tunnel emissions, but at this stage remains an emerging or developing technology in such applications.

Reference: Child & Associates (2004). M5 East Freeway: A review of emission treatment technologies, systems and applications. Review undertaken by Child & Associates for the Roads and Traffic Authority of NSW.

Around the world, there are relatively few road tunnels with installed filtration systems. There are no Australian road tunnel projects that have installed air filtration systems, these projects rely on the primary approach of dilution of air pollution, through ventilation systems. The inclusion of in-tunnel air filtration for the project was evaluated, based on the predicted air quality results, and found not to provide any material benefit to air quality or community health. As a result, no in-tunnel filtration system is proposed for the project.

Ventilation system

The project would rely on the primary approach of dilution of air pollution, through a ventilation system. On an open roadway, vehicle emissions are diluted and dispersed by natural surface air flows. However, in a tunnel, mechanical ventilation is required to ensure the maintenance of air quality standards and to control smoke in the rare case of fire. Tunnel ventilation requirements are determined by the air flows, the forecast vehicle emissions in the tunnel and the limits of pollutant levels set by regulatory authorities. Air quality is managed by ensuring that the volume of fresh air coming into the tunnel adequately dilutes emissions and balances the air removed through the elevated ventilation outlets. Elevated ventilation outlets are used for tunnels longer than about one kilometre in Australia's urban areas to disperse tunnel air at a height that ensures compliance with ambient air quality criteria. A number of options for the design of the ventilation system were considered. There are several types of ventilation systems, these are described in **Table 9-3**.

Table 9-3 In-tunnel air ventilation options

Ventilation type	Description
Natural ventilation	Road tunnels with natural ventilation rely on vehicle movements, prevailing winds and differences in air pressure between the tunnel portals to move air through the tunnels without the assistance of mechanical ventilation, such as fans. In the case of unidirectional naturally ventilated tunnels, the piston effect generated by traffic using the tunnels also assists in the movement of air. Because naturally ventilated tunnels do not have mechanical ventilation outlets, all air from within the tunnels is emitted via the tunnel portals. In NSW, natural ventilation is only acceptable for use in relatively short tunnels (i.e. less than one kilometre) as without the assistance of mechanical ventilation, vehicle emissions can build up within the tunnels leading to unacceptable in-tunnel air quality under some traffic scenarios. Emergency smoke management considerations may also dictate a mechanical solution. Natural ventilation is not practical for the longer road tunnels proposed for the project, as it would not achieve acceptable in-tunnel air quality under low vehicle speed conditions or during emergencies. It is therefore not an appropriate ventilation design for the project.
Longitudinal ventilation	The simplest form of ventilation for road tunnels is longitudinal ventilation, in which fresh air is drawn in at the entry portal and passes out through the exit portal with the flow of traffic. For longer tunnels, the air flow is supplemented by fans that are used when traffic is moving too slowly to maintain adequate air flow, or to draw air back from the exit portals against the flow of exiting traffic. This air is then exhausted through an elevated ventilation outlet to maximise dispersion. All road tunnels longer than one kilometre built in Australia in the last 20 years have been designed and operated with longitudinal ventilation systems. This includes the Eastern Distributor, Lane Cove and Cross City Tunnels in Sydney.
Transverse ventilation	Emissions can be adequately diluted with the provision of fresh air inlets along the length of the tunnel along one side, with outlets on the opposite side. This system requires two ducts to be constructed along the length of the tunnel: one for the fresh air supply and one for the exhaust air. Transverse ventilation has been used in the past when vehicle emissions produced greater levels of pollutants than they do today. A transverse ventilation system is more expensive to construct because of the additional ducts that need to be excavated for each tunnel. This type of system is less effective than a longitudinal system for controlling smoke in the tunnel in case of a fire. It is also more energy intensive as more power is consumed to manage air flows.
Semi-transverse ventilation	Semi-transverse ventilation combines both longitudinal and transverse ventilation. Fresh air can be supplied through the portals and can be continuously exhausted through a duct along the length of the tunnel. Alternatively, fresh air can be supplied through a duct and exhausted through the portals. This option would be slightly less energy intensive than transverse ventilation, however it would still require the construction of some additional fresh air ducts and would not be as effective as a longitudinal system for controlling smoke in the tunnel in the case of a fire. The Sydney Harbour Tunnel uses a semi-transverse ventilation system.

The development of new vehicle technologies in response to cleaner fuel and emissions standards has led to a significant reduction in vehicle emissions over the past 20 years. Consistent with other motorway tunnels in Sydney, a longitudinal ventilation system was chosen as the preferred ventilation system for the project.

Although other mechanical ventilation systems (such as natural ventilation, transverse ventilation and semi-transverse ventilation as discussed above) could be designed to meet in-tunnel air quality criteria, a well-designed longitudinal ventilation system is considered most suitable as it can maintain acceptable air quality in long tunnels, has proven effectiveness for smoke management in the case of fire, and would provide the most efficient and effective tunnel ventilation[1].

The effectiveness of elevated ventilation outlets in dispersing emissions is well established.

Monitoring and management of the ventilation system

Detailed design of the in-tunnel monitoring system will be undertaken in future project development phases and will comprise the following;

NO_x, NO_2, CO and visibility: Monitoring of each pollutant will be undertaken throughout the tunnel. Locations for monitoring equipment will generally be at the beginning and end of each ventilation section. For example, at each entry ramp, exit ramp, merge point, diverge point and ventilation exhaust and supply points. The location of monitors will be governed by the need to meet the in-tunnel air quality criteria for all possible journeys, especially in the case of NO_2. This will require sufficient monitors to calculate a journey average exposure and they will be integrated with the monitoring system for the adjoining WestConnex tunnels for this purpose.

Velocity monitors will be placed in each tunnel ventilation section and at portal entry and exit points. The velocity monitors in combination with the air quality monitors will be used to modulate the ventilation system to manage air quality and to ensure net inflow at the tunnel portals.

9.1.3 Ambient air quality

The inclusion of filtration would result in no material change in air quality in the surrounding community as compared to the current project ventilation system and outlet design. Any predicted changes in the concentration of pollutants would be driven by changes in the surface road traffic.

Section 9.6 presents the air quality assessments for both in-tunnel and ambient air quality.

9.2 Construction assessment methodology

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

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

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

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

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

[1] Advisory Committee on Tunnel Air Quality (2014). *Technical Paper 04: Road Tunnel Ventilation Systems NSW Government*

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

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

It is difficult to reliably quantify dust emissions from construction activities, due to the variability of the weather at times when specific construction activities are undertaken. Any effects of construction on airborne particle concentrations would also generally be temporary and relatively short-lived.

Construction activities would occur at several sites, as described in **Chapter 7** (Construction), **section 9.5** and **Table 9-16**. Many of these activities would be transitory (i.e. not permanent). The majority of the project would be underground; however, surface works would be required to support tunnelling activities and to construct surface infrastructure.

The guidance published by the Institute of Air Quality Management (IAQM)[2] was used for the assessment of air quality during construction (**Appendix E** (Air quality technical report)). The IAQM guidance has been adapted for use in NSW, taking into account factors such as the assessment criteria for ambient PM_{10} concentrations. The potential construction air quality impacts were assessed based on the proposed works, plant and equipment, and the potential emission sources and levels.

The assessment of construction dust using the IAQM procedure is outlined in **Figure 9-2**.

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[2] IAQM (2014) Guidance on the assessment of dust from demolition and construction. Institute of Air Quality Management, London. http://iaqm.co.uk/text/guidance/construction-dust-2014.pdf

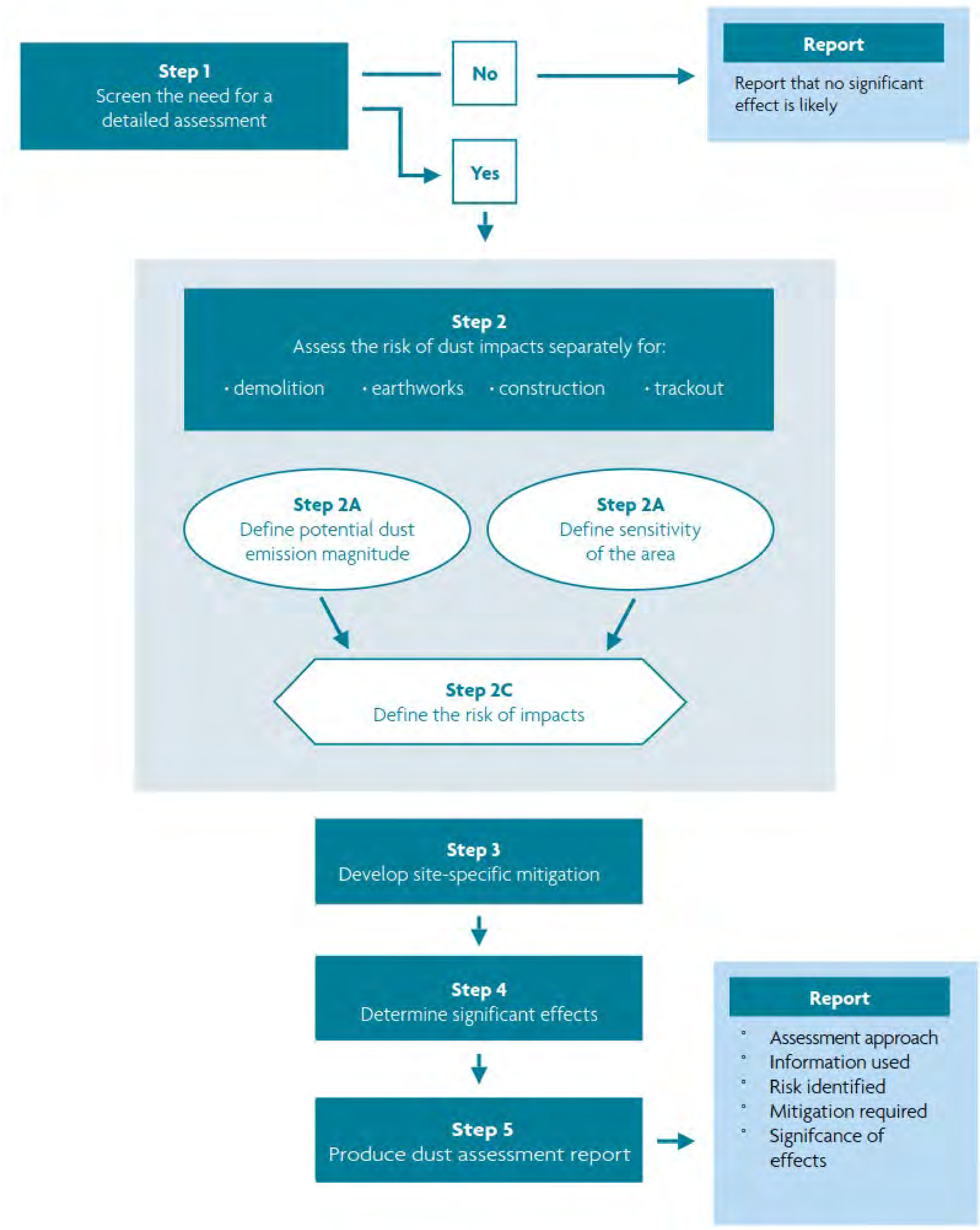

Figure 9-2 Steps in the assessment of construction dust[3]

[3] IAQM (2014) Guidance on the assessment of dust from demolition and construction. Institute of Air Quality Management, London. http://iaqm.co.uk/text/guidance/construction-dust-2014.pdf

9.3 Operation assessment methodology

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

Two types of criteria were used to assess the air quality for the operation of the project. These are ambient or outdoor air quality criteria and in-tunnel criteria. Compliance with both criteria is an essential consideration during road tunnel design and operation. An ambient air quality standard defines a metric (measure) relating to the concentration of an air pollutant in the outdoor air. Standards are usually designed to protect human health, including sensitive people such as children, the elderly and people suffering from respiratory disease. Air quality standards are typically a concentration limit for a given averaging period (e.g. annual mean, 24-hour mean), which may be stated as a 'not-to-be-exceeded' value or with some exceedances permitted (see **section 9.3.2**). Several different averaging periods may be used for the same pollutant to address long-term and short-term exposure.

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

9.3.1 In-tunnel air quality assessment

In-tunnel traffic, air flows, pollution levels, and temperatures for the project were modelled using the IDA Tunnel software[4]. The criteria, scenarios, data and detailed method that were used in the tunnel ventilation simulations, and the detailed results of the simulations, are provided in full in Annexure K of **Appendix E** (Air quality technical report).

Air quality criteria

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

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

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

In February 2016, the NSW Government Advisory Committee on Tunnel Air Quality (ACTAQ) issued a document entitled *In-tunnel Air Quality (Nitrogen Dioxide) Policy*[5]. The policy wording requires tunnels to be *'designed and operated so that the tunnel average nitrogen dioxide (NO_2) concentration is less than 0.5 ppm as a rolling 15-minute average'*. This criterion compares favourably to the international in-tunnel guidelines which range between 0.4 and 1.0 ppm. Examples of in-tunnel NO_2 values for ventilation control from other projects across several countries are summarised in **Table 9-4**.

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

[5] ACTAQ (2016) In-tunnel air quality (nitrogen dioxide) policy. Advisory Committee on Tunnel Air Quality. NSW Government, Sydney, February 2016. http://www.chiefscientist.nsw.gov.au/__data/assets/pdf_file/0004/81778/In-Tunnel-Air-Quality-Policy-FINAL.pdf

Table 9-4 Comparative in-tunnel NO_2 limits (from ACTAQ *In-tunnel Air Quality (Nitrogen Dioxide) Policy*[5])

Jurisdiction	In tunnel NO_2 criteria	Design or compliance	Averaging period
NSW/NorthConnex/WestConnex	0.5 ppm tunnel average	Design and compliance	15-minutes
Brisbane City Council/Clem 7 (2007/LegacyWay (2010) tunnels	1 ppm average	Design and compliance	None given
Permanent International Association of Road Congresses (PIARC)	1 ppm tunnel average	Design only	None given
New Zealand	1 ppm	Design only	15-minutes
Hong Kong	1 ppm	Design only	5-minutes
Norway	0.75 ppm tunnel midpoint (equivalent to tunnel average)	Design and compliance	15-minutes
France	0.4 ppm	Design	15-minutes

Route average NO_2 calculations

For the F6 Extension Stage 1, 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' which includes the interconnecting WestConnex tunnels. The project only has one portal as it connects with the New M5 Motorway tunnel underground and so the eight routes assessed were to and from the New M5 Motorway interface with the M4-M5 Link at St Peters to President Avenue, and to and from the New M5 Motorway portals to Kingsgrove. The routes assessed are listed **Table 9-5** and range between 6.7 and 9.2 kilometres in length.

For routes that would travel from the project into the M4-M5 Link past St Peters, the entire underground sections of WestConnex will meet the route average criteria, as specified in the conditions of approval for the those projects. As each portion of the entire trip will meet the air quality criteria on its own, the average of the entire route from origin portal to destination portal will meet or be better than the air quality criteria.

Visibility and particulate matter

Visibility is an important consideration in the design of a road tunnel ventilation system. The visibility is required to be greater than the minimum vehicle stopping distance at the design speed[6]. Visibility is reduced by the scattering and absorption of light by particles suspended in the air. The measurement of visibility in a tunnel (using an opacity meter) is based on the concept that a light beam reduces in intensity as it passes through air containing particles or other pollutants.

The amount of light scattering, or absorption, in road tunnels is principally dependent on the composition, diameter and density of the particles in the air. Particles that affect visibility are generally in a size range of 0.4 to 1.0 µm. A coefficient of light extinction is used as an indicator of the particulate matter concentration in the tunnel. It is the inverse of visibility, i.e. it is a measure of opacity or blocking of light by particles seen as haze in a tunnel. The operational extinction coefficient limit of 0.005 m^{-1} may result in tunnel emissions being visible under congested conditions, but not at sufficient levels to produce hazy conditions[7]. The criteria against which the in-tunnel air quality was assessed are shown in **Table 9-6**.

[6] PIARC (2012) Road tunnels: vehicle emissions and air demand for ventilation. World Road Association, Paris. Report 2012R05, December 2012.
[7] PIARC (2012) Road tunnels: vehicle emissions and air demand for ventilation. World Road Association, Paris. Report 2012R05, December 2012.

Table 9-6 In-tunnel air quality criteria

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

Notes:
1 m^{-1} = reciprocal metre: Standard unit of measurement of extinction coefficient

Tunnel portal emission restrictions

A key operating restriction for road tunnels over one kilometre long in Sydney since 2001, and indeed in most Australian road tunnels, is the requirement for there to be no emissions of air pollutants from the portals. To avoid portal emissions, the polluted air from within a tunnel must be expelled from one or more elevated ventilation outlets along its length. There are some circumstances when portal emissions may be permitted, such as emergency situations and during major maintenance periods.

In-tunnel – modelling scenarios

The traffic scenarios for in-tunnel assessment use the same traffic data and assessment years as those used for the ambient air quality assessment except that additional scenarios for traffic travelling at different speeds through the tunnel are also modelled. Each direction of travel was modelled separately as each tunnel only carries traffic in one direction, southbound or northbound. The in-tunnel scenarios are:

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

9.3.2 Ambient air quality assessment methodology

Air quality criteria

NSW Environment Protection Authority (NSW EPA) approved methods

The Australian states and territories manage emissions and air quality. In NSW the statutory methods used for assessing air pollution from stationary sources are listed in the NSW EPA Approved Methods[8].

Air quality was assessed in relation to the criteria listed in **Table 9-7**. These criteria include the latest (2016) update of the NSW EPA Approved Methods for particulate matter. The NSW EPA Approved Methods specify air quality criteria for many other substances, including air toxics. The SEARs for the project require an evaluation of volatile organic compounds including the group known as BTEX compounds i.e. benzene, toluene, ethylbenzene, and xylenes.

Table 9-7 Air quality criteria applicable to the project assessment

Pollutant/metric	Concentration	Averaging period	Source
Criteria pollutants			
Carbon monoxide (CO)	30 mg/m^3	1 hour	NSW EPA (2016)
	10 mg/m^3	8 hours (rolling)	NSW EPA (2016)
NO_2	246 µg/m^3	1 hour	NSW EPA (2016)
	62 µg/m^3	1 year	NSW EPA (2016)
PM_{10} micrometre (µm)	50 µg/m^3	24 hours	NSW EPA (2016)
	25 µg/m^3	1 year	NSW EPA (2016)
Particulate matter less than or equal to 2.5 micrometre diameter ($PM_{2.5}$) µm	25 µg/m^3	24 hours	NSW EPA (2016)
	20 µg/m^3 (goal by 2025)	24 hours	NEPC[1] (2016)
	8 µg/m^3	1 year	NSW EPA (2016)
	7 µg/m^3 (goal by 2025)	1 year	NEPC (2016)
Air toxics			
Benzene	0.029 mg/m^3	1 hour	NSW EPA (2016)
PAHs (as b(a)p)[2]	0.0004 mg/m^3	1 hour	NSW EPA (2016)
Formaldehyde	0.02 mg/m^3	1 hour	NSW EPA (2016)
1,3-butadiene	0.04 mg/m^3	1 hour	NSW EPA (2016)

Notes:
1 National Environment Protection Council.
2 Polycyclic aromatic hydrocarbon as benzo(a)pyrene.

The application of the assessment criteria is described in the NSW EPA Approved Methods. Further details of the application of the criteria pollutants are presented in Annexure B of **Appendix E** (Air quality technical report).

[8] NSW EPA (2016). Approved Methods for the Modelling and Assessment of Air Pollutants in NSW. NSW Environment Protection Authority, Sydney. http://www.epa.nsw.gov.au/resources/epa/approved-methods-for-modelling-and-assessment-of-air-pollutants-in-NSW-160666.pdf

Comparison of NSW ambient air quality criteria with national and international standards

For the criteria pollutants included in the assessment, the impact assessment criteria in the NSW EPA Approved Methods[9] and the National Environment Protection (Ambient Air Quality) Measure (AAQNEPM) from February 2016 are compared with the World Health Organisation (WHO) guidelines and the standards in other countries/organisations in **Table 9-8**. The comparison found:

- For CO, the NSW standards are similar to those in most other countries and organisations
- The NSW standards for NO_2 are more stringent than Canada and the United States Environmental Protection Agency (US EPA), but less stringent than California (USA). The standards in the European Union are numerically lower but the European Union allows 18 exceedances compared to one in NSW
- In the case of PM_{10}, the NSW standard for the 24 hour mean is lower than or equivalent to the standards in force elsewhere, whereas the annual mean standard is in the middle of the range of values for other locations
- The NSW annual average standard for $PM_{2.5}$ is numerically lower than or equivalent to those used elsewhere.

There are differences in implementation of standards regarding where they apply and how many exceedances are permitted. For example, 35 exceedances per year of the 24-hour PM_{10} standard are permitted in the European Union. In comparison, the 24-hour PM_{10} standard may be exceeded on up to five days a year in NSW.

[9] NSW EPA (2016). Approved Methods for the Modelling and Assessment of Air Pollutants in NSW. NSW Environment Protection Authority, Sydney. http://www.epa.nsw.gov.au/resources/epa/approved-methods-for-modelling-and-assessment-of-air-pollutants-in-NSW-160666.pdf

Table 9-8 Comparison of international health-related ambient air quality standards and criteria[(a)]

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

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

Ambient Modelling scenarios

Two types of scenarios were used for the assessment of ambient air quality:

- Expected traffic scenarios for surface roads and ventilation outlets
- Regulatory worst case scenarios for tunnel ventilation outlets.

Expected traffic scenarios

The six expected traffic scenarios included in the operational air quality assessment are summarised in **Table 9-9**. The scenarios took into account future changes over time in the composition and performance of the vehicle fleet, as well as predicted traffic volumes, the distribution of traffic on the network and vehicle speeds, as represented in the Sydney Strategic Motorway Project Model (SMPM). The results from the modelling of these scenarios were also used in the health risk assessment for the project (refer to **Chapter 10** (Health, safety and hazards)). The development of the scenarios to model traffic demand for the project is based the following model years;

- 2014 which was adopted as the existing traffic case to match the year of the SMPM model calibration. This represented the current road network with no new projects or upgrades. For air quality modelling, a Base Year of 2016 Base Year was used. This represented the current road network with no new 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. The base year also provided a current baseline which helped to define underlying trends in projected emissions and air quality, and gave a sense of scale to the project impacts (i.e. compared with how emissions and air quality would be predicted to change anyway without the project)
- 2026 which was adopted as the year of opening for the project
- 2036 which would represent the traffic on the road network 10 years after project opening, and was considered to allow for the full increase in traffic as travellers respond to the provision of the fully completed project and the associated tolls, as well as changes in vehicle emissions over that time period.

The descriptions of the future year traffic modelling scenarios are:

- 2026 Do Minimum (2026-DM). In this scenario it is assumed that the following projects would be open:
  - WestConnex (including M4 Widening, M4 East, New M5 and M4-M5 Link)
  - King Street Gateway
  - Sydney Gateway

  It is called ‘do minimum’ rather than ‘do nothing’ as it assumes that on-going improvements would be made to the broader transport network, including some new infrastructure and intersection improvements to improve capacity and cater for traffic growth
- 2026 Do Something (2026-DS). As for 2026 Do Minimum, but with the F6 Extension Stage 1 also completed
- 2036 Do Minimum (2036-DM). As for 2026 Do Minimum, but for 10 years after project opening
- 2036 Do Something (2036-DS). As for 2036 Do Minimum, including the F6 Extension Stage 1 completed, but for 10 years after project opening
- 2036 Do Something Cumulative (2036-DSC). As for 2036 Do Something, with the Sydney Gateway, F6 Extension Stages 2 & 3, Western Harbour Tunnel (WHT) and Beaches Link (BL) also completed.

There is no 2026 Do Something Cumulative scenario as there are no other projects that would be open in that year in addition to those included in the 2026 Do Something scenario.

Table 9-9 Expected traffic scenarios for the operational air quality assessment

Scenario code	Scenario description	Inclusions							
		Existing network	F6 Extension		Other projects				
			Stage 1	Future stages	NorthConnex	WestConnex program of works	Sydney Gateway	King Street Gateway	Western Harbour Tunnel and Beaches Link program of works
2016	Base case (2016)	✓							
DM 2026	Operation 'do minimum' (DM 2026)	✓			✓	✓	✓	✓	
DS 2026	Operation 'do something' (DS 2026)	✓	✓		✓	✓	✓	✓	
DM 2036	Operation 'do minimum' (DM 2036)	✓			✓	✓	✓	✓	
DS 2036	Operation 'do something' (DS 2036)	✓	✓		✓	✓	✓	✓	
DSC 2036	Operation 'cumulative' (DSC 2036)	✓	✓	✓	✓	✓	✓	✓	✓

Ventilation outlets only - Regulatory worst case scenarios

The objective of these scenarios was to demonstrate that compliance with the concentration limits for the tunnel ventilation outlets would deliver acceptable ambient air quality. The scenarios assessed were the 2026 and 2036 cumulative emissions from the ventilation outlets only, with concentrations fixed at the limits for 24 hours, i.e. the maximum pollutant concentrations permitted. This represented the theoretical maximum changes in air quality for all potential traffic operations in the tunnel, including unconstrained and worst case traffic conditions (including heavy congestion) from an emissions perspective, as well as vehicle breakdown situations. The results of the analysis demonstrate the air quality performance of the project if it operates continuously at the limits, which is very unlikely. In reality, ventilation outlet concentrations would vary over a daily cycle due to changing traffic volumes and the responsive operation of the ventilation system. Further information, including the modelled results of the regulatory worst case scenarios is provided in **Appendix E** (Air quality technical report).

GRAMM/GRAL modelling system

The atmosphere is a complex physical system, and the movement of air in a given location is dependent on a number of variables, including temperature, topography and land use, as well as larger-scale weather patterns. Dispersion modelling is a method of simulating the movement of air pollutants in the atmosphere using mathematical equations.

The operational ambient air quality assessment was based on the GRAMM/GRAL modelling system. This system consists of two main modules: a meteorological model (GRAMM) and a dispersion model (GRAL). The elements of the system are shown in **Figure 9-3** and summarised below. Full details of the methodology are presented in **Appendix E** (Air quality technical report).

The GRAL dispersion model is a three-dimensional model used to predict pollutant concentrations which uses a full year of meteorological data. It is specifically designed for the simultaneous modelling of surface roads, point sources (in this case, tunnel ventilation outlets) and tunnel portals (where relevant) including in very low wind conditions.

GRAL models pollution dispersion in complex local terrain and topography, including the presence of buildings in urban areas and has been optimised for Australian conditions (refer to Annexure H of **Appendix E** (Air quality technical report). The size of the GRAL domain and the fine grid resolution meant that building data could not be practically included in the modelling. However, there are only a small number of tall buildings in proximity to the proposed ventilation outlets, and therefore the effects of building downwash (refer to Annexure B of **Appendix E** (Air quality technical report)) would probably have been rather limited. Sensitivity tests were completed for the effect of building downwash, and ventilation outlet temperature height (see **section 9.6.6**)

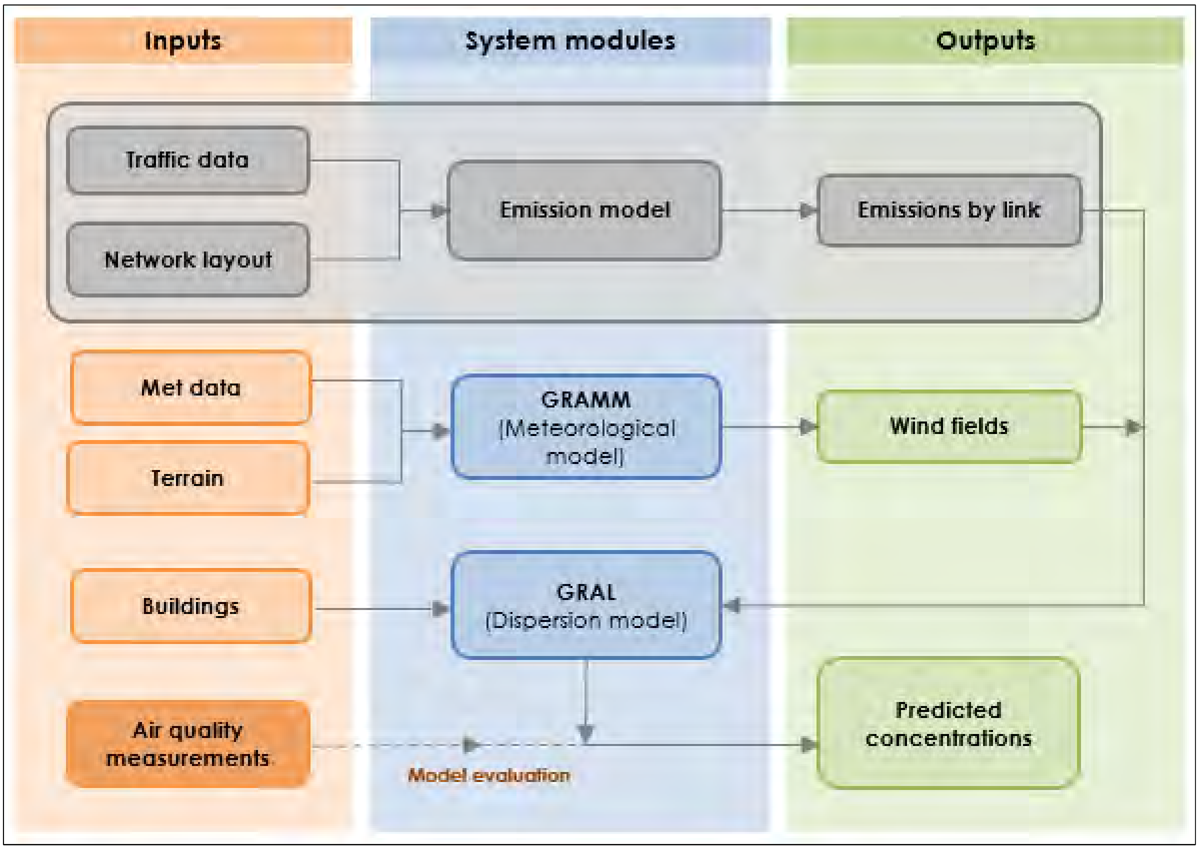

Figure 9-3 Overview of the GRAMM/GRAL modelling system

Further detail of the GRAMM/GRAL modelling system and its performance is provided in **Appendix E** (Air quality technical report).

Definition of modelling domain

Separate domains were required for the meteorological modelling and dispersion modelling, and these domains are shown relative to the project and all modelled tunnel ventilation outlets in **Figure 9-4**.

The GRAMM domain (also referred to as the 'study area' in places) for the modelling of meteorology is shown by the red boundary in **Figure 9-4**. The domain covered a substantial part of Sydney, extending 18 kilometres in the east–west (x) direction and 15 kilometres in the north–south (y) direction.

The F6 Extension Stage 1 GRAL domain for dispersion modelling is shown by the dashed grey boundary in **Figure 9-4**. Every dispersion model run was undertaken for this domain, which extended 9.0 kilometres in the east–west direction and 11.6 kilometres in the north–south direction. The domain extended well beyond the project itself to allow for the traffic interactions between the F6 Extension Stage 1 and other projects (M4-M5 Link, New M5 and Sydney Gateway), as well as effects on all affected roads. Having a relatively large GRAMM and GRAL domain also increased the number of meteorological and air quality monitoring stations that could be included for model evaluation purposes.

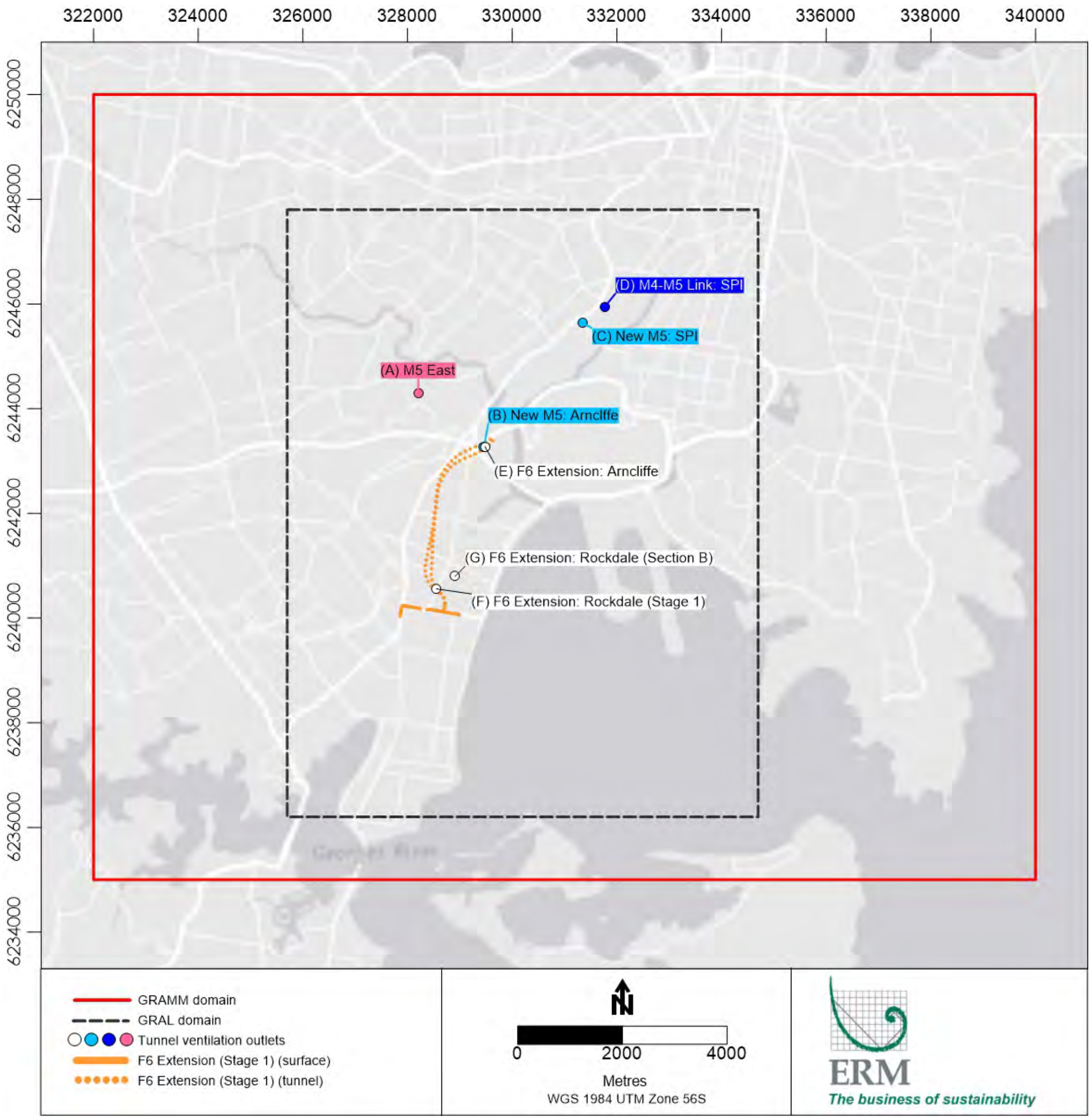

Figure 9-4 Modelling domains for GRAMM and GRAL (grid system MGA94) showing the ventilation outlets included in the air quality assessment.

Background air quality

Background concentrations were based on measurements from air quality monitoring stations at urban background locations in the study area, but well away from roads (as defined in Australian Standard AS/NZS 350.1.1:2007 – Methods for sampling and analysis of ambient air – Guide to siting air monitoring equipment). These stations are located in urban areas to provide information on air quality away from specific sources of pollution such as major roads or industry.

The approaches used to determine long-term and short-term background concentrations are explained in Annexure D of **Appendix E** (Air quality technical report). It was considered that the concentrations in 2016 would represent typical (but probably slightly conservative) background concentrations in the future.

Discrete receptors

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

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

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

- ‘Community receptors’ (CR): These were taken to be representative of particularly sensitive locations such as schools, childcare centres and hospitals within the vicinity of the project, and generally near affected roadways. For these receptors, a more detailed method was used to calculate the total concentration of each pollutant. In total, 30 community receptors were included in the assessment and these are listed in **Table 9-10**. Thirty community receptors were selected due to the time required to complete additional detailed modelling of community receptors for the assessment. They were selected as representative of the community, or sensitive, receptors across the study area and in consultation with the receptor organisations and the Roads and Maritime communications team. Schools located closest to the project were selected, and some receptors to the north were chosen due to the potential for cumulative impacts from the M4-M5 Link and New M5 Motorway projects. All sensitive receptors, including the 30 selected for more detailed analysis, are included in the 17,509 receptors modelled in the assessment.
- Residential, workplace and recreational (RWR) receptors’: These were all discrete receptor locations within the vicinity of the project, and were generally residential and commercial land uses. For these receptors a simpler[10] statistical approach was used to combine a concentration statistic for the modelled roads and outlets (e.g. maximum 24 hour mean PM_{10}) with an appropriate background statistic. In total, 17,509 RWR receptors were included in the assessment (this included the 30 community receptors). The RWR receptors are discrete points at ground level – where people are likely to be present for some period of the day – classified according to the land use identified at that location. The RWR receptors do not identify the number of residential (or other) properties at the location; the residential land use at an RWR receptor location may range from a single-storey dwelling to a multi-storey, multi-dwelling building.

  The RWR receptors are not designed for the assessment of changes in total population exposure. The Human health technical report (**Appendix F**) combines the air quality information with the highest resolution population data available from the Australian Bureau of Statistics to calculate key health indicators that reflect varying population density across the study area.

Figure 9-5 shows the locations of the discrete receptors.

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

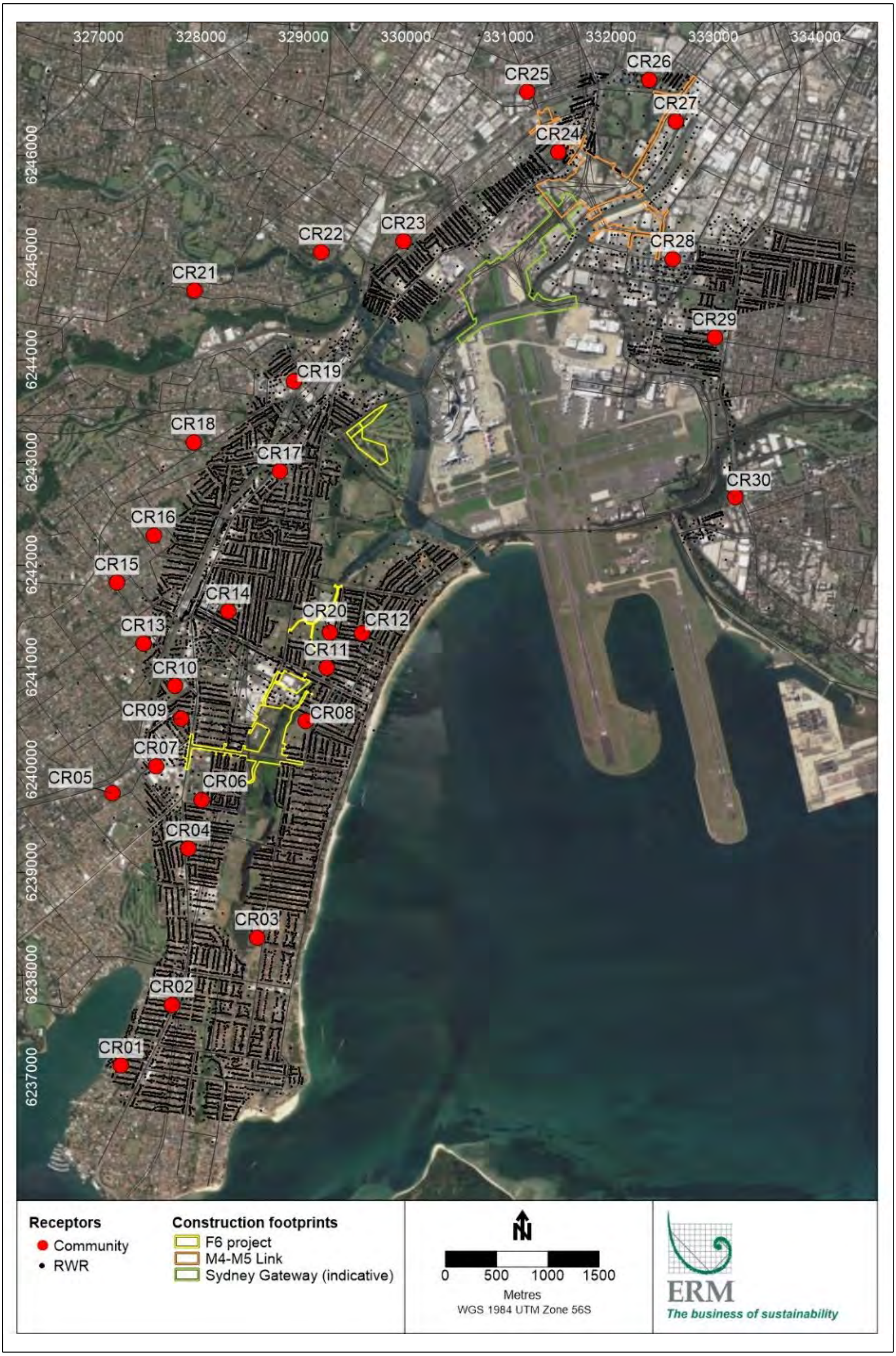

Figure 9-5 Modelled discrete receptor locations and construction footprints

The types of RWR receptors are listed by category in **Table 9-11**. Further discussion of the assessment of the receptors is in **Appendix E** (Air quality technical report).

Receptors locations in proximity to the WestConnex program of works (such as St Peters Public School at St Peters, Frobel Alexandria Early Learning Centre at Alexandria and Active Kids Mascot at Mascot) and indicative Sydney Gateway designs were included to enable an assessment of the cumulative impacts of these projects. The following were excluded:

- Any receptors outside the GRAL domain for the F6 Extension Stage 1
- Any receptor locations that would be removed for construction of surface roads and facilities.

Table 9-10 Full list of community receptors (grid system MGA94)

Receptor code	Receptor name	Address	Suburb
CR01	St Finbar's Primary School	21 Broughton Street	Sans Souci
CR02	St George Christian School Infants	2 Hillview Street	Sans Souci
CR03	Ramsgate Public School	Chuter Avenue	Ramsgate Beach
CR04	Estia Health	74-76 Rocky Point Road	Kogarah
CR05	Wesley Hospital Kogarah	7 Blake Street	Kogarah
CR06	St George School	2A Marshall Street	Kogarah
CR07	St George Hospital	28A Gray Street	Kogarah
CR08	Brighton-Le-Sands Public School	35 Crawford Road	Brighton-Le-Sands
CR09	Kogarah Public School	24B Gladstone Street	Kogarah
CR10	St George Girls High School	Victoria Street	Kogarah
CR11	St Thomas More's Catholic School	Francis Avenue	Brighton-Le-Sands
CR12	Jenny-Lyn Nursing Home	13 Henson Street	Brighton-Le-Sands
CR13	Huntingdon Gardens Aged Care Facility	11 Connemarra Street	Bexley
CR14	Rockdale Public School	4 Lord Street	Rockdale
CR15	Scalabrini Village Nursing Home – Bexley	28-34 Harrow Road	Bexley
CR16	Rockdale Nursing Home	22 Woodford Road	Rockdale
CR17	Arncliffe Public School	168 Princes Highway	Arncliffe
CR18	Athelstane Public School	2 Athelstane Avenue	Arncliffe
CR19	Al Zahra College	3-5 Wollongong Road	Arncliffe
CR20	Cairnsfoot School	58A Francis Avenue	Brighton-Le-Sands
CR21	Undercliffe Public School	143-157 Bayview Avenue	Earlwood
CR22	Ferncourt Public School	74 Premier Street	Marrickville
CR23	Tempe High School	Unwins Bridge Road	Tempe
CR24	St Peters Public School	Church Street	St Peters
CR25	St Pius' Catholic Primary School	209 Edgeware Road	Enmore
CR26	Frobel Alexandria Early Learning Centre	177/219 Mitchell Road	Alexandria
CR27	Little Learning School – Alexandria	95 Burrows Road	Alexandria
CR28	Active Kids Mascot	18 Church Avenue	Mascot
CR29	Mascot Public School	207 King Street	Mascot
CR30	Hippos Friends	1082 Botany Road	Botany

Table 9-11 Summary of RWR receptor types

Receptor type	Number	Percentage of total
Aged care		0.18%
Childcare/pre-school	21	0.12%
Commercial	1,359	7.77%
Community	3	0.02%
Further education	4	0.02%
Hospital	7	0.04%
Industrial	455	2.03%
Mixed use	617	3.52%
Park/sport/recreation	174	0.99%
Residential	14,408	82.28%
School	84	0.48%
Other[1]	445	2.547%
Total	17,509	100%

Notes:

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

Elevated receptors

The main emphasis in the air quality assessment was on ground-level concentrations (as specified in the Approved Methods). However, at a number of locations in the GRAL domain, there are multi-storey residential and commercial buildings. The potential impacts of the project at these elevated points are likely to be different to the impacts at ground level, and therefore these were evaluated separately. The locations and heights of a sample of buildings in the GRAL domain are shown in **Appendix E** (Air quality technical report). It is also important to understand how future building developments (egg apartment blocks) in the domain may be restricted from an air quality perspective. The results for elevated receptors are presented in **section 9.6.5**.

Redistribution of air quality impacts

Section 2(f) of the SEARs requires 'a qualitative assessment of the redistribution of ambient air quality impacts compared with existing conditions, due to the predicted changes in traffic volumes'. The intention of this requirement is to provide assurance that those locations with relatively high concentrations in the Do Minimum scenarios do not have a large increase in concentrations in the Do Something and Do Something Cumulative scenarios. This has been addressed through the use of density plots which show the smoothed distributions of the concentrations of annual mean and maximum 24-hour $PM_{2.5}$ at all RWR receptors.

Tunnel Ventilation outlets

Reforms announced by the NSW Government on the 17 February 2018 mean that the ventilation outlets of all current and future operating motorway tunnels in NSW will be regulated by NSW EPA. The EPA will require tunnel operators to meet air quality limits and undertake air quality monitoring.

In addition, for new motorway tunnels that are at the Environmental Impact Statement stage, such as F6 Extension Stage 1, additional checks will be required prior to planning determination, including:

- The Advisory Committee on Tunnel Air Quality (ACTAQ) will coordinate a scientific review of a project's air emissions from ventilation outlets
- The NSW Chief Health Officer will release a statement on the potential health impacts of emissions from tunnel ventilation outlets. To facilitate these checks, a summary report of the performance of the ventilation outlets is provided in Annexure K to **Appendix E** (Air quality technical report), and a summary of the results of the ventilation outlet assessment in presented in **section 9.6**.

The locations of the seven ventilation outlets included in the air quality assessment are shown in Figure 8-1 of **Appendix E.** The ground levels and outlet heights are presented in **Table 9-12** and **Table 9-13**. The ground levels and heights rounded to the nearest metre.

Table 9-12 Heights of the existing ventilation outlets used in the assessment

Ventilation outlet code used in model	Tunnel project	Location	Traffic direction	Ground elevation (m) (mAHD)	Height of top of outlet (mAHD)	Function of outlet
A	M5 East	Turrella	Eastbound / Westbound	5	38	Single point of release from M5 East tunnel
B	New M5 Motorway	Arncliffe	East bound	4.0	38	Exhaust from first section of tunnel, between Kingsgrove and Arncliffe
C	New M5 Motorway	St Peters	Eastbound	12	25	Exhaust from second section of tunnel between Arncliffe and St Peters
D	M4-M5 Link	St Peters	Southbound	11	33-36[11]	Exhaust from southbound tunnel from Haberfield to St Peters

Table 9-13 Heights of the project ventilation outlets and the indicative height and location for the potential future F6 Extension Section B

Ventilation outlet	Tunnel project	Location	Traffic direction	Ground elevation (m) (mAHD)	Height of top of outlet (mAHD)	Function of outlet
E	F6 Extension (Stage 1)	Arncliffe	Northbound	4	38	Exhaust from the northbound project tunnel from Kogarah to Arncliffe
F	F6 Extension (Stage 1)	Rockdale	Soutbound	3	38	Exhaust from the southbound project tunnel Arncliffe to Kogarah
G	F6 Extension (Section B)	Rockdale	NB	3	38	Exhaust from the northbound tunnel of future F6 Extension stage.

[11] The Conditions of Approval for the WestConnex M4-M5 Link provided a range of heights for the ventilation outlets subject to detailed design optimisation. https://majorprojects.accelo.com/public/5f97265d6e3da061f13b9c86a82e82c2/WestConnex%20M4-M5%20Link%20Instrument%20of%20Approval.pdf

For tunnels in Sydney, limits are also imposed on the discharges from the ventilation outlets. The limits specified for the NorthConnex and WestConnex projects are shown in **Table 9-14**.

Table 9-14 Concentrations for the NorthConnex and WestConnex ventilation outlets

Pollutant	Maximum value (mg/m^3)	Averaging period	Reference conditions
Solid particles	1.1	1 hour, or the minimum sampling period specified in the relevant test method, whichever is the greater	Dry, 273 K, 101.3 kPa
NO_2 or NO or both, as NO_2 equivalent	20	1 hour	Dry, 273 K, 101.3 kPa
NO_2	2.0	1 hour	Dry, 273 K, 101.3 kPa
CO	40	Rolling 1 hour	Dry, 273 K, 101.3 kPa
Volatile organic compounds (VOCs) (as propane)	4.0[1]	Rolling 1 hour	Dry, 273 K, 101.3 kPa

Notes:
1 Stated as 1.0 in the conditions of approval for NorthConnex.

9.3.3 Accuracy and conservatism

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

- Allowing for uncertainty: an assessment on the scale undertaken for this project is a complex, multi-step process that involves a range of assumptions, inputs, models and post-processing procedures. There is an inherent uncertainty in methods used to estimate emissions and concentrations, and there are clearly limits to how accurately any impacts in future years can be predicted. For these reasons, conservatism is built into predictions to ensure that a margin of safety is applied to minimise the risk that any potential impacts are underestimated
- Providing flexibility: it is undesirable to define the potential environmental impacts of a project too narrowly in the early stages of the development process. A conservative approach provides flexibility, allowing for ongoing design refinements within an approved environmental envelope. Conversely, excessive conservatism in an assessment risks overstating potential air quality impacts and associated human health risks. An overly conservative approach may create, or contribute to, unnecessary concerns within the local community and among other stakeholders about the impacts of the project. It may lead to additional or more stringent conditions of approval than necessary, including requirements for the mitigation, monitoring and management of air quality. Overstatement of vehicle contributions to local air quality may also lead to overstating the benefit where vehicle emissions are reduced by the project[12].

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

However, the scale of the conservatism can be difficult to define, and this can sometimes result in assumptions being overly conservative. By demonstrating that a deliberate overestimate of impacts is acceptable, it can be confidently predicted that the actual impacts that are likely to be experienced in reality would also lie within acceptable limits[12]. A number of key assumptions with implications for conservatism are discussed in **Appendix E** (Air quality technical report).

[12] AECOM (2014) NorthConnex – Environmental Impact Statement – Submissions and Preferred Infrastructure Report. ISBN 978-1-925093-99-5

9.4 Existing Environment

This section describes the existing environment and conditions in the study area. The meteorological inputs and background pollutant concentrations required for the operational air-quality assessment are described in more detail in **Appendix E** (Air quality technical report).

9.4.1 Climate

Table 9-15 presents the long-term average temperature and rainfall data for the Bureau of Meteorology (BoM) weather station at Sydney Airport (site number 066037), which is located near to the centre of the GRAMM domain (see **Figure 9-7**) and broadly representative of the area. The annual average daily maximum and minimum temperatures are 22.3°C and 13.5°C, respectively. On average, January is the hottest month with an average daily maximum temperature of 26.6°C. July is the coldest month, with average daily minimum temperature of 7.3°C. The wettest month is March, with 117 millimetres falling over five rain days. The average annual rainfall is 1,083 millimetres over an average of 104 rain days per year.

Table 9-15 Long term average temperature and rainfall data for Sydney Airport

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Mean daily maximum temperature (ºC)												
26.6	26.5	25.3	22.9	20.1	17.6	17.1	18.4	20.7	22.7	24.1	25.9	22.3
Mean daily minimum temperature (ºC)												
18.9	19.1	17.6	14.3	11.0	8.7	7.3	8.2	10.5	13.3	15.5	17.6	13.5
Mean monthly rainfall (mm)												
94.6	111.4	117.1	108.8	96.9	124.2	68.6	76.8	59.7	69.7	80.4	73.6	1083.4
Mean rain days per month (number)												
6.8	5.5	7.7	8.8	9.3	9.1	12.0	13.2	11.0	8.2	6.4	6.5	104.5

Source: BoM (2018) Climate averages for Station: 066037; Commenced: 1929 – last record January 2018; Latitude: 33.99°S; Longitude: 151.17 °E

9.4.2 Meteorology

Several meteorological stations in the study area were considered, and their locations are shown in **Figure 9-7**. Data relevant to the dispersion modelling such as wind speed, wind direction, temperature and cloud cover were obtained for the following:

- OEH (Office of Environment and Heritage) meteorological stations:
  - Randwick
  - Earlwood.
- BoM meteorological stations:
  - Canterbury Racecourse
  - Sydney Airport
  - Kurnell
  - Little Bay (The Coast Golf Club).

A detailed analysis of the meteorological data from the weather stations within the GRAMM domain is presented in Annexure F of **Appendix E** (Air quality technical report). Based on this analysis and other considerations, the measurements from the OEH Randwick and OEH Earlwood stations in 2016 were chosen as the reference meteorological data for modelling. The rationale for this selection is summarised in Annexure F of **Appendix E** (Air quality technical report).

At Randwick the wind speed and wind direction patterns over the eight-year period between 2009 and 2016 were quite consistent; the annual average wind speed ranged from 1.9 metres per second to 2.6 metres per second. It is worth noting that the station was surrounded by trees until 2010 when they were removed. The annual average wind speeds between 2011 and 2016 were 2.4 to 2.6 metres per second. The annual percentage of calms (wind speeds <0.5 metres per second) ranged from 9.1 to 10.7 per cent between 2011 and 2016.

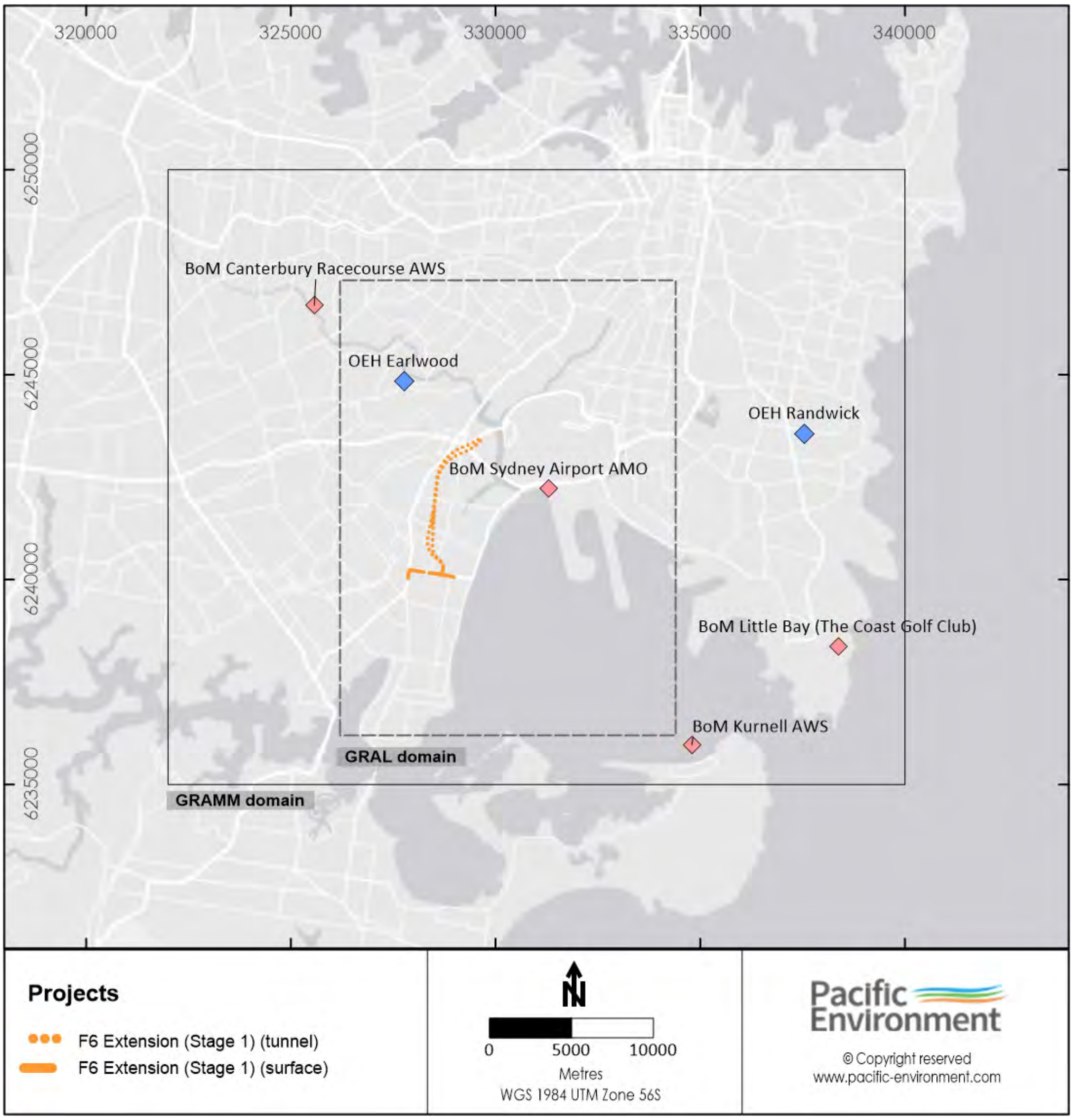

Figure 9-7 Meteorological stations in the model domains (grid system MGA94)

9.4.3 Emissions

Exhaust emissions of some pollutants from road transport have decreased as the vehicle emission legislation has tightened, and are predicted to decrease further in the future[13]. The most detailed and comprehensive source of information on current and future emissions in the Sydney area is the emissions inventory[14] that is compiled periodically by NSW EPA. The base year of the latest published inventory is 2008[15] and projections are available for future years to 2036.

The contribution of road transport to air pollution in Sydney can be illustrated by reference to sectoral emissions. The data for emissions, produced by human activity (anthropogenic) and biological sources (biogenic) in Sydney, as well as a detailed breakdown of emissions from road transport, were extracted from the inventory by NSW EPA[16] and are presented here. Emissions were considered for the most recent historical year (2016) and for the future years.

[13] Bureau of Infrastructure, Transport and Regional Economics (BITRE) (2010) Long-term Projections of Australian Transport Emissions: Base Case 2010. Bureau of Infrastructure, Transport and Regional Economics, Canberra.
[14] An emissions inventory defines the amount (in tonnes per year) of pollution that is emitted from each source in a given area.
[15] NSW EPA (2012) Air Emissions Inventory for the Greater Metropolitan Region in New South Wales – 2008 Calendar Year. Technical Report No. 1 – Consolidated Natural and Human-Made Emissions: Results. NSW Environment Protection Authority, Sydney South
[16] The data were provided for the project Economic Analysis to Inform the National Plan for Clean Air (Particles), undertaken by Pacific Environment on behalf of the NEPC Service Corporation.

Figure 9-8 shows that road transport was the single largest sectoral contributor to emissions of CO (34 per cent) and NO_x (47 per cent) in Sydney during 2016. It was also responsible for a proportion of emissions of VOCs (13 per cent), PM_{10} (nine per cent) and $PM_{2.5}$ (10 per cent). The main contributors to VOCs were domestic-commercial activity and biogenic sources. The most important sources of PM_{10} and $PM_{2.5}$ emissions were the domestic-commercial sector and industry. The contribution to PM from the domestic sector in Sydney was due largely to wood burning for heating in winter. Emissions from natural sources, such as bushfires, dust storms and marine aerosol, will have contributed significantly to ambient PM concentrations.

The EPA projections of sectoral emissions show that the road transport contribution to emissions CO, VOCs and NO_X is projected to decrease substantially between 2011 and 2036 due to improvements in emission-control technology. For PM_{10}, $PM_{2.5}$ and SO_2 the road transport contributions are also expected to decrease, but their smaller contributions to these pollutants mean that these decreases would have only a minor impact on total emissions. In addition, although exhaust emissions can be reduced through emissions technology, non-exhaust emissions (dust from brake wear, road dust and so) are more difficult to reduce and would become a growing proportion of the overall particulate emissions from roads. Further detail of road transport emissions are provided in **Appendix E** (Air quality technical report).

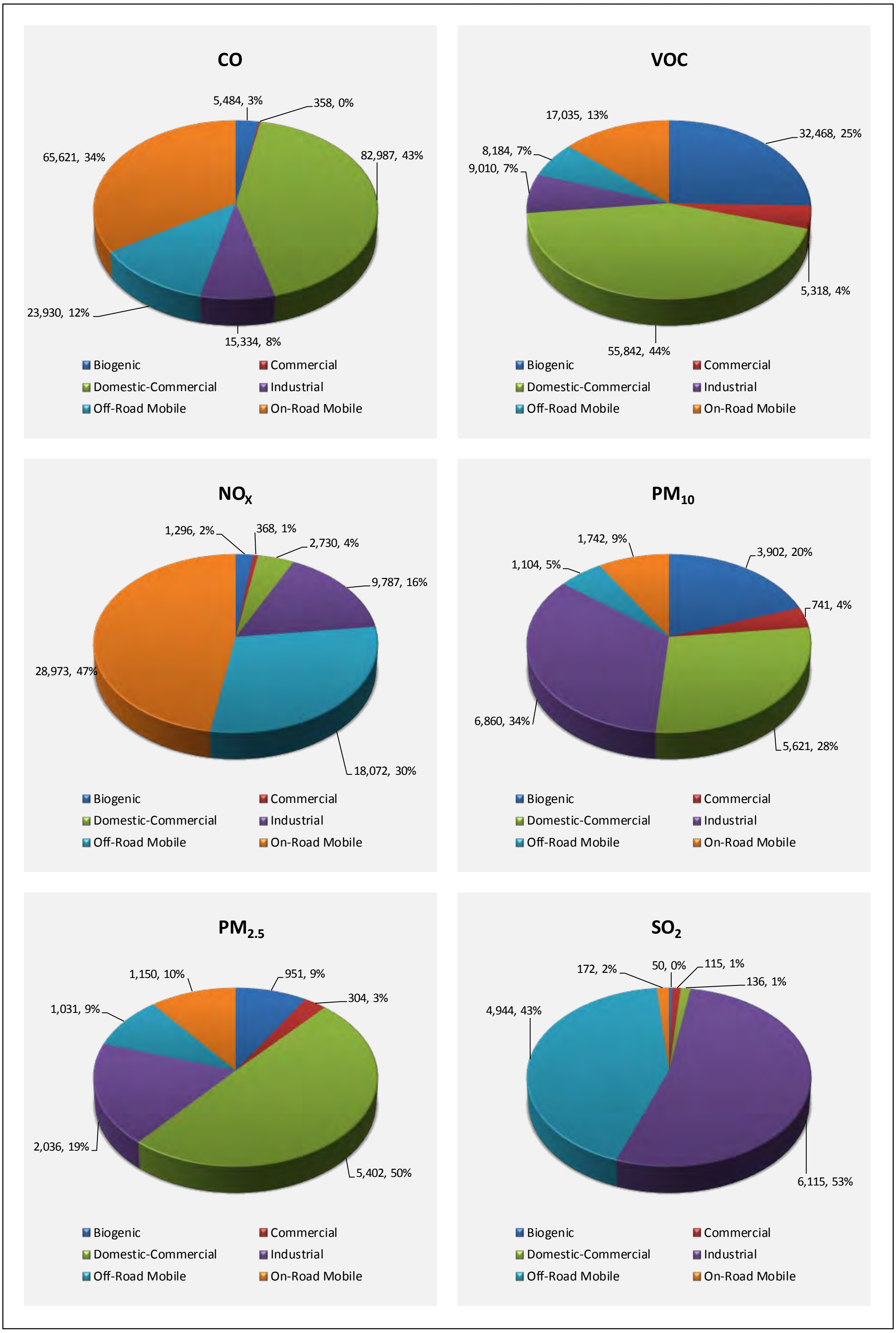

Figure 9-8 Sectoral emissions in Sydney, 2016 (tonnes per year and percentage of total)

9.4.4 Ambient air quality

In order to understand the likely and potential impacts of the project on air quality, a good understanding of the existing air quality in Sydney is essential. A thorough analysis of the air quality monitoring data that were available for the study area was undertaken and is provided in Annexure D of **Appendix E** (Air quality technical report). The analysis was based mainly on measurements conducted between 2004 and 2016, the principal aim being to establish background pollutant concentrations for use in the assessment. The analysis dealt with temporal and spatial patterns in the data, and contributed to the general understanding of air quality in Sydney.

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

Since the introduction of unleaded petrol and catalytic converters in 1985, peak CO concentrations in central Sydney declined rapidly, and the last exceedance of the air quality standard for CO in NSW was recorded in 1998[17]. Levels of NO_2, SO_2 and CO also continue to be below national standards across Sydney.

Levels of ozone and particles (PM_{10} and $PM_{2.5}$) can still exceed the standards on occasion. Ozone and PM levels are affected by the annual variability in the weather, natural events such as bushfires and dust storms, hazard reduction burns and temperature inversions in winter and the location and intensity of local emission sources, such as wood heaters, transport and industry[18].

9.4.5 Data from monitoring sites in the study area

A detailed analysis of the historical trends in Sydney's air quality (2004-2016), and the current situation, is provided in Annexure D of **Appendix E** (Air quality technical report). The analysis was based upon hourly data from long-term monitoring stations operated by OEH and Roads and Maritime. Consideration was also given to the shorter-term data from other Roads and Maritime air quality monitoring stations.

The location of the monitoring stations and a summary of the results are provided in Annexure D of **Appendix E** (Air quality technical report). The data from these stations were also used to define appropriate background concentrations of pollutants for the project assessment.

9.4.6 Project-specific air quality monitoring

Two project-specific monitoring stations were established for the F6 Extension by Roads and Maritime in 2017. One of these (station F6:01) was at a background location, and the other at a roadside location. Given the date of deployment, the time period covered was too short for these to be included in the development of background concentrations and model evaluation. However, the data from the stations are presented in Annexure D of **Appendix E** (Air quality technical report).

The F6 Extension stations were designed to:

- Supplement the existing OEH and Roads and Maritime stations in Sydney
- Establish the representativeness of the data from these stations that were used to characterise air quality in the F6 Extension modelling domain
- Provide a time series of air quality data in the vicinity of the project.

For background air quality, the data from the F6:01 station have been compared with the range of measurements at OEH/Roads and Maritime stations. These comparisons are provided in Annexure D of **Appendix E** (Air quality technical report). In summary, F6:01 measurements of CO, NO_x, NO_2, O_3 and $PM_{2.5}$ were generally comparable with the OEH/Roads and Maritime stations. The PM_{10} measurements at F6:01 were generally towards the lower end of the range of values at the OEH/Roads and Maritime sites.

[17] NSW Department of Environment, Climate Change and Water (DECCW) (2009) New South Wales State of the Environment 2009. New South Wales and Department of Environment, Climate Change and Water, Sydney.
[18] OEH (2015) New South Wales Air Quality Statement 2014. NSW and Office of Environment and Heritage, Sydney, January 2015.

9.4.7 Assumed background concentrations

Assumed background concentrations were identified, to be used as a base against which impacts on air quality as a result of the project are assessed. The detailed methods for calculating the background concentration and the resulting assumed background concentrations are provided in Annexure D of **Appendix E** (Air quality technical report).

9.5 Potential impacts – construction

9.5.1 Overview

The construction activities for the project are described in **Chapter 7** (Construction). This section addresses the potential impacts of the construction phase of the project, in particular this section:

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

In the absence of specific direction for road and tunnel projects in NSW, the potential impacts of the construction phase of the project were assessed using guidance published by the UK Institute of Air Quality Management. The UK guidance was adapted for use in NSW, taking into account factors such as the assessment criteria for ambient PM_{10} concentrations.

The risks associated with construction dust emissions were assessed for four types of activity: demolition, earthworks, construction, and track-out. The assessment methodology considered three separate dust impacts: annoyance due to dust soiling, the risk of health effects due to an increase in exposure to PM_{10}, and harm to ecological receptors.

For the F6 Extension Stage 1, above-ground construction activities would take place at a number of separate locations, and these were grouped into 2 distinct zones for the purpose of the assessment.

For dust soiling impacts, the sensitivity of assessment zones and all relevant activities was determined to be ‘medium’ for Zone 1 and ‘high’ for Zone 2. For human health impacts, the sensitivity for each area and all relevant activities was determined to be ‘medium’ for Zone 1 and ‘high’ for Zone 2. For ecological impacts, the sensitivity of activities and areas was ‘high’.

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

The power line has not been included in either of the construction zones. This line would be underground for its entire length, either by trenching or, where required, under-boring to avoid sensitive features. Where the power line crosses waterways or railways, conduits would be attached to existing bridges. The trench would require very minor earth works, which would be backfilled at the end of each day. It is not expected to be a significant source of dust and is not included in this assessment of construction.

9.5.2 Construction surface works and scenarios

The impacts associated with surface works and construction sites are described below. The above ground construction activities would take place at several separate locations (refer to **Table 9-16**).

Table 9-16 Construction ancillary facilities

Construction ancillary facility	Description	Indicative construction period
C1	Arncliffe construction ancillary facility	1 October 2020 - 31 December 2024
C2	Rockdale construction ancillary facility	1 October 2020 - 31 December 2024
C3	President Avenue construction ancillary facility	1 October 2020 — 31 March 2024
C4	Shared cycle and pedestrian pathways east construction ancillary facilities	1 October 2021 – 31 March 2023
C5	Shared cycle and pedestrian pathways wast construction ancillary facilities	1 October 2021 – 31 March 2023
C6	Princes Highway construction ancillary facility	1 April 2021 – 31 March 2024

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

Figure 9-9 Screening assessment - receptors near the project

The criteria for assessing the potential scale of dust emissions based on the type of construction activity are provided in the IAQM guidance and summarised in Annexure E of **Appendix E** (Air quality technical report). Based on these criteria, the results of the risk categorisation for the construction activities that would be carried out at each construction ancillary facility are shown in **Table 9-17**.

Table 9-17 Results of risk categorisation of construction ancillary facility for each type of construction activity

Type of construction activity	Site category by Zone	
	Zone 1 (C1)	Zone 2 (C2, 3, 4, 5 and 6)
Demolition	N/A	Large
Earthworks	Large	Large
Construction	Small	Large
Track-out	Large	Large

Sensitivity of area to dust soiling effects on people and property

The criteria for determining the sensitivity of an area to dust soiling impacts are provided in the IAQM guidance and are summarised in of **Appendix E** (Air quality technical report). The criteria are based on the numbers of receptors within distance bands from the source between 20 and 350metres.The number of receptors is based on land use zoning. The results for each construction ancillary facility are shown in **Table 9-18**. The sensitivity of people to the health effects of PM_{10} is based on exposure to elevated concentrations over a 24 hour period. High-sensitivity receptors relate to locations where members of the public are exposed over a time period that is relevant to the air quality criterion for PM_{10} (in the case of the 24 hour criterion a relevant location would be one where individuals may be exposed for eight hours or more in a day). The main example of this would be a residential property. All non-residential sensitive receptor locations were considered as having equal sensitivity to residential locations for the purposes of this assessment. In view of the types of receptor shown in, being predominantly residences in addition to community centres, and in consideration of the IAQM guidance, the receptor sensitivity was assumed to be 'high'.

Table 9-18 Results of sensitivity to dust soiling effects

Zone	Activity	Receptor sensitivity	Number of receptors by distance from source (m)				Sensitivity of area
			<20	20‑50	50‑100	100‑350	
Zone 1 (C1)	Demolition	N/A	N/A	N/A	N/A	N/A	N/A
	Earthworks	High	0	25	149	1339	Medium
	Construction	High	0	25	149	1339	Medium
	Track-out	High	0	25	N/A	N/A	Medium
Zone 2 (C2, 3, 4, 5 and 6)	Demolition	High	1256	1014	3875	1853	
	Earthworks	HIgh	1256	1014	3875	1853	High
	Construction	High	1256	1014	3875	1853	High
	Track-out	High	1256	1014	N/A	N/A	High

Sensitivity of area to human health impacts

The criteria for determining the sensitivity of an area to human health impacts caused by construction dust are shown in **Appendix E** (Air quality technical report). Air quality monitoring data from monitoring stations in the vicinity were used to establish an annual average PM_{10} concentration of 19 µg/m³. Based on the IAQM guidance the receptor sensitivity was assumed to be 'high'. The numbers of receptors for each zone and activity, and the resulting outcomes, are shown in **Table 9-19**.

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

Zone	Activity	Receptor sensitivity	Annual mean PM_{10} conc. (µg/m³)	Number of receptors by distance from source (m)					Sensitivity of area
				<20	20 – 50	50 – 100	100 – 200	200 – 350	
Zone 1 (C1)	Demolition	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Earthworks	High	17.5 – 20	0	25	149	424	915	Medium
	Construction	High	17.5 – 20	0	25	149	424	915	Medium
	Track-out	High	17.5 – 20	0	25	N/A	N/A	N/A	Medium
Zone 2 (C2, 3, 4, 5 and 6)	Demolition	High	17.5 – 20	1256	1014	3875	7169	11184	High
	Earthworks	High	17.5 – 20	1256	1014	3875	7169	11184	High
	Construction	High	17.5 – 20	1256	1014	3875	7169	11184	High
	Track-out	High	17.5 – 20	1256	1014	N/A	N/A	N/A	High

Sensitivity of area to ecological impacts

The construction impacts on local ecology were assessed based on the criteria in the IAQM guidance (summarised in **Appendix E** (Air quality technical report)). The results for each construction ancillary facility are shown in **Table 9-20**.

Table 9-20 Results of sensitivity to ecological impacts

Construction ancillary facility	Activity	Receptor sensitivity	Distance from source (m)	Sensitivity of area
Zone 1 (C1)	Demolition	N/A	<20	N/A
	Earthworks	High	<20	High
	Construction	High	<20	High
	Track-out	High	<20	High
Zone 2 (C2, 3, 4, 5 and 6)	Demolition	High	<20	High
	Earthworks	High	<20	High
	Construction	High	<20	High
	Track-out	High	<20	High

Risk of dust impacts

The dust emission potential is combined with the sensitivity of the area determined to give the risk of impacts with no mitigation applied. The criteria are shown in **Table 9-21**.

Table 9-21 Risk categories

Type of activity	Sensitivity of area	Dust emission potential		
		Large	Medium	Small
Demolition	High	High Risk	Medium Risk	Medium Risk
	Medium	High Risk	Medium Risk	Low Risk
	Low	Medium Risk	Low Risk	Negligible
Earthworks	High	High Risk	Medium Risk	Low Risk
	Medium	Medium Risk	Medium Risk	Low Risk
	Low	Low Risk	Low Risk	Negligible
Construction	High	High Risk	Medium Risk	Low Risk
	Medium	Medium Risk	Medium Risk	Low Risk
	Low	Low Risk	Low Risk	Negligible
Track-out	High	High Risk	Medium Risk	Low Risk
	Medium	Medium Risk	Low Risk	Negligible
	Low	Low Risk	Low Risk	Negligible

The final results for the risk assessment are provided in **Table 9-22**, combining the scale of the activity and the sensitivity of the area. As the level of risk varies in accordance with zone and activity, those activities that were determined to be of high risk have been identified as follows:

- Zone 1 (C1): High risk for earthworks and track-out for ecological
- Zone 2 (C2, 3, 4, 5 and 6): High risk for dust soiling, human health and ecological for all type of activities.

Table 9-22 Summary of risk assessment for the construction of the F6 Extension Stage 1

Zone	Activity	Potential for dust emissions	Sensitivity of area			Risk of dust impacts		
			Dust soiling	Human health	Ecological	Dust soiling	Human health	Ecological
Zone 1 (C1)	Demolition	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Earthworks	Large	Medium	Medium	High	Medium Risk	Medium Risk	High Risk
	Construction	Small	Medium	Medium	High	Low Risk	Low Risk	Low Risk
	Track-out	Large	Medium	Medium	High	Medium Risk	Medium Risk	High Risk
Zone 2 (C2, 3, 4, 5 and 6)	Demolition	Large	High	High	High	High Risk	High Risk	High Risk
	Earthworks	Large	High	High	High	High Risk	High Risk	High Risk
	Construction	Large	High	High	High	High Risk	High Risk	High Risk
	Track-out	Large	High	High	High	High Risk	High Risk	High Risk

9.5.3 Mitigation

Mitigation measures were determined for each of the four potential activities. This was based on the risk of dust impacts identified. For each activity, the highest risk category was used. The suggested mitigation measures are discussed in **section 9.7**.

9.5.4 Significance of risks

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

However, even with a rigorous Dust Management Plan in place, it is not possible to guarantee that the dust mitigation measures would be effective all the time. There is the risk that nearby residences, commercial buildings, hotel, cafés and schools in the immediate vicinity of the construction zone, would experience some occasional dust soiling impacts. 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'.

9.5.5 Odour

The source of odour for this project is the release of hydrogen sulphide gas when the excavation activities disturb an historical landfill site. This is in the area north of President Avenue and west of West Botany Street which will be disturbed as part of the construction of a cut and cover tunnel.

There is potential for impacts from odour during this process as contaminated acid sulfate soils will be exposed to the air. This has the potential to release the odorous hydrogen sulphide gas (H_2S) into the atmosphere impacting nearby receptors.

This section provides an assessment of H_2S emissions and resulting ground level concentrations predicted using atmospheric dispersion modelling. **Appendix E** (Air quality technical report) provides discussion of the goals applied in NSW and the methodology applied to the project.

Table 9-23 lists the odour criteria to be exceeded not more than 1% of the time for different population sizes. The most stringent of the impact assessment criterion of 2 odour units (OU) at the 99th percentile has been applied to the assessment. With regard to H_2S, the relevant odorous pollutant for this assessment, odour units (OU) are converted to micrograms per cubic metre (µg/m^3) as a function of population density, using the following equation from the Approved Methods:

Impact assessment criterion (µg/m^3) = (log$_{10}$ (population) – 4.5) / (– 0.87)

Table 9-23 also presents these equivalent H_2S criteria for the corresponding odour values. The most stringent of the impact assessment criterion of 1.38 µg/m^3 at the 99th percentile has been applied to the assessment.

Table 9-23 Criteria for the assessment of odour and hydrogen sulphide (NSW EPA, 2016)

Population of affected community	Complex mixtures of odour (OU)	Hydrogen sulphide (µg/m^3)
≤ ~2	7	4.83
~10	6	4.14
~30	5	3.45
~125	4	2.76
~500	3	2.07
Urban (≥ ~2000)	2	1.38

Note: these criteria apply to the 99th percentile 1-hour average

9.5.6 Modelling results

This section provides the predicted H_2S concentrations due to proposed construction activities, stockpiling and treatment north of President Avenue. The results, presented in **Figure 9-10** show that the predicted 99th percentile H_2S concentrations at the nearest receptors are well below the criterion of 1.38 µg/m^3 and likely to be below the level of detection. This is not to say that there will be no odour experienced at these locations, but that it is not predicted to be above the criteria for more than 1% of the time. The level of odour emission is dependent on the odour concentration of the material being excavated and the sizes of the areas left exposed.

Figure 9-10 Predicted 99th percentile H_2S concentration due to exposure of acid sulfate material (μg/m^3)

9.5.7 Mitigation

It is recommended that on-site odour measurements be carried out once excavation operations begin so that specific odour emission rates can be determined and used to remodel. It is also recommended that the size of the exposed areas of odorous material be kept to a minimum to reduce the total emission from the site. Odorous material should be treated as soon as possible and removed from the site.

9.5.8 Significance of risks

It is assumed in the methodology used, that these areas will be exposed for all hours of the year, which may be the case for the treatment area, but unlikely for the excavation areas.

9.6 Potential impacts – operation

9.6.1 In-tunnel air quality

In-tunnel air quality for the project was modelled using the IDA Tunnel software and Australia-specific emission factors from PIARC. Consideration was given to peak in-tunnel concentrations of CO and NO_2, as well as the peak extinction coefficient (for visibility). The work covered expected traffic, regulatory demand, and worst case operations scenarios.

In addition, all possible travel routes through the F6 Extension Stage 1 and the adjoining tunnels were identified for each direction of travel, and these were assessed against the in-tunnel criterion for NO_2 assessed as an average along any route through the tunnel network.

The information presented in the report has confirmed that the tunnel ventilation system will be designed to maintain in-tunnel air quality well within operational limits for all scenarios.

Expected traffic

The results are shown in the form of graphs, depicting graphs, individual lines for each period of the day with major tunnel features (intersections, interface locations) added for reference. The results for the 2026 and 2036 Do Something and Cumulative scenarios are provided in graphs for the routes from President Avenue to the mainline interface point between M4-M5 Link and New M5 in both directions of travel. Further detail including the tables showing the in-tunnel maximum values for NO_2, CO and visibility and the outlet emissions are provided in Annexure K of **Appendix E** (Air quality technical report).

The route average NO_2, CO and visibility, measured as the extinction coefficient, are all within the criteria for all sections of the journeys between President Avenue on ramps and the interface with the M4-M5 Link tunnel at St Peters in both northbound and southbound directions. The list of routes assessed is shown in **Table 9-24**.

Table 9-24 List of routes assessed

Route ID	Start at		Finish at		Approx. length
Southbound (M4 to M5) direction					
1A	New M5 Motorway	St Peters	F6 Extension Stage 1	President Ave	6.7 km
1B	New M5 Motorway	St Peters	New M5 Motorway	New M5 Motorway portal (Kingsgrove)	9.1 km
1C	New M5 Motorway	M4-M5 Link interface	F6 Extension Stage 1	President Ave	6.7 km
1D	New M5 Motorway	M4-M5 Link interface	New M5 Motorway	New M5 Motorway portal (Kingsgrove)	9.0 km
Northbound (M5 to M4) direction					
2A	F6 Extension Stage 1	President Ave	New M5 Motorway	St Peters	6.8 km
2B	F6 Extension Stage 1	President Ave	New M5 Motorway	M4-M5 Link interface	6.7 km
2C	New M5 Motorway	M5 portal (Kingsgrove)	New M5 Motorway	M4-M5 Link interface	9.0 km
2D	New M5 Motorway	M5 portal (Kingsgrove)	New M5 Motorway	St Peters	9.2 km

Each line in the graph represents a traffic period of the 24 hours as shown in **Table 9-25**.

Table 9-25 Daily traffic periods

ID	Description	Period of the day
AM	Morning Peak	7am to 9am
IP	Inter peak	9am to 3pm
PM	Afternoon peak	3pm to 6pm
EV	Evening	6pm to 7am

Results for southbound journeys in 2026 with the project

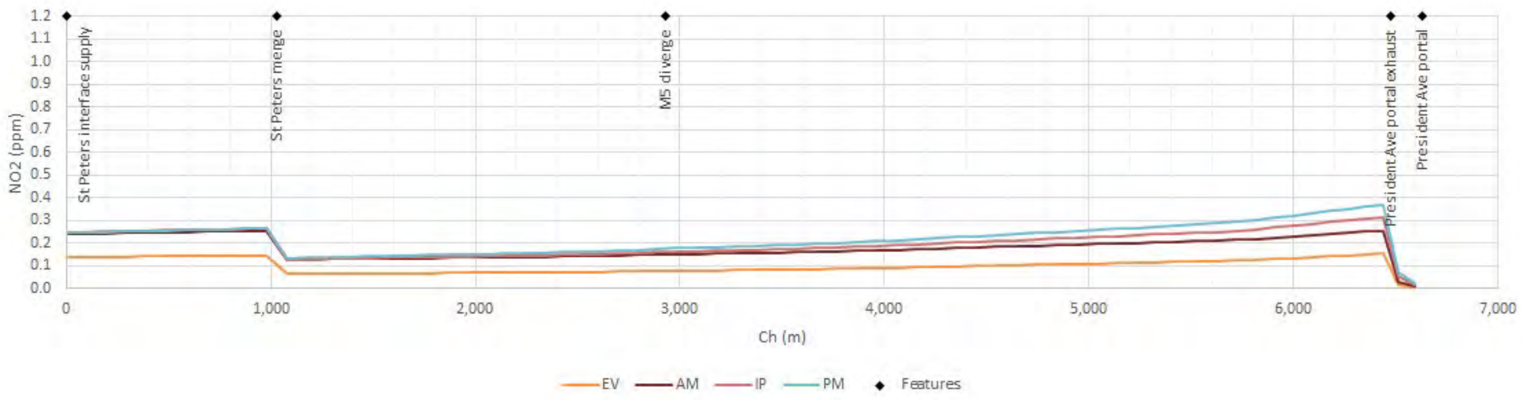

Figure 9-11 In-tunnel NO_2 levels along route 1C from M4-M5 Link to President Ave [2026 Do something, expected traffic]

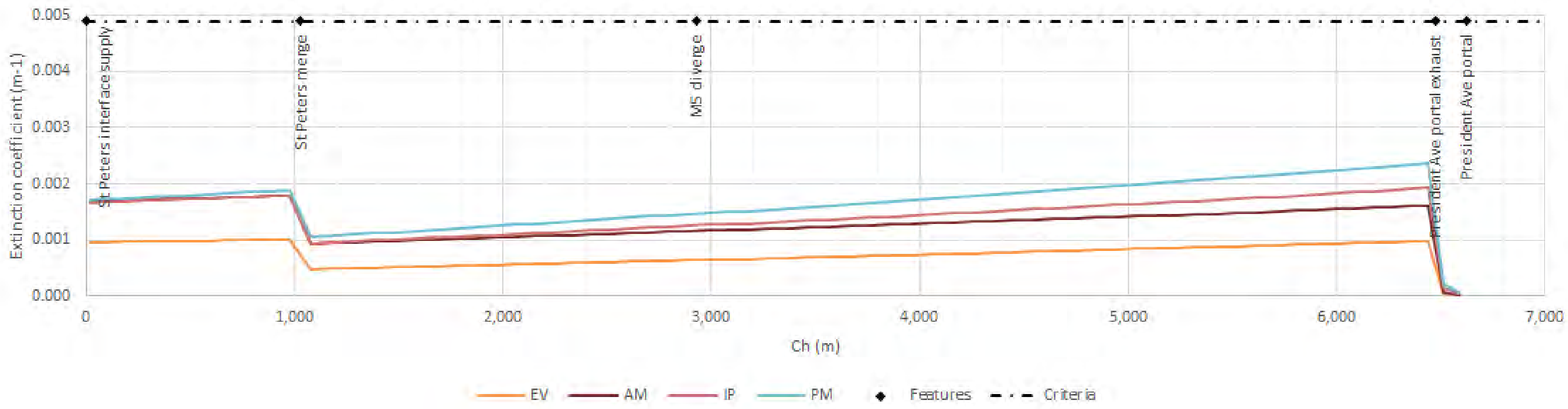

Figure 9-12 In-tunnel visibility along route 1C from M4-M5 Link to President Ave [2026 Do something, expected traffic]

Results for northbound journeys in 2026 with the project

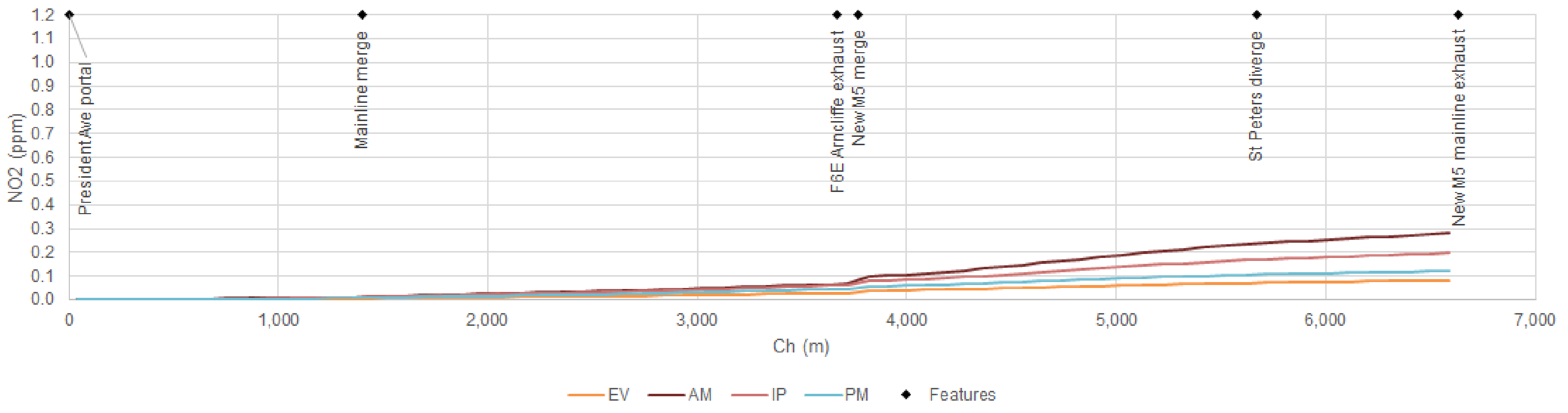

Figure 9-13 In-tunnel NO_2 levels along route 2A from President Ave to M4-M5 Link [2026 Do something, expected traffic]

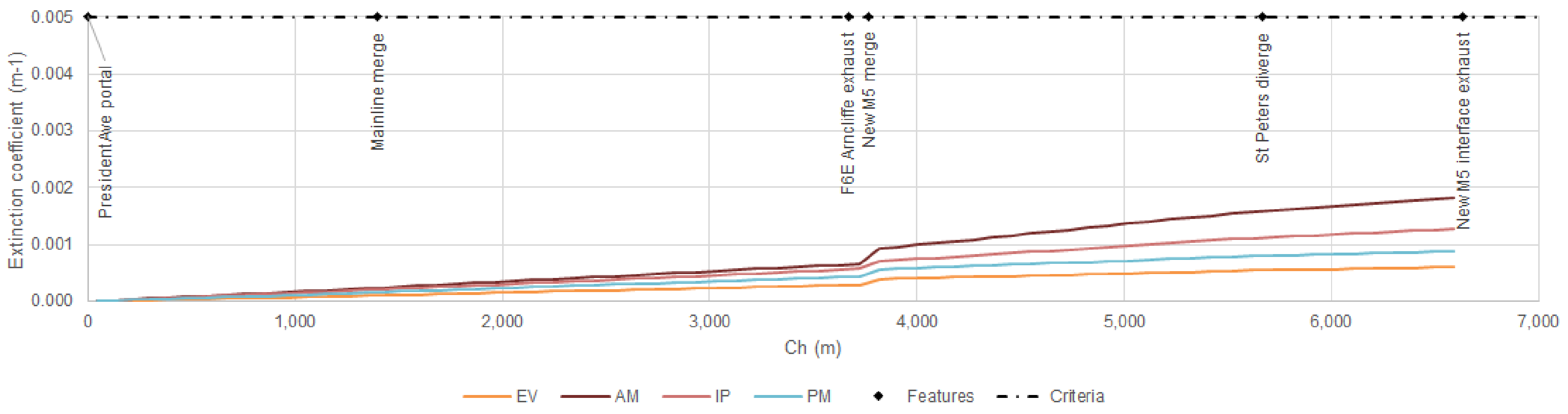

Figure 9-14 In-tunnel visibility along route 2A from President Ave to M4-M5 Link [2026 Do something, expected traffic]

Results for in-tunnel journeys through in 2036

Similar low levels of NO_2 and visibility can be seen in the graphs for the 2036 in-tunnel journeys with the project as shown in Annexure K of **Appendix E** (Air quality technical report). The increase in traffic is partially offset by the future improvement in vehicle emissions.

Worst case operations

The Do Something scenarios are based on the maximum traffic volumes in the tunnel at 20 kilometres per hour and 80 kilometres per hour and so the maximum traffic is the same for both 2026 and 2036. However the model uses 2024 emissions, (based on expected year of project opening) as the worst case emissions, since exhaust emissions would reduce, i.e. improve, in future years. The details of these scenarios for the operation of the ventilation system, the traffic assumptions and the maximum levels of in-tunnel pollutants are shown in Annexure K of **Appendix E** (Air quality technical report), and demonstrate that the criteria would be met, with maximum NO_2 levels between 0.18 ppm and 0.44 ppm in the worst case conditions, depending on the route taken and the scenario.

In-tunnel air quality conclusion

The concept ventilation scheme meets the in-tunnel air quality criteria for all expected traffic scenarios. The traffic scenarios analysed to simulate worst case operations are more onerous on the ventilation system compared to the expected traffic cases, however the analysis showed that the criteria would also be met under all circumstances. There is a substantial reduction in pollutant levels inside the cabins on vehicles with windows closed and the recirculation mode used for vehicle ventilation (see **Appendix F** (Human health technical report).

9.6.2 Ambient air quality

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

Overview

- The predicted total concentrations of all criteria pollutants at receptors were nearly always dominated by the existing background contribution
- For some pollutants and metrics (such as annual mean NO_2) there was also predicted to be a significant contribution from the modelled surface road traffic
- Under expected traffic conditions, the predicted contribution of tunnel ventilation outlets to pollutant concentrations was negligible for all receptors
- Any predicted changes in concentrations were driven by changes in the traffic volumes on the modelled surface road network, not by the tunnel ventilation outlets
- For some metrics (one-hour NO_2 and 24-hour PM_{10}), exceedances of the criteria were predicted to occur both with and without the project. However, where this was the case the total numbers of receptors with exceedances decreased slightly with the project and in the cumulative scenario
- Where increases in pollutant concentrations at receptors were predicted, these were mostly small and a very small proportion of receptors were predicted to have larger, but acceptable increases. Refer to the pollutant specific results in this section.
- The spatial changes in air quality as a result of the project were quite complex, reflecting the complex changes in traffic on the network. For example:
  - There were noticeable decreases in $PM_{2.5}$ along several roads with the project, including Botany Street, Southern Cross Drive, General Holmes Drive, The Grand Parade to the north of President Avenue, President Avenue to the east of the project, and Marsh Street. These changes reflected reductions in traffic of between 2 per cent and 22 per cent on these roads. There were increases in concentration along President Avenue to the west of the F6 Extension Stage 1 project and Princes Highway to the south of the junction with Rocky Point Road
  - For the cumulative scenario (2036-DSC) there were some additional changes associated with the introduction of the later stages F6 Extension. These included reductions in $PM_{2.5}$ concentration along The Grand Parade to the south of President Avenue, Sandringham Street and Rocky Point Road. In addition, the increase in concentration on Princes Highway in the Do Something scenarios changed to a reduction in concentration in the Cumulative scenario
  - With respect to the overall concentration distributions, there was no marked redistribution of air quality impacts. There was no significant increase in concentration at receptor locations which already had a relatively high concentration in the Do Minimum cases
  - Contour plots were developed to illustrate the spatial distribution of pollutant concentrations (from all sources) across the GRAL domain. Some plots are provided here to illustrate the most important results. All other contour plots are provided in **Annexure I** of **Appendix E** (Air quality technical report**)**. The plots illustrate the strong links between the spatial distribution of air pollution and the traffic on the road network.

Pollutant specific results

Results for all pollutants and metrics are summarised below graphs and contour plots are shown for the key pollutants of NO_2, PM_{10} and $PM_{2.5}$ to illustrate the most important air quality results, and the changes as a result of the project. All other graphs and contour plots are shown in **Appendix E** (Air quality technical report) and Annexure I to Appendix E.

Contour plots were developed to illustrate the spatial distribution of pollutant concentrations (from all sources) across the GRAL domain. As noted earlier, to avoid a large amount of duplication only the contour plots showing the change in pollutants concentrations for 2036 Do Something and the corresponding Do Minimum case, 2036-Do Minimum, where applicable. For all other scenarios the contour plots are given in **Annexure I** of **Appendix E** (Air quality technical report**)**. The plots illustrate the strong links between the spatial distribution of air pollution and the traffic on the road network.

Carbon monoxide (maximum one hour mean)

- For all receptors and scenarios, the predicted maximum 1-hour CO concentration was well below the NSW impact assessment criterion of 30 µg/m^3, as well as the lowest international air quality standard identified in the literature (22 µg/m^3)
- There was an increase in CO at between 26 and 43 per cent of RWR receptors, although even the largest increases were an order of magnitude below the criterion
- The largest contribution from ventilation outlets at any receptor was less than 0.09 mg/m^3.

Carbon monoxide (maximum rolling eight hour mean)

- As with the one-hour mean, at all receptors the concentration was well below the NSW impact assessment criterion, which in this case is 10 µg/m^3. No lower criteria appear to be in force internationally
- The largest increase at any community receptor with the project or in the cumulative scenarios was around 0.06 mg/m^3 (equating to 0.6 per cent of the criterion).

Nitrogen dioxide (annual mean)

- At all receptors, the NO_2 concentration was well below the NSW impact assessment criterion of 62 µg/m^3. At all but two receptors the NO_2 concentration was also below the EU limit value of 40 µg/m^3. Concentrations at the vast majority (more than 98 per cent) of receptors were between around 20 µg/m^3 and 30 µg/m^3
- The maximum contribution of tunnel ventilation outlets for any scenario and receptor was 0.5 µg/m^3, whereas the maximum surface road contribution was 21 µg/m^3. Given that NO_2 concentrations at the majority of receptors were well below the NSW criterion, the contribution of the ventilation outlets was not a material concern
- There was predicted to be an increase in the annual mean NO_2 concentration at around 40 per cent of receptors in the Do Something scenarios, and 17 per cent in the 2036 Cumulative scenario. Whilst the largest increases in annual NO_2 were around 1.6 µg/m^3, the increase was greater than 0.5 µg/m^3 for no more than 3 per cent of receptors.

Results for community receptors

Figure 9-15 shows the annual mean NO_2 concentrations for the with-project and cumulative scenarios at the community receptors. At all these locations the concentration was below 30 µg/m^3, and therefore well below the NSW impact assessment criterion of 62 µg/m^3. The concentrations at receptors were also well below the lower air quality standards that have been adopted elsewhere (e.g. 40 µg/m^3 in the EU).

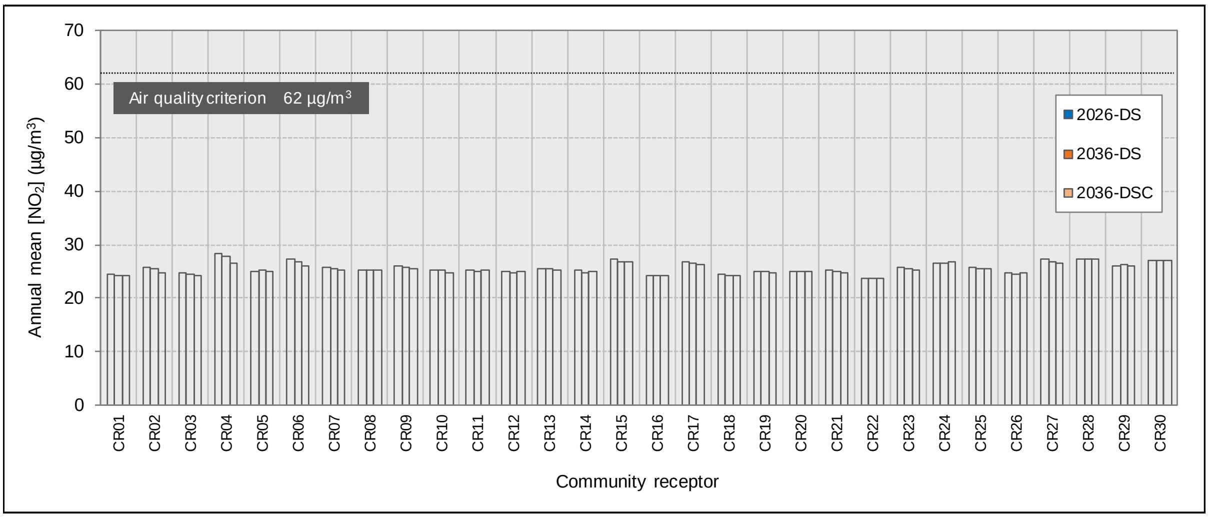

Figure 9-15 Annual mean NO_2 concentration at community receptors (with-project and cumulative scenarios)

Figure 9-16 shows the changes in concentration with the project. There was a small increase in the NO_2 concentration at some receptors. The largest increase with the project was around 0.4 µg/m^3 at receptor CR06 (St George School, Kogarah), equating to less than one per cent of the criterion. At most receptors, there were reductions in NO_2, the largest of which – between around 0.6 and 0.8 µg/m^3 – were predicted to occur at receptors CR02 (St George Christian School Infants, Sans Souci) and CR04 (Estia Health, Kogarah).

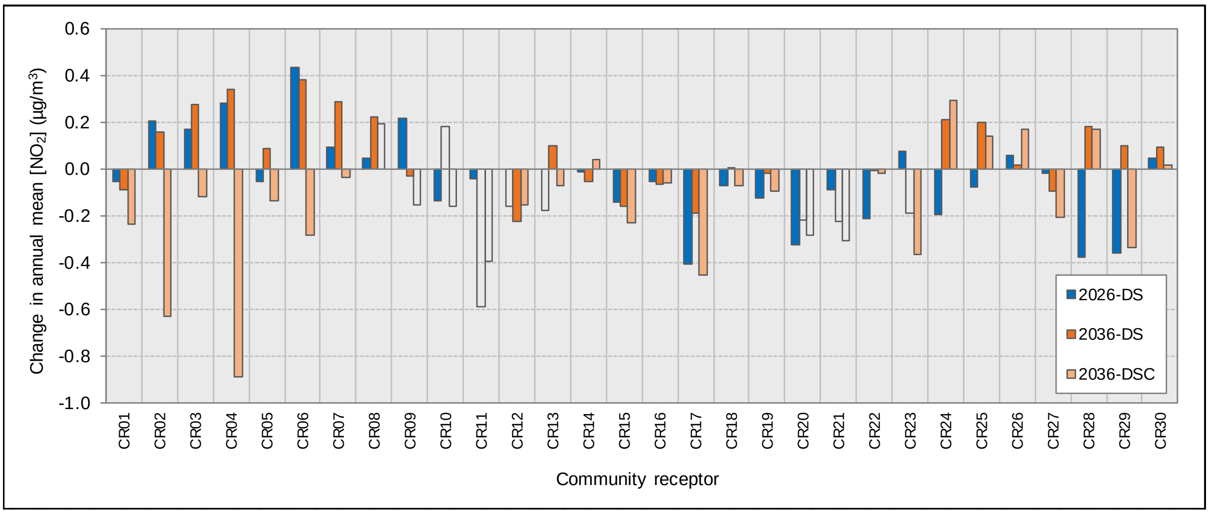

Figure 9-16 Change in annual mean NO_2 concentration at community receptors (with-project and cumulative scenarios, minus Do Minimum scenarios)

Results for RWR receptors

The highest total concentrations of annual mean NO_2 are found along the most heavily trafficked roads in the GRAL domain, such as General Holmes Drive and Southern Cross Drive. It is noticeable that tunnel ventilation outlets had little impact on total annual mean NO_2 concentrations. The spatial changes in pollutant concentrations were qualitatively similar for all pollutants. The Figures also show main surface roads and the locations of tunnel ventilation outlets.

Contour plots – all sources

The contour plots in **Figure 9-17** and **Figure 9-18** shows the changes in annual mean NO_2 concentration in the 2026 and 2036 with the project. The green shading represents a decrease in concentration with the projects included in the cumulative scenario, and the purple shading an increase in concentration. Any changes in NO_2 of less than 1 µg/m^3 (and hence the changes at a large proportion of RWR receptors) are not shown. This explains the observation that increases in concentration were predicted for up to half of all receptors, whereas the contour plot showing the change in NO_2 suggests that there would be considerably more receptors with decreases than increases, especially close to the roads affected by the project.

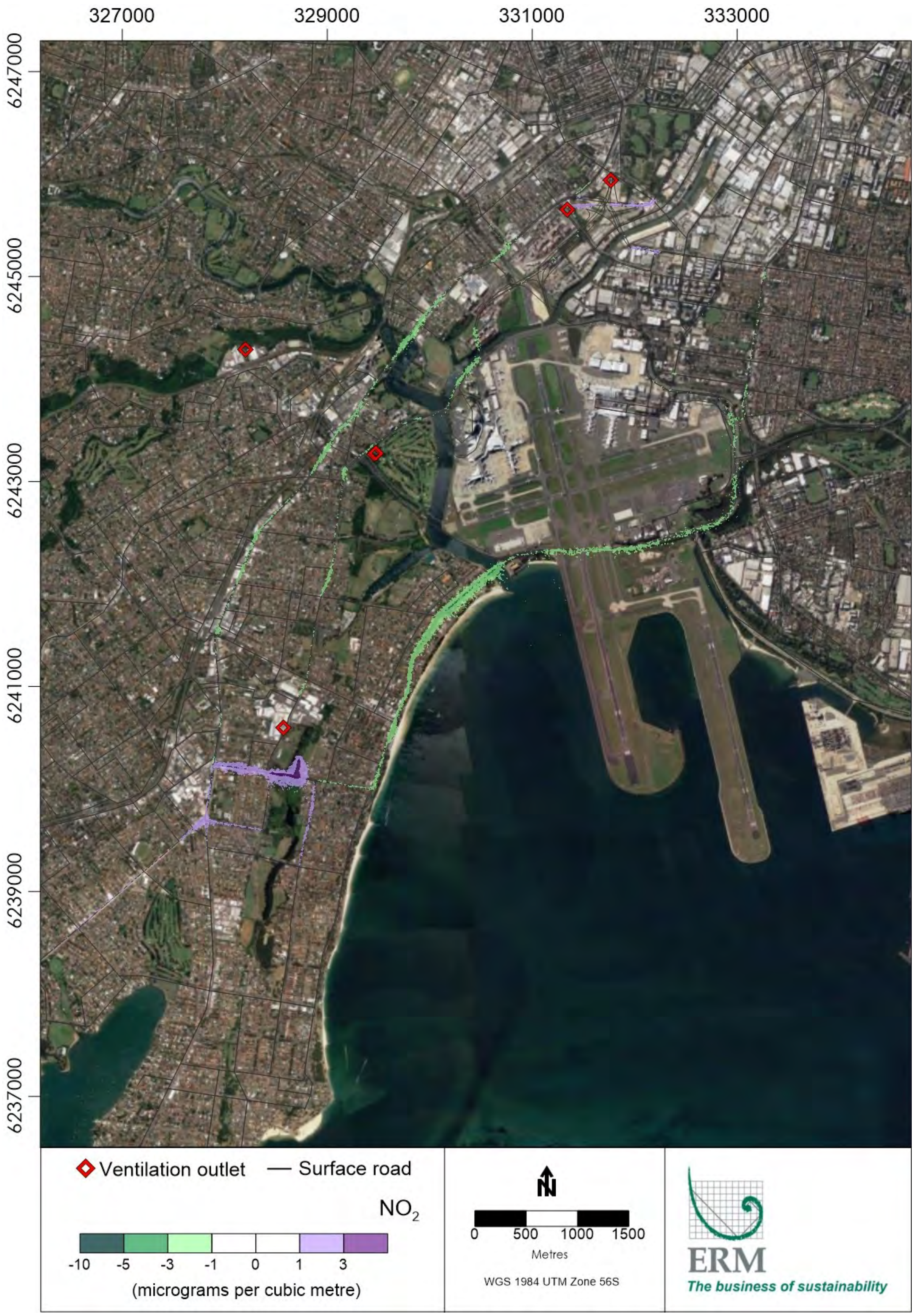

Figure 9-17 Contour plot of change in annual mean NO_2 concentration in the 2026 Do something scenario (all sources, 2026-DS minus 2026-DM)

Figure 9-18 Contour plot of change in annual mean NO_2 concentration in the 2036 Do Something scenario (2036-DS minus 2036-DM)

Nitrogen dioxide (maximum one hour mean)

- At all community receptor locations investigated in detail, the maximum on-hour NO_2 concentration was below the NSW impact assessment criterion of 246 µg/m^3. There was a mixture of small increases and decreases, although again the increases did not result in any exceedances of the NSW criterion

At the RWR receptors, there were small numbers of predicted exceedances of the NSW one-hour NO_2 criterion, both with and without the project. The number of receptors with exceedances decreased with the project, although in the cumulative scenario the number of receptors with an exceedance increased slightly.

Results for community receptors

The changes in the maximum 1-hour NO_2 concentration minus the Do Minimum scenarios are shown in **Figure 9-19**. Again, there was a mixture of small (relative to the NSW criterion) increases and decreases. As observed above, the increases did not result in any exceedances of the NSW criterion.

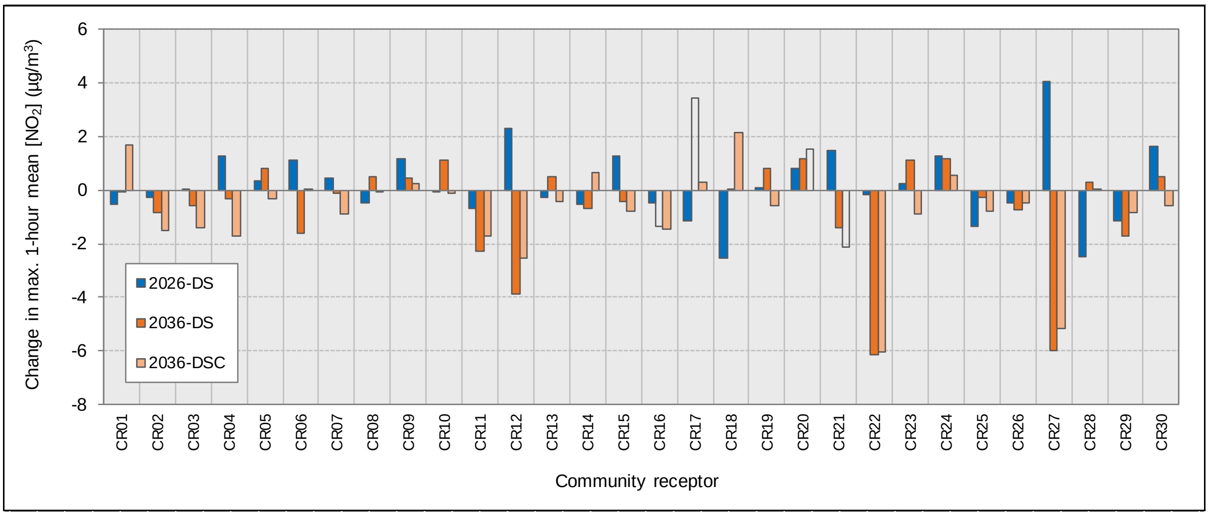

Figure 9-19 Change in maximum 1-hour mean NO_2 concentration at community receptors (with-project and cumulative scenarios, minus Do Minimum scenario)

Results for RWR receptors

At the majority of receptors the change was relatively small; at around 95 per cent of receptors the change in concentration (either an increase or a decrease) was less than 5 µg/m^3. Some of the changes at receptors were larger (up to 42 µg/m^3). However these changes did not result in any exceedances of air quality standards.

<u>Contour plots – all sources</u>

Figure 9-20 and **Figure 9-21** shows that there is very little change in maximum one-hour concentrations with the project in 2026 and 2036.

Figure 9-20 Contour plot of change in maximum one-hour mean NO_2 concentration in the 2026 Do Something scenario (all sources, 2026-DS minus 2026-DM)

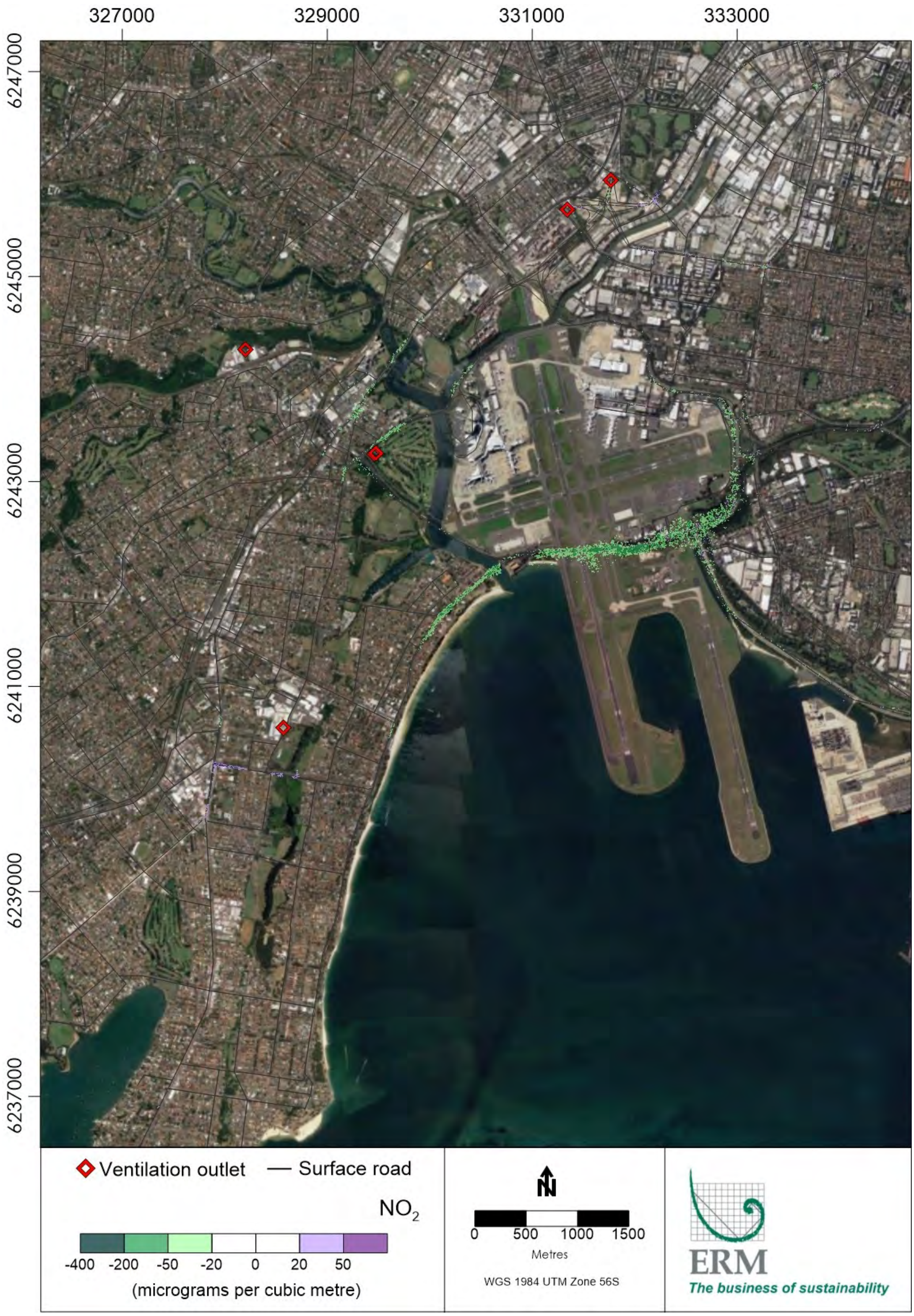

Figure 9-21 Contour plot of change in maximum one-hour NO_2 concentration in the 2036 Do Something scenario (2036-DS minus 2036-DM)

PM_{10} (annual mean)

- The concentration at the majority of receptors was below 20 µg/m3, with only four receptors having a concentration just above the NSW assessment criterion of 25 µg/m3.
- The surface road contribution was less than 12 µg/m3, with an average of 1.3 µg/m3. The largest contribution from tunnel ventilation outlets at any receptor was 0.5 µg/m3
- There was an increase in concentration at 30–48 per cent of the receptors, depending on the scenario. At the majority of receptors the change was relatively small, and where there was an increase, this was greater than 0.25 µg/m3 (one per cent of the criterion) at less than 2 per cent of receptors.

Results for community receptors

The annual mean PM_{10} concentrations community receptors are shown in **Figure 9-22**. These were all below the NSW impact assessment criterion of 25 µg/m^3. At most the receptors the concentration was close to 20 µg/m^3, and therefore only slightly above the lowest PM_{10} standards in force in other countries (18 µg/m^3 in Scotland).

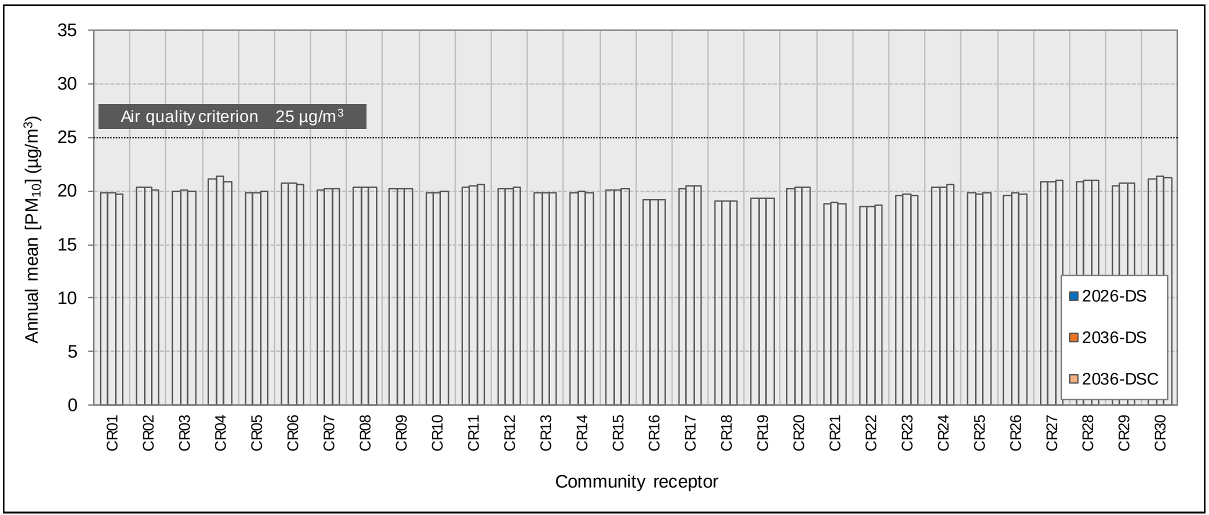

Figure 9-22 Annual mean PM_{10} concentration at community receptors (with-project and cumulative scenarios)

Figure 9-23 shows the changes in PM_{10} concentration. The largest increase was around 0.2 µg/m^3 (less than one per cent of the criterion) at receptor CR27 (Little Learning School, Alexandria), and the largest decrease was around 0.25 µg/m^3.

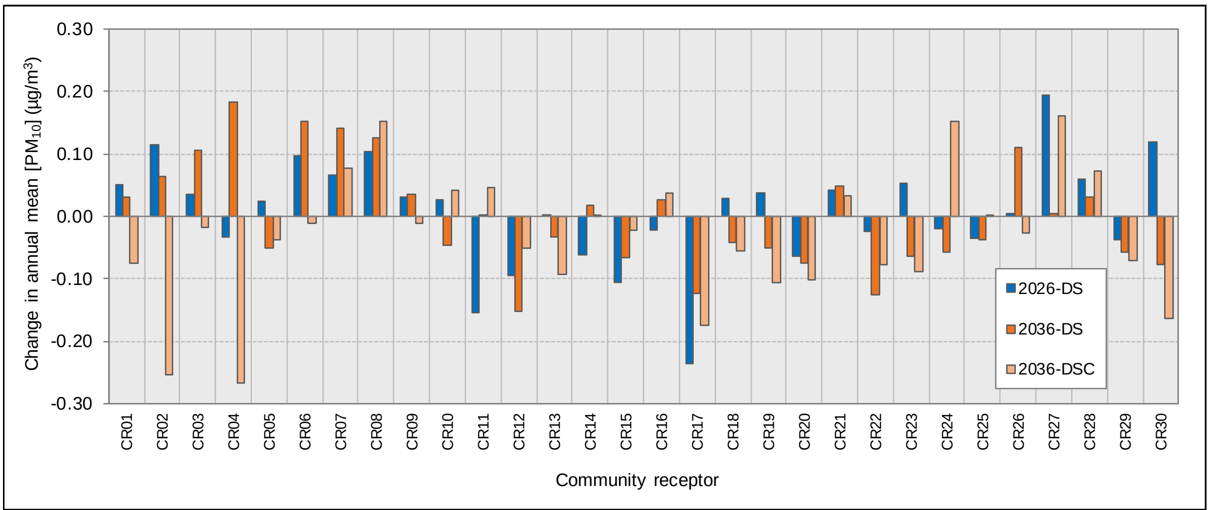

Figure 9-23 Change in annual mean PM_{10} concentration at community receptors (with-project and cumulative scenarios, minus Do Minimum scenarios)

Results for RWR receptors

Contour plots – all sources

The contour plots for changes in annual mean PM_{10} in the 2026-DS and 2036-DSC scenarios are given in **Figure 9-25** and **Figure 9-26**. As in the case of NO_2, elevated concentrations are evident at the ramps to the project tunnel at President Avenue.

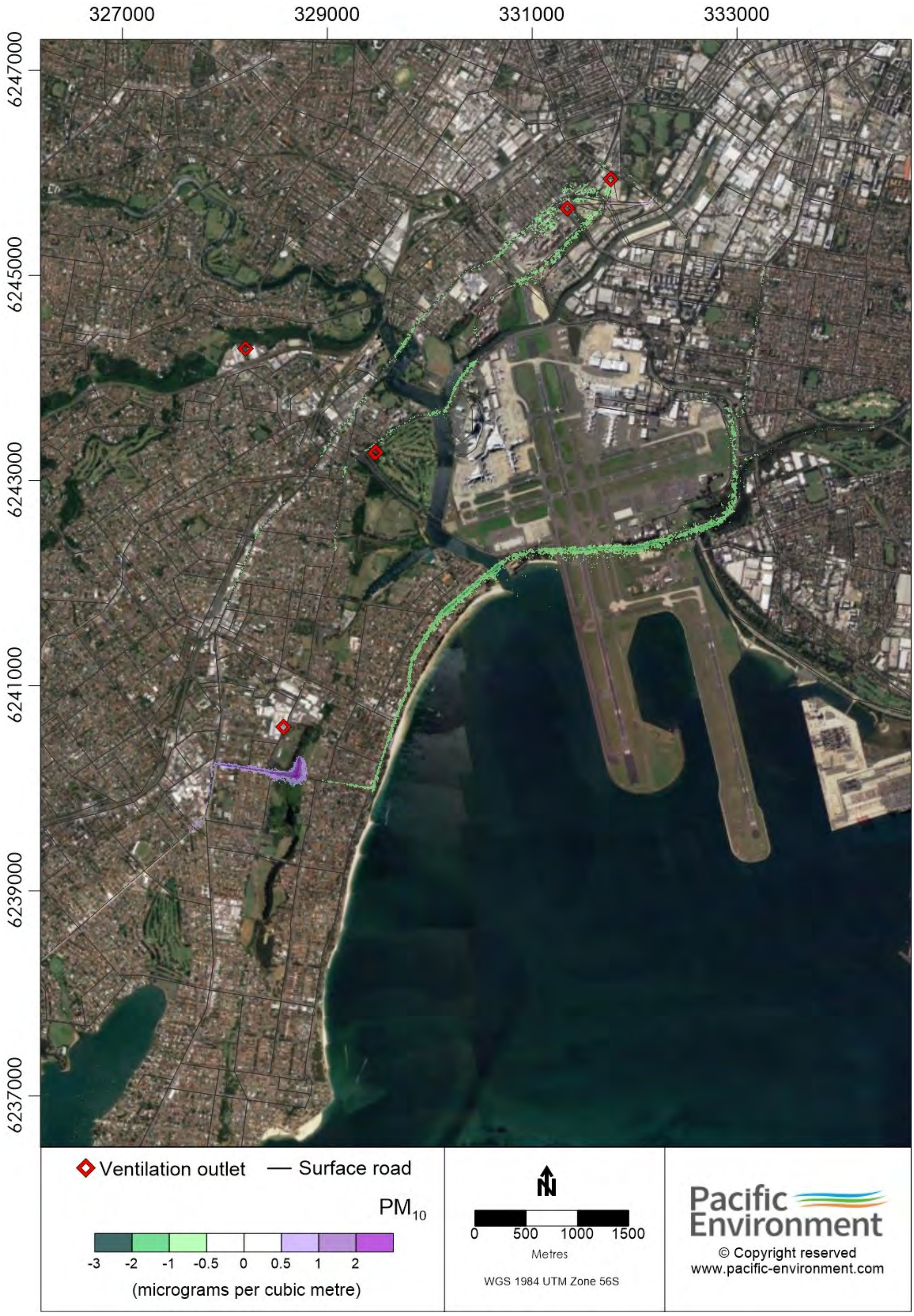

Figure 9-25 Contour plot of change in annual mean PM_{10} concentration in 2026 Do something scenario (all sources, 2026-DS minus 2026-DM)

Figure 9-26 Contour plot of change in annual mean PM_{10} concentration in 2036 cumulative scenario (all sources, 2036-DSC minus 2036-DM)

9.6.3.1.1 PM_{10} (maximum 24-hour mean)

The maximum contribution of tunnel ventilation outlets at any receptor was 2.0 µg/m³ and 2.5 µg/m³ depending on the scenario.

Results for community receptors

Figure 9-27 presents the maximum 24-hour mean PM_{10} concentrations at the community receptors. At all locations, and in all scenarios, the concentration was below the NSW impact assessment criterion of 50 µg/m³, which is also the most stringent standard in force internationally.

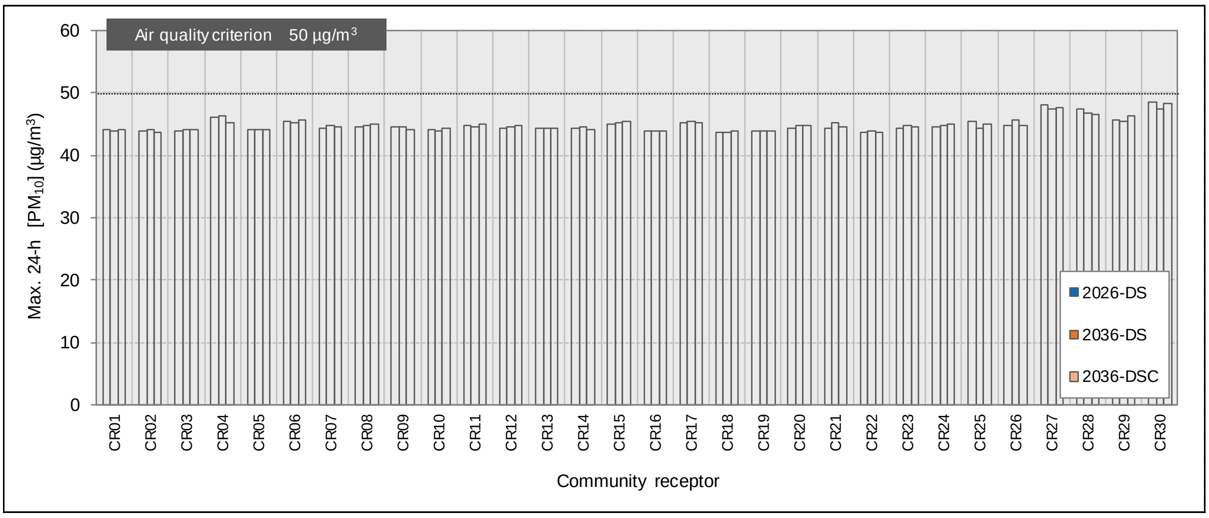

Figure 9-27 Maximum 24-hour mean PM_{10} concentration at community receptors (with-project and cumulative scenarios)

Figure 9-28 shows the changes in concentration in the Do Something scenarios minus the Do Minimum scenarios for the community receptors. There were no systematic changes by year or by scenario. At most receptors, the change was less than 1 µg/m³, and at all receptors it was less than 2 µg/m³. The largest increase was 1.8 µg/m³ at receptor CR30 (Hippos Friends, Botany) in the 2026-DS scenario.

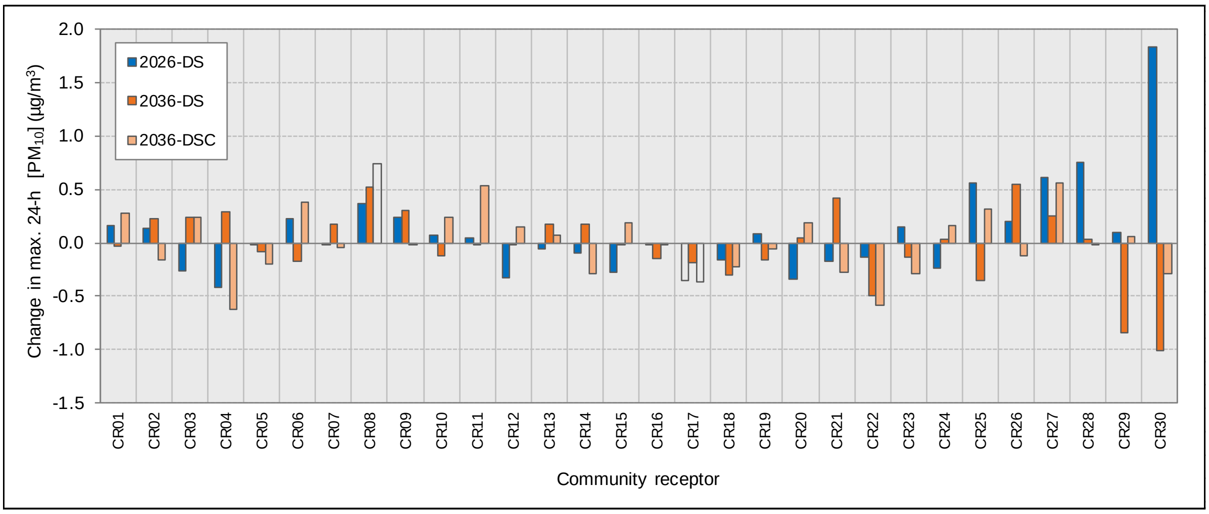

Figure 9-28 Change in maximum 24-hour mean PM_{10} concentration at community receptors (with-project and cumulative scenarios, minus Do Minimum scenarios)

Results for RWR receptors

- The results for the RWR receptors were highly dependent on the assumption for the background concentration. Because this was quite high (43.6 µg/m3), the total concentration in the with-project and cumulative scenarios was above the NSW impact assessment criterion of 50µg/m3 at between 8 and 11 per cent of receptors. However, the proportion of receptors with a concentration above the criterion decreased slightly as a result of the project
- There was an increase in concentration between 29 and 45 per cent of receptors, depending on the scenario. There was an increase of 0.50 µg/m3 (one per cent of the criterion) at four to eight per cent of receptors, depending on the scenario.

Contour plots – all sources

The contour plots for changes in maximum 24-hour average PM_{10} in the 2026-D5 and 2036-DS scenarios are given in **Figure 9-29** and **Figure 9-30**.

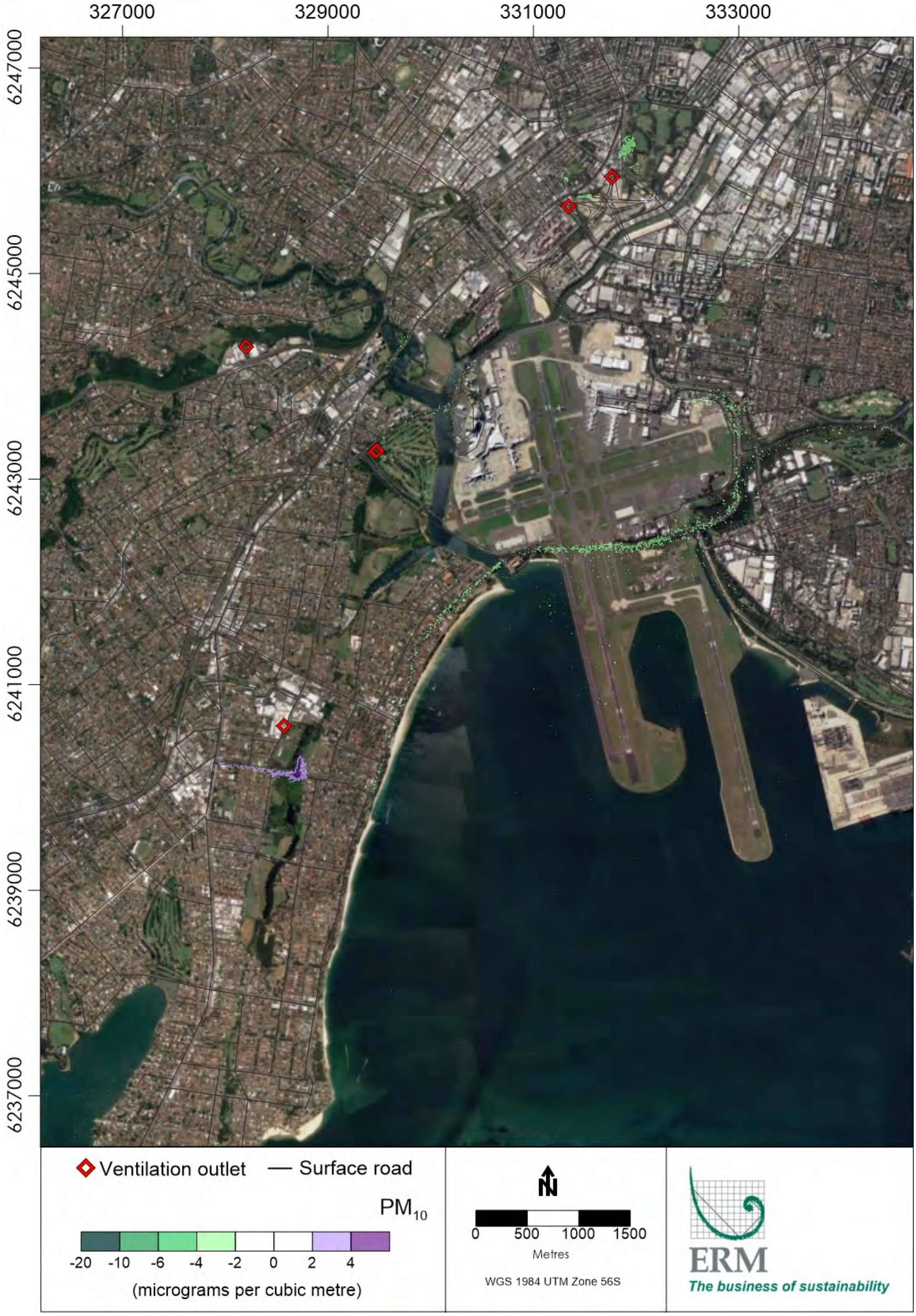

Figure 9-29 Contour plot of change in maximum 24-hour mean PM_{10} concentration in 2026 Do Something scenario (all sources, 2026-DS minus 2026-DM)

Figure 9-30 Contour plot of change in maximum 24-hour mean PM_{10} concentration in the 2036 Do Something scenario (2036-DS minus 2036-DM)

$PM_{2.5}$ (annual mean)

The predictions for annual mean $PM_{2.5}$ were based on a mapped background of between 8.0 and 9.2 µg/m^3, and therefore exceedances of the NSW criterion of 8 µg/m^3 were predicted at all receptors. Clearly, there would also be exceedances of the AAQ NEPM long-term target of 7 µg/m^3. Internationally, there are no standards lower than 8 µg/m^3 for annual mean $PM_{2.5}$.

The highest concentration at any receptor was 16.3 µg/m^3. In the with-project and cumulative scenarios, the largest surface road contribution was 7.1 µg/m^3. The largest contribution from tunnel ventilation outlets in these scenarios was 0.34 µg/m^3

There was an increase in concentration at between 31 per cent and 46 per cent of receptors, depending on the scenario. The largest predicted increase in concentration at any receptor as a result of the project was 0.45 µg/m^3. Where there was an increase, this was greater than 0.1 µg/m^3 at around 4 per cent of receptors

No RWR receptor had an increase in annual mean $PM_{2.5}$ concentration that was above the acceptable threshold of 1.8 µg/m^3.

Results for community receptors

Figure 9-31 presents the annual mean $PM_{2.5}$ concentrations at the community receptors. The results are based on a mapped background concentration with values at these locations of between 8.0 and 9.2 µg/m^3, and therefore the Figure shows exceedances of the NSW criterion of 8 µg/m^3 at all receptors. Clearly, there would also be exceedances of the AAQ NEPM long-term target of 7 µg/m^3. Internationally, there are no standards lower than 8 µg/m^3 for annual mean $PM_{2.5}$. The next lowest is 12 µg/m^3 (California, Scotland).

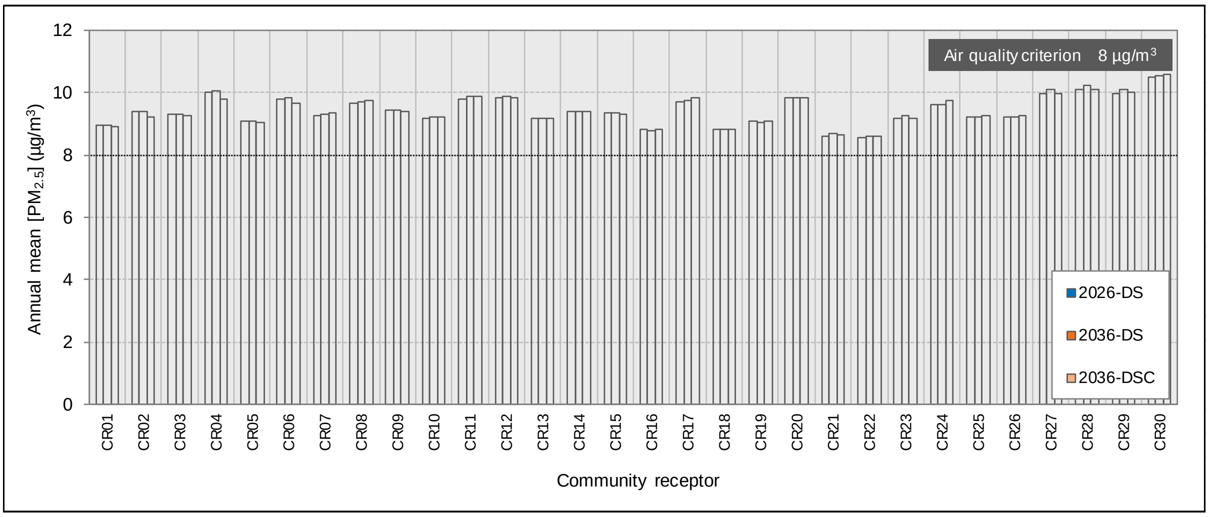

Figure 9-31 Annual mean $PM_{2.5}$ concentration at community receptors (with-project and cumulative scenarios)

Figure 9-32 presents the changes in annual mean $PM_{2.5}$ with the project and in the cumulative scenario at the community receptors. Any increases in concentration at these locations were less than 0.2 µg/m^3; the largest increase (0.17 µg/m^3 at receptor CR06 (St George School, Kogarah) in the 2026-DS scenario) equated to two per cent of the air quality criterion. Concentrations were again dominated by the background contribution. The surface road contribution was between 0.3 µg/m^3 and 1.7 µg/m^3. The largest contribution from tunnel ventilation outlets at any receptor was just 0.18 µg/m^3.

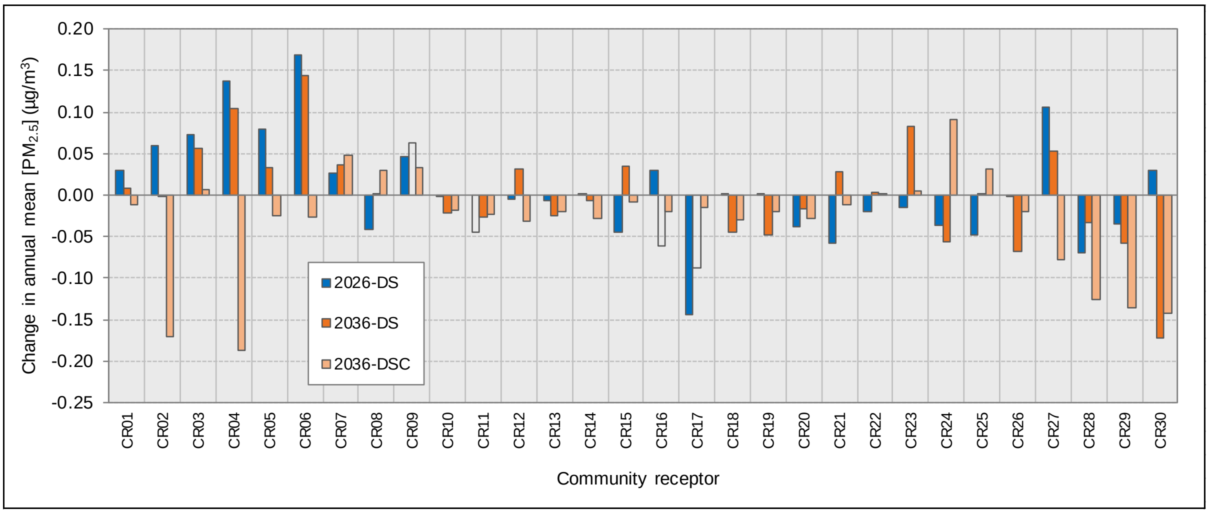

Figure 9-32 Change in annual mean $PM_{2.5}$ concentration at community receptors (with-project and cumulative scenarios, minus Do Minimum scenarios)

Results for RWR receptors

<u>Contour plots – all sources</u>

The contour plots for changes in total annual mean $PM_{2.5}$ are given in **Figure 9-33** (2026-DS) and **Figure 9-34** (2036-DS).

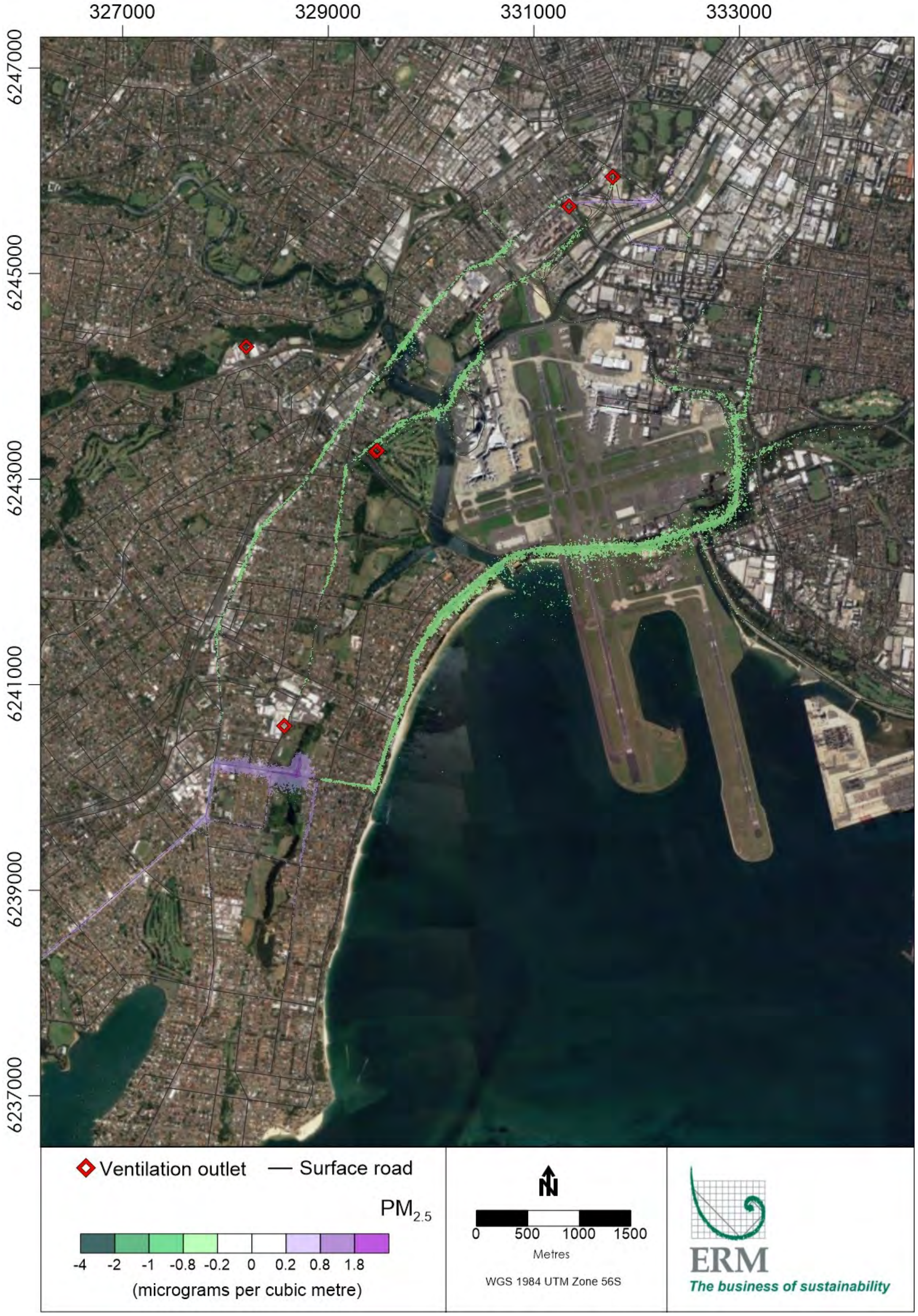

Figure 9-33 Contour plot of change in annual mean $PM_{2.5}$ concentration in 2026 Do Something scenario (all sources, 2026-DS minus 2026-DM)

Figure 9-34 Contour plot of change in annual mean $PM_{2.5}$ concentration in 2036 Do Something scenario (all sources, 2036-DS minus 2036-DM)

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

- Given the high background concentration for 24-hour PM2.5, the total concentration at up to 35 per cent of receptors in a with-project scenario was above the NSW impact assessment criterion of 25 µg/m3. . Exceedances of the impact assessment criterion decreased as a result of the project. In the without-project scenarios the maximum number of receptors over the criterion was 39 per cent.
- The maximum contribution of tunnel ventilation outlets at receptors with the project and in the cumulative scenario was 1.6 µg/m3 (equating to 6 per cent of the criterion)
- The largest predicted increase in concentration at any receptor as a result of the project was 1.5 µg/m3 (2026-DS scenario). For most of the receptors the change in concentration was small; where there was an increase in concentration, this was greater than 0.5 µg/m3 at only one to two–per cent of receptors.

Results for community receptors

The maximum 24-hour mean $PM_{2.5}$ concentrations at the community receptors with the project and in the cumulative scenarios are presented in **Figure 9-35**. At four receptors the maximum concentration was above the NSW impact assessment criterion of 25 µg/m^3, although exceedances were also predicted without the project. Internationally, there are no standards lower than 25 µg/m^3 for 24-hour $PM_{2.5}$. However, the AAQ NEPM includes a long-term goal of 20 µg/m^3, and the results suggest that this would be difficult to achieve in the study area at present.

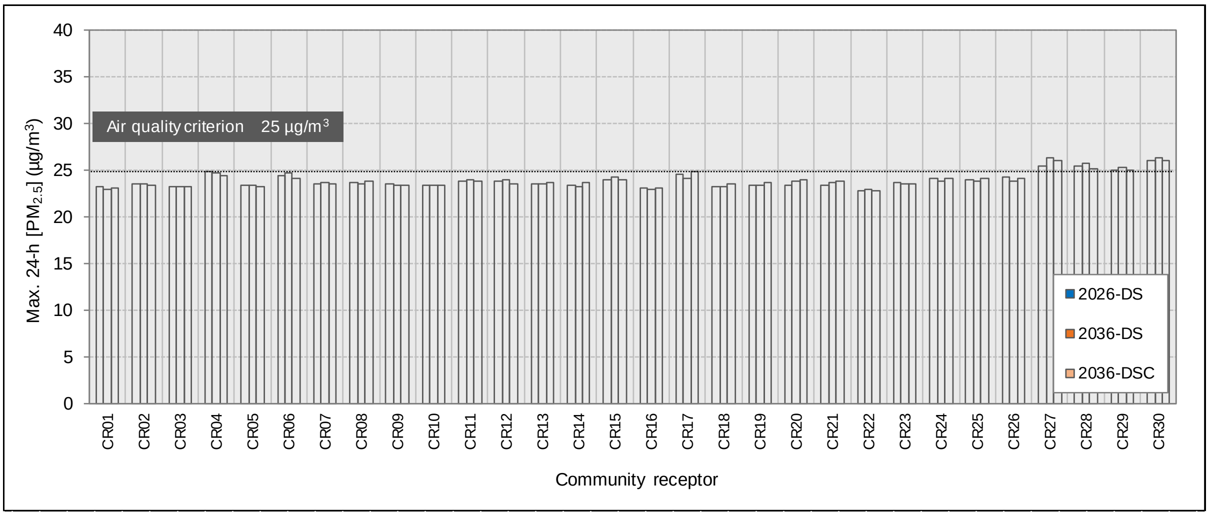

Figure 9-35 Maximum 24-hour $PM_{2.5}$ concentration at community receptors (with-project and cumulative scenarios)

Figure 9-36 presents the changes in maximum 24-hour $PM_{2.5}$ with the project and in the cumulative scenarios at the community receptors. Any increases in concentration were less than 1 µg/m^3. The largest increase (0.8 µg/m^3 at receptor CR06 (St George School, Kogarah) in the 2036-DS scenario) equated to three per cent of the air quality criterion.

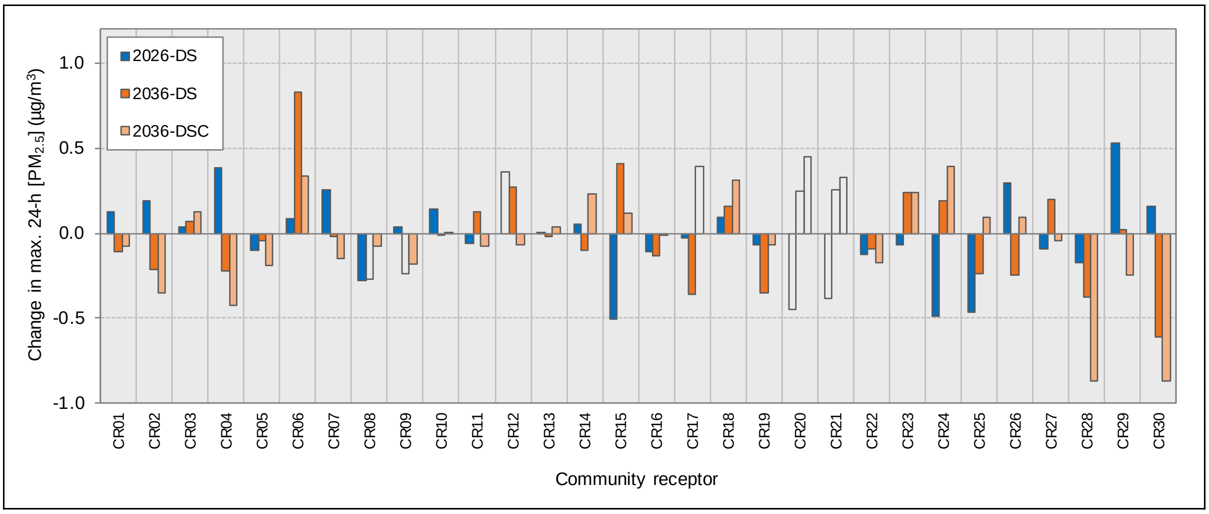

Figure 9-36 Change in maximum 24-hour $PM_{2.5}$ concentration at community receptors (with-project and cumulative scenarios, minus Do Minimum scenarios)

The combined road/outlet contributions to the maximum 24-hour $PM_{2.5}$ concentration at the community receptors were relatively small. The tunnel ventilation outlet contributions alone were negligible in all cases (less than or equal to 0.1 µg/m^3).

At all community receptors, the maximum total 24-hour concentration occurred on the same date, and coincided with the highest 24-hour background concentrations in the synthetic $PM_{2.5}$ profile (22.6 µg/m^3).

Results for RWR receptors

Contour plots – all sources

The contour plots for changes in maximum 24-hour $PM_{2.5}$ in the 2026 and 2036 project scenarios are given in **Figure 9-37** and **Figure 9-38** respectively. The very small changes reflect the minimal changes as a result of the project compared with the background concentration.

Figure 9-37 Contour plot of change in maximum 24-hour mean $PM_{2.5}$ concentration in 2026 Do Something scenario (all sources, 2026-DS minus 2026-DM)

Figure 9-38 Contour plot of change in maximum 24-hour mean $PM_{2.5}$ concentration in 2036 Do Something scenario (all sources, 2036-DS minus 2036-DM)

Air toxics

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

The changes in the maximum one-hour concentrations were compared with the relevant NSW impact assessment criteria. For each compound, where there was an increase in the concentration, this was well below the NSW impact assessment criterion.

The changes in the maximum one-hour benzene concentration at the community receptors as a result of the project are shown in **Figure 9-39**, where they are compared with the NSW impact assessment criterion from the Approved Methods. These changes took into account emissions from both surface roads and tunnel ventilation outlets. It can be seen from the Figure that there where there was an increase in the concentration, this was well below the assessment criterion. The changes in the maximum 1-hour BaP, formaldehyde and 1,3-butadiene concentration are presented in **Figure 9-40**, **Figure 9-41**, and **Figure 9-42** respectively. For each compound, where there was an increase in the concentration, this was well below the NSW impact assessment criterion. The largest increases for the community receptors were also representative of the largest increases for the RWR receptors.

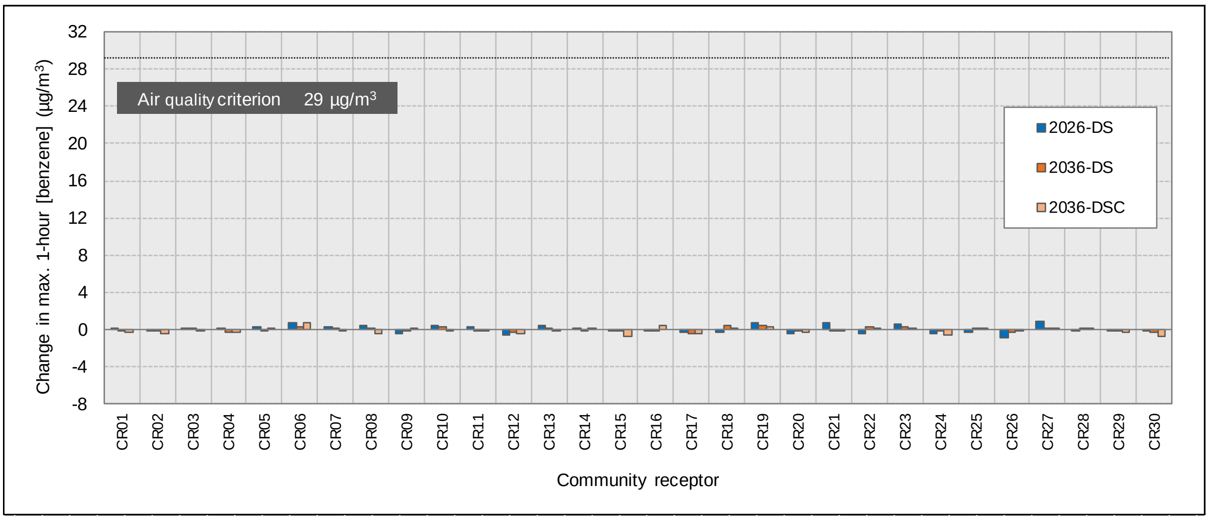

Figure 9-39 Change in maximum one-hour mean benzene concentration at community receptors (with-project and cumulative scenarios)

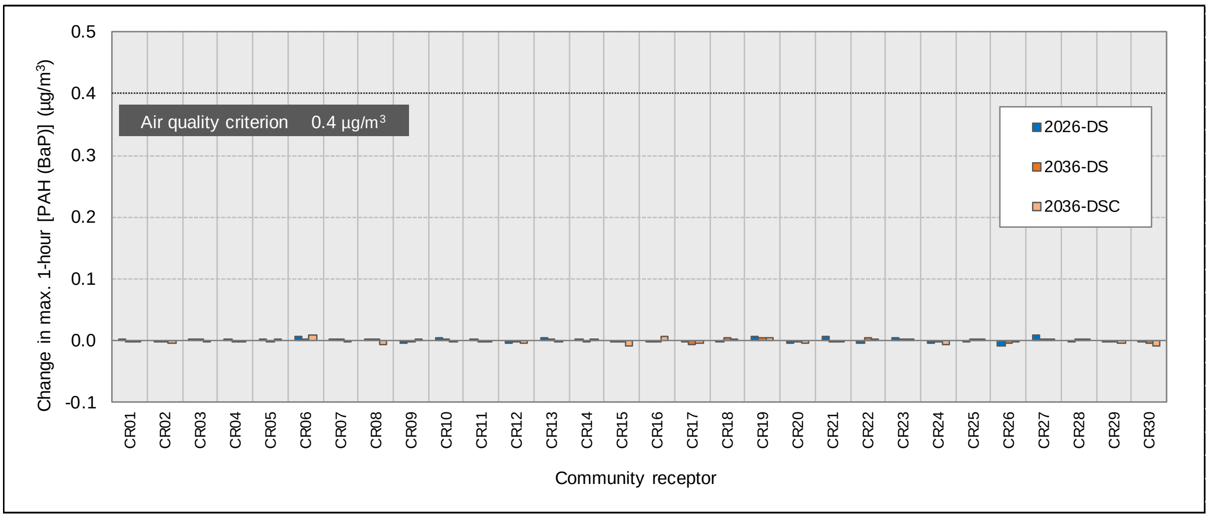

Figure 9-40 Change in maximum one-hour mean b(a)p concentration at community receptors (with-project and cumulative scenarios)

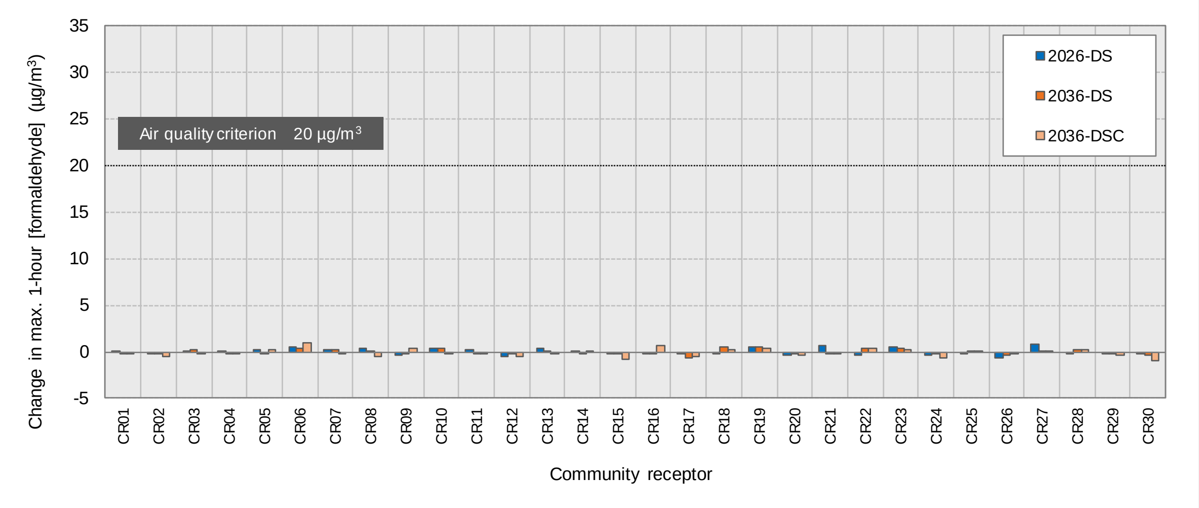

Figure 9-41 Change in maximum one-hour mean formaldehyde concentration at community receptors (with-project and cumulative scenarios)

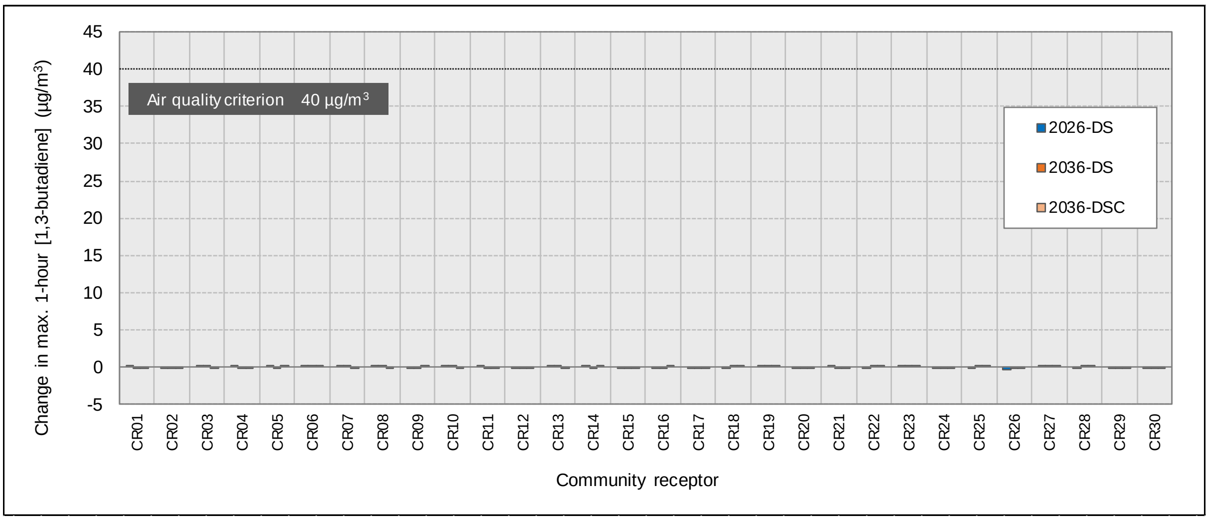

Figure 9-42 Change in maximum one-hour mean 1,3-butadiene concentration at community receptors (with-project and cumulative scenarios)

9.6.4 Results for expected traffic scenarios (elevated receptors)

Elevated receptors were considered in the assessment for two main reasons:

- To determine the potential impacts of the project at *existing* multi-storey residential and commercial buildings, based on the RWR receptor locations
- To understand, provisionally, how *future* building developments (e.g. apartment blocks) in the domain might be restricted from an air pollution perspective.

Concentrations at three elevated receptor heights (10, 20 and 30 metres) were considered for both annual mean and 24-hour $PM_{2.5}$.

Concentrations at three elevated receptor heights (10, 20 and 30 metres) were considered for annual mean and 24-hour $PM_{2.5}$ for the 2036 cumulative scenario.

Existing receptor locations

Annual mean $PM_{2.5}$

Figure 9-44 and **Figure 9-45** present contour plots for the changes in annual mean $PM_{2.5}$ concentration in the 2036-DSC scenario, and for heights of 10 metres and 30 metres, respectively. The contour plot for 20 metres I in **Appendix E** (Air quality technical report.)These plots can be compared with the changes in ground-level annual mean concentration for the same scenario (Figure I-39 in **Annexure I**). The reduced influence of surface roads at a height of 10 metres compared with ground level can be seen in **Figure 9-44** (note that the influence of surface roads in the Do Minimum case at 10 metres was also reduced. The results show that at heights of 20 metres and 30 metres the surface road contribution was further reduced. At the height of 30 metres the tunnel ventilation outlet contribution became more noticeable, although the largest changes in annual mean $PM_{2.5}$ across the GRAL domain were still lower than at ground level (see below).

Statistics relating to the changes in annual mean concentration at RWR receptors are provided in **Table 9-26**. Where there was an increase in annual mean $PM_{2.5}$ at the height of 10 metres, this was greater than 0.1 µg/m^3 for 1.1 per cent of receptors, compared with 1.4 per cent at ground level. The largest changes in concentration at 10 metres were also smaller than those at ground level. The largest increase at the height of 10 metres for the RWR receptors was 0.23 µg/m^3, compared with the maximum increase for any ground-level receptor in the 2036-DSC scenario of 0.45 µg/m^3. Although the maximum increase in annual mean $PM_{2.5}$ at 30 metres was larger than that at 10 metres and 20 metres (due to the increased influence of the outlets), it was still below the maximum increase at ground level.

Table 9-26 Changes in annual mean PM2.5 concentration at elevated receptors (RWR receptors, 2036-DSC compared with 2036-DM)

Height of modelled concentrations	Maximum increase in concentration at any RWR receptor (µg/m^3)	Number of RWR receptors with an increase of more than 0.1 µg/m^3	Number of RWR receptors above model output height with an increase of more than 0.1 µg/m^3
Ground level	0.45	250 (1.4%)	All
10 metres	0.23	197 (1.1%)	24
20 metres	0.23	218 (1.3%)	0
30 metres	0.30	345 (2.0%)	0

It should be noted that, for the 10, 20 and 30 metre outputs, it was not necessarily the case that there were existing buildings at these heights at the RWR receptor locations. It should be noted that it was not necessarily the case that there are existing buildings at these heights at the RWR receptor locations (see **Chapter 14** (Property and land use) for description of the building height restrictions in the areas potentially affected by the ventilation outlets).

It can be seen from the last column of **Table 9-26** that none of the receptors with an increase in annual mean $PM_{2.5}$ of more than 0.1 µg/m^3 had a height of more than 20 metres.

The results indicate that, for all RWR receptor locations, and assuming no further construction at those locations, the changes in annual mean $PM_{2.5}$ concentration at heights of up to 30 metres above ground level are acceptable (i.e. lower than at ground level, and well below the criterion for an increase in $PM_{2.5}$ of 1.8 µg/m^3).

The reduced influence of surface roads and portals at a receptor height of 10 metres compared with ground level can be seen in **Figure 9-43** (note that the influence of surface roads in the Do Minimum case at 10 metres was also reduced). For example, where there was an increase in annual mean $PM_{2.5}$ at the height of 10 metres, this was greater than 0.1 µg/m^3 for 1.1 per cent of receptors, compared with 1.4 per cent at ground level. The largest changes in concentration at 10 metres were also smaller than those at ground level. The largest increase at the height of 10 metres for the RWR receptors was 0.24 µg/m^3, which can be compared with the maximum increase for any ground-level receptor in the 2036-DSC scenario of 0.45 µg/m^3.

The contour plot showing the change in concentrations of annual mean $PM_{2.5}$ at 30 metres is shown in **Figure 9-44**.

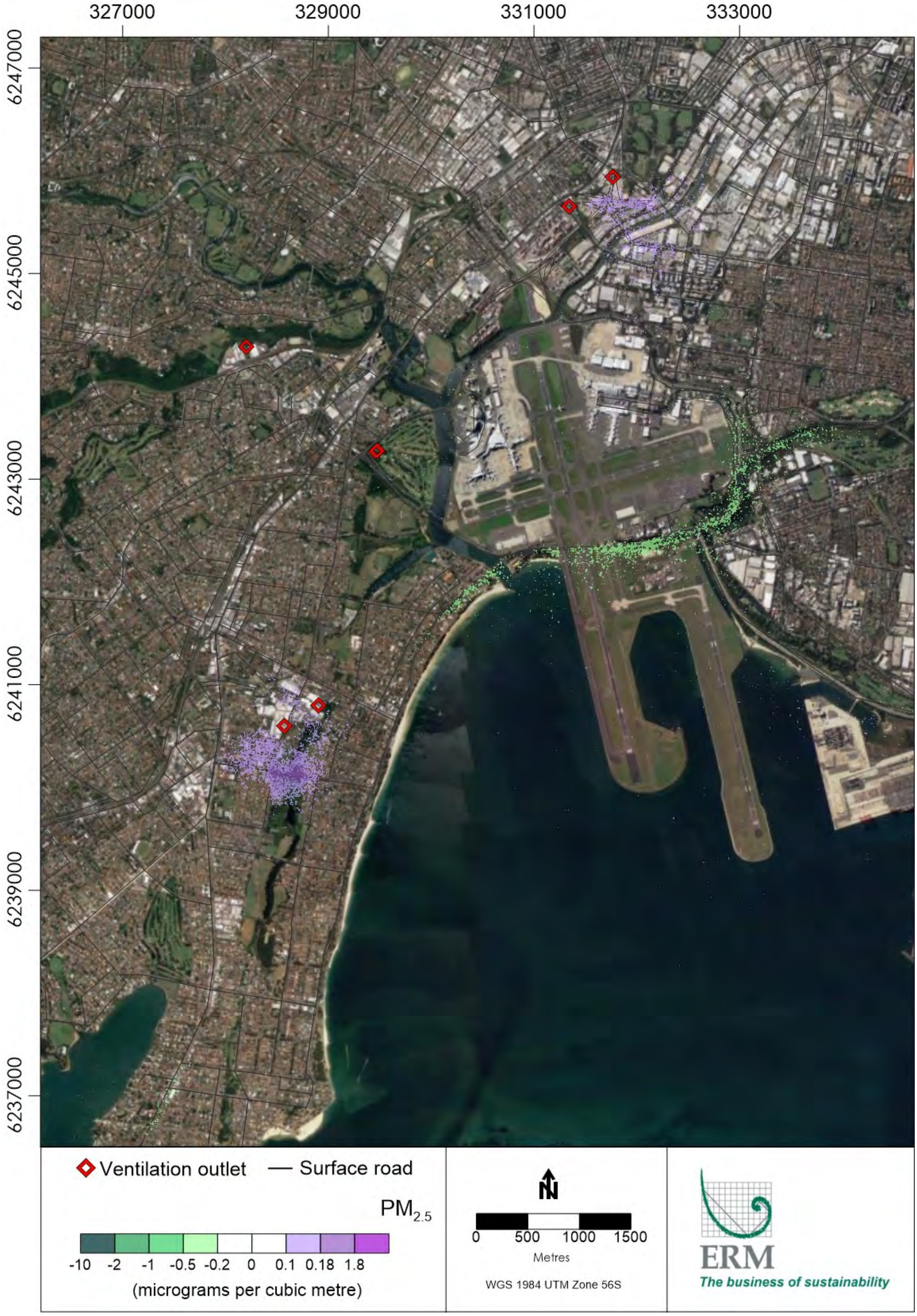

Figure 9-43 Contour plot of change in annual mean $PM_{2.5}$ concentration (2036-DSC minus 2036-DM, 10 metre receptor height)

Figure 9-44 Contour plot of change in annual mean $PM_{2.5}$ concentration (2036-DSC minus 2036-DM, 30 metre receptor height)

Maximum 24 hour $PM_{2.5}$

The changes in concentrations of in maximum 24-hour $PM_{2.5}$ concentration in the 2036-DSC scenario at receptor heights of 10 metres, 20 metres and 30 metres, are shown in **Table 9-27.**

Table 9-27 Changes in maximum 24-hour $PM_{2.5}$ concentration at elevated receptors (RWR receptors, 2036-DSC compared with 2036-DM)

Height of modelled concentrations	Maximum increase in concentration at any RWR receptor (µg/m^3)	Number of RWR receptors with an increase of more than 0.5 µg/m^3	Number of RWR receptors above model output height with an increase of more than 0.5 µg/m^3
Ground level	1.47	216 (1.2%)	All
10 metres	1.40	129 (0.7%)	0
20 metres	1.09	88 (0.5%)	0
30 metres	1.22	109 (0.6%)	0

As mentioned in the previous section, it is not necessarily the case that there would be existing buildings with heights of 10, 20 or 30 metres at the RWR receptor locations. The last column of **Table 9-27** suggests that none of the receptors with an increase in maximum 24-hour $PM_{2.5}$ of more than 0.5 µg/m^3 had a height of more than 10 metres.

These results indicate that, for all existing receptor locations, and assuming no further construction at those locations, the changes in maximum 24-hour $PM_{2.5}$ concentration are likely to be acceptable (i.e. they are lower than at ground level).

The contour plot for maximum 24-hour $PM_{2.5}$ at 30 metres in the 2036 Cumulative scenario is shown in **Figure 9-45**.

Figure 9-45 Contour plot for change in maximum 24-hour $PM_{2.5}$ concentration (2036-DSC minus 2036-DM, 30 metre receptor height

Implications for future developments

The results for both annual mean and 24-hour $PM_{2.5}$ do not seem to impose any significant restrictions on future developments in the GRAL domain up to a height of 30 metres above ground level. This statement only applies to the RWR receptor locations included in the modelling, although these should be broadly representative of other similar locations. However, planning controls should be developed in the vicinity of the ventilation outlets to ensure that future developments at heights of 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.

9.6.5 Results for regulatory worst case scenarios

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

- The maximum one-hour CO concentration was negligible, especially taking into account the fact that CO concentrations are well below the NSW impact assessment criterion. For example, the maximum one-hour outlet contribution in the regulatory worst case scenario (0.76 mg/m^3) was a very small fraction of the criterion (30 mg/m^3). The maximum background one-hour CO concentration (3.13 mg/m^3) was also well below the criterion. Exceedances of the criterion due to the ventilation outlets are therefore highly unlikely to occur
- For PM_{10} the maximum contribution of the ventilation outlets would be small. For the annual mean and maximum 24-hour metrics the outlet contributions were seven per cent and 20 per cent of the respective criteria. This would be significant for some receptors, but any exceedances of the criteria would be dominated by background concentrations
- The ventilation outlet contribution would be most important for $PM_{2.5}$, with the maximum contributions equating to 22 per cent and 40 per cent of the annual mean and 24-hour criteria respectively. Again, any exceedances of the criteria would be dominated by background concentrations.

For annual mean NO2, the maximum outlet concentrations in the regulatory worst case were an order of magnitude higher than those in the expected traffic case, although total concentrations would still remain below the NSW air quality criterion.

A detailed analysis was conducted for one-hour NO2. Although in some cases the ventilation outlet contributions appeared to be substantial, this was deceptive. As the background and surface road contributions (and hence total NOx) increased, there was a pronounced reduction in the contribution of the outlets to NO2. The analysis showed that maximum outlet contribution occurred when other contributions were low, such that overall NO_2 concentrations were well below the criterion or even the predicted maximum.

Although the contributions to maximum one-hour concentrations of NO_2 and 24-hour concentrations of $PM_{2.5}$ could have been significant, the contributions would be theoretical worst cases, and there are several reasons why they would not represent a cause for concern in reality. For example:

- The probability of a 'worst case event' occurring that would lead to these concentrations in the ventilation outlets is very low
- Were a worst case event to occur, the probability of it lasting up to one hour would be very low. It is extremely unlikely that such an event would last for 24 hours
- The probability of a worst case event coinciding with the worst 24-hour period for dispersion would be very unlikely
- The probability of a worst case event coinciding with a high background concentration would also be very low. In the case of NO_2, even if this were to occur the NO_2/NO_X ratio would be low.

Peak in-tunnel concentrations for all traffic scenarios, including the capacity traffic at different speeds, were well within the in-tunnel concentrations associated with the regulatory worst case scenarios. It therefore follows that the predicted ventilation outlet contributions to ambient concentrations for any in-tunnel traffic scenario would be lower than those used in the regulatory worst case assessment.

It can be concluded that emissions from the project ventilation outlets, even in the regulatory worst case scenarios, would be unlikely to result in adverse impacts on local air quality. Roads and Maritime would conduct ambient air quality monitoring of emissions from the ventilation outlets to enable continual assessment of any impact on local air quality.

CO and PM

The results for CO, PM_{10} and $PM_{2.5}$ in the regulatory worst case scenario (RWC-2036-DSC only) are given in **Table 9-28**. The table shows the maximum contribution of tunnel ventilation outlets at any of the RWR receptors in this scenario, as well as the maximum contribution at any sensitive receptor (residence, schools, hospitals, etc.). However, the results were similar in both cases.

Table 9-28 Results of regulatory worst case assessment (RWR receptors) – CO and PM

Pollutant and Period	Units	Maximum ventilation outlet contribution at any receptor				
		Regulatory worst case scenario (RWC 2036 DSC)		Expected traffic scenarios (all receptors)		
		All receptors	Sensitive receptors	2026 DS	2036 DS	2036 DSC
CO (one hour)	(mg/m^3)	0.76	0.73	0.07	0.08	0.08
PM_{10} (annual)	($\mu g/m^3$)	1.79	1.24	0.40	0.46	0.50
PM_{10} (24-h)	($\mu g/m^3$)	9.96	9.56	1.99	2.29	2.47
$PM_{2.5}$ (annual)[(a)]	($\mu g/m^3$)	1.79	1.24	0.28	0.30	0.34
$PM_{2.5}$ (24-h)[(a)]	($\mu g/m^3$)	9.96	9.56	1.37	1.55	1.57

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

NO_x and NO_2

The results for NO_X and NO_2 in all regulatory worst case scenarios are given in **Table 9-29**. The table shows the maximum contribution of tunnel ventilation outlets at any of the RWR receptors in each scenario, as well as the maximum contribution at any sensitive receptor (residence, schools, hospitals, etc.). However, the results were similar in both cases. The maximum outlet concentrations in the regulatory worst case were an order of magnitude higher than those in the expected traffic case, although total annual mean NO_2 concentrations would still remain below the NSW air quality criterion.

Table 9-29 Results of regulatory worst case assessment (RWR receptors) – annual mean NO_X and NO_2

Receptor type and pollutant metric	Maximum ventilation outlet contribution by scenario ($\mu g/m^3$)		
	2026 DS	2036 DS	2036 DSC
Regulatory worst case scenarios			
All RWR receptors			
NO_x (annual mean)	30.46	31.08	32.39
NO_2 (annual mean)	5.74	5.75	5.92
All sensitive RWR receptors			
NO_x (annual mean)	21.13	21.45	22.54
NO_2 (annual mean)	4.39	4.48	4.68
Expected traffic scenarios			
All RWR receptors			
NO_x (annual mean)	2.40	2.39	2.06
NO_2 (annual mean)	0.50	0.49	0.42

The and the results for the one hour NO_2 regulatory worst case top ten RWR receptors are provided in **Table 9-30** detailed results are shown in **Appendix E** (Air quality technical report).

Table 9-30 Results of regulatory worst case assessment ('top 10' RWR receptors) – one-hour NO_2

Outlet and metric	Maximum ventilation outlet contribution across 'top 10' receptors (µg/m³)		
	2026 DS	2036 DS	2036 DSC
Outlets B and E: New M5 Motorway and F6 Extension Stage 1 (Arncliffe)			
NO_2 (one hour) [when maximum total NO_2 occurs]	0.2	3.2	0.8
NO_2 (one hour) [when maximum outlet contribution to NO_2 occurs]	98.5	84.6	100.4
Outlets F and G: F6 Extension Stage 1 and Section B (Rockdale)(a)			
NO_2 (one hour) [when maximum total NO_2 occurs]	4.5	5.1	3.4
NO_2 (one hour) [when maximum outlet contribution to NO_2 occurs]	36.2	21.2	56.4

(a) F6 Extension – Section B outlet was only included in the 2036-DSC scenario.

Total hydrocarbons and air toxics

The table shows the maximum contribution of tunnel ventilation outlets at any of the RWR receptors in this scenario (for most of the pollutant metrics these were residential receptors). The outlet contributions to the specific air toxics are well below the impact assessment criteria in the *Approved Methods for the Modelling and Assessment of Air Pollutants in New South Wales*.

Table 9-31 shows that, even if the maximum outlet contribution is added to the maximum increase in concentration in the cumulative scenario (which implies some double counting), the results are still comfortably below the impact assessment criteria.

Table 9-31 Results of regulatory worst case assessment (RWR receptors) – air toxics (ventilation outlets plus traffic)

Pollutant and period	Units	Maximum outlet contribution at any receptor	Maximum increase due to project (outlet + expected traffic)	Sum	Impact assessment criteria
THC (1 hour)	(µg/m³)	54.92	-	-	-
Benzene (1 hour)	(µg/m³)	2.55	5.23	7.78	*29*
PAH (BaP) (1 hour)	(µg/m³)	0.032	0.065	0.097	*0.4*
Formaldehyde (1 hour)	(µg/m³)	3.32	6.79	10.11	*20*
1,3-butadiene (1 hour)	(µg/m³)	0.70	1.43	2.13	*40*

9.6.6 Sensitivity tests

Several sensitivity tests were conducted to investigate the effects of the influence of;

- ventilation outlet temperature
- height of ventilation outlet, and
- the inclusion of buildings near tunnel ventilation outlets.

For each parameter the value used in the model was varied around a central estimate that was representative of the value used in the expected traffic case model scenarios.

The sensitivity tests were only conducted for the ventilation outlet contribution (i.e. background and surface road contributions were excluded), and for maximum one-hour, maximum 24-hour $PM_{2.5}$ and annual mean $PM_{2.5}$. Both absolute and percentage changes in concentration were considered. The percentage changes could also be considered as being representative for other pollutants (e.g. CO, NO_X, and PM_{10}).

The tests were mainly conducted for a sub-area of the project model domain of approximately 2 km x 2 km around the Rockdale ventilation outlets and for seven community receptors representative of the area. The detailed results for each test are provided in **Appendix E** (Air quality technical report)

Ventilation outlet temperature

For the outlet temperature of 15ºC the predicted $PM_{2.5}$ concentrations were systematically higher than those in the central estimate (25 ºC) as a consequence of the reduced thermal buoyancy of the plume leading to poorer dispersion. Across all $PM_{2.5}$ metrics the largest increase at any community receptor was 23 per cent, and the average increase was 9 per cent. The predicted outlet concentrations remained well below the air quality criteria for $PM_{2.5}$.

For the outlet temperature of 35˚C the predicted $PM_{2.5}$ concentrations were systematically lower than those in the central estimate of 25˚C because of increased thermal plume buoyancy. The largest decrease at any community receptor was 19 per cent, and the average decrease was 10 per cent.

Ventilation outlet height

For the ventilation outlet heights the central estimate for (test HT02) was taken to be 35 metres above the ground (the outlet height used in the expected traffic case modelling). In height test HT01 the height was set to 25 metres, and in height test HT03 the height was set to 45 metres. This was considered to be a realistic potential range for the outlet height at this location.

For the outlet height of 25 metres the predicted $PM_{2.5}$ concentrations were almost all systematically higher than those in the central estimate. This is a consequence of the reduction of ambient wind speed with height in the atmosphere (which results in poorer dispersion), and the shorter distances between the source and the receptors. The largest increase at any community receptor was 43 per cent, and the average increase was 22 per cent. As with the temperature tests, the predicted outlet concentrations remained well below the air quality criteria for $PM_{2.5}$.

For the outlet height of 45 metres the predicted $PM_{2.5}$ concentrations were in most cases lower than those in the central estimate. The largest decrease at any community receptor was 30 per cent, and the average decrease was 21 per cent.

Buildings

The project assessment excluded buildings from the dispersion modelling (the rationale for this was provided in **section 9.3.2**). The sensitivity of the inclusion of buildings to predicted concentrations was therefore assessed. The effects of stack-tip downwash were also included in this test.

The results for the buildings tests are shown in **Appendix E** (Air quality technical report). These show that, when buildings were included, there was a maximum increase in concentrations associated with the ventilation outlet of 32 per cent, and an average increase of 20 per cent.

As with the height and temperature tests, the predicted outlet concentrations remained well below the air quality criteria for $PM_{2.5}$.

Traffic and emissions

The daily PM and NO_x emission profiles were scaled up until the relevant emission limit for each pollutant was reached for at least one hour of each day, using a scaling factor of 3.7 for both pollutants. The detailed result are provided in **Appendix** E (Air quality technical report) and show that all assumptions for ventilation outlets resulted in relatively small contributions compared with the total concentrations from all other sources. The total predicted concentrations of NO_2 were not very sensitive to the assumptions for ventilation outlet emissions.

9.6.7 Redistribution of air quality impacts

Spatial distribution of air pollutants

The spatial changes in air quality are presented in the form of contour plots in **section 9.6.3**. The corresponding contour plots for all scenarios are provided in Annexure I of **Appendix E** (Air quality technical report). The spatial changes in pollutant concentrations are summarised below. The discussion refers to annual mean $PM_{2.5}$, given its importance in terms of health. However, the spatial changes were qualitatively similar for all pollutants, and therefore the discussion is more widely relevant.

There were predicted to be marked reductions in concentration along some major roads as a result of the F6 Extension Stage 1 project, and increases on other roads. These changes broadly reflected the effects of the project on traffic in SMPM, also taking into account factors such as road gradient and meteorology. **Table 9-32** summarises the average weekday two-way traffic on some affected roads in all scenarios, **Table 9-33** and gives the changes between scenarios.

Table 9-32 Average weekday two-way traffic volume on selected roads

Road	Average weekday two way traffic volume by scenario (vehicles per day)				
	2026 DM	2026 DS	2036 DM	2036 DS	2036 DSC
Joyce Drive	61,705	59,342	70,346	68,011	64,616
Botany Road	32,481	29,103	36,949	32,643	32,262
Southern Cross Drive	118,357	115,518	125,973	123,360	113,302
General Holmes Drive, south of Sydney Airport	169,359	160,568	182,593	172,478	167,460
General Holmes Drive, near Bestic Street	112,399	103,130	119,349	109,362	106,195
The Grand Parade, north of President Avenue	81,797	71,055	85,970	72,868	71,458
President Ave, east of F6 Extension Stage 1	43,440	34,030	45,220	33,282	40,754
President Ave, west of F6 Extension Stage 1	54,702	65,690	56,258	68,945	63,692
Sandringham Street	21,786	22,043	24,725	25,291	13,593
Rocky Point Road	33,460	34,648	40,333	37,624	25,936
Princes Highway, north of junction with Rocky Point Road	77,252	82,028	80,517	85,147	75,870
Princes Highway, south of junction with Rocky Point Road	34,576	33,861	43,700	39,085	38,877
Marsh Street	52,386	45,963	57,406	50,261	50,627

Table 9-33 Changes in average weekday two-way traffic volume on selected roads

Road	Change in average weekday two way traffic volume by scenario (vehicles per day/%)					
	2026 DS minus 2026 DM		2036 DS minus 2036 DM		2036 DSC minus 2036 DM	
Joyce Drive	-2,363	-4%	-2,335	-3%	-5,730	-8%
Botany Road	-3,378	-10%	-4,306	-12%	-4,687	-13%
Southern Cross Drive	-2,839	-2%	-2,613	-2%	-12,671	-10%
General Holmes Drive, south of Sydney Airport	-8,791	-5%	-10,115	-6%	-15,133	-8%
General Holmes Drive, near Bestic Street	-9,269	-8%	-9,987	-8%	-13,154	-11%
The Grand Parade, north of President Avenue	-10,742	-13%	-13,102	-15%	-14,512	-17%
President Ave, east of F6 Extension Stage 1	-9,410	-22%	-11,938	-26%	-4,466	-10%
President Ave, west of F6 Extension Stage 1	10,988	+20%	12,687	+23%	7,434	+13%
Sandringham Street	257	+1%	566	+2%	-11,132	-45%
Rocky Point Road	1,188	+4%	-2,709	-7%	-14,397	-36%
Princes Highway, north of junction with Rocky Point Road	4,776	+6%	4,630	+6%	-4,647	-6%
Princes Highway, south of junction with Rocky Point Road	-715	-2%	-4,615	-11%	-4,823	-11%
Marsh Street	-6,423	-12%	-7,145	-12%	-6,779	-12%

The contour plots for changes in total annual mean $PM_{2.5}$ are given in **Figure 9-33** (2026-DS) and **Figure 9-34** (2036-DS). With the F6 Extension Stage 1 there were noticeable decreases in $PM_{2.5}$ along several roads, including Botany Street, Southern Cross Drive, General Holmes Drive, The Grand Parade to the North of President Avenue, President Avenue to the east of the F6 Extension Stage 1 project, and Marsh Street. **Table 9-31** shows that there were reductions in traffic of between 2 per cent and 22 per cent on these roads. There were increases in concentration along President Avenue to the west of the F6 Extension Stage 1 project and Princes Highway to the south of the junction with Rocky Point Road. These were associated with increases in traffic volume on these roads. Similar spatial changes to these were also predicted for the 2036-DS scenario.

For the cumulative scenario (2036-DSC) there were some additional changes associated with the introduction of the full F6 Extension. These included reductions in $PM_{2.5}$ concentration along The Grand Parade to the south of President Avenue, Sandringham Street and Rocky Point Road. In addition, the increase in concentration on Princes Highway in the Do Something scenarios was converted to a reduction in concentration in the cumulative scenario.

Concentration distribution

The redistribution of air quality impacts across the GRAL domain as a result of the project was also addressed through the use of density plots which show the smoothed distributions of the concentrations at all RWR receptors. This analysis was conducted for annual mean and maximum 24-hour $PM_{2.5}$ only, as it was considered that these metrics would be representative of other pollutants for this purpose.

The results for annual mean $PM_{2.5}$ are shown in **Figure 9-47** to **Figure 9-49**, and those for maximum 24-hour $PM_{2.5}$ are presented in **Figure 9-50** to **Figure 9-52**. In each plot the Do-Something (or cumulative) scenario is compared with the corresponding Do Minimum scenario. In all cases, the distributions with and without the project were very similar. In other words, there was no marked redistribution of air quality impacts, although it can be seen from the 24-hour plots that there was a slight shift towards lower concentrations in the 2036-DSC scenario. There was no significant increase in concentration predicted at receptor locations which already had a relatively high concentration in the Do Minimum cases.

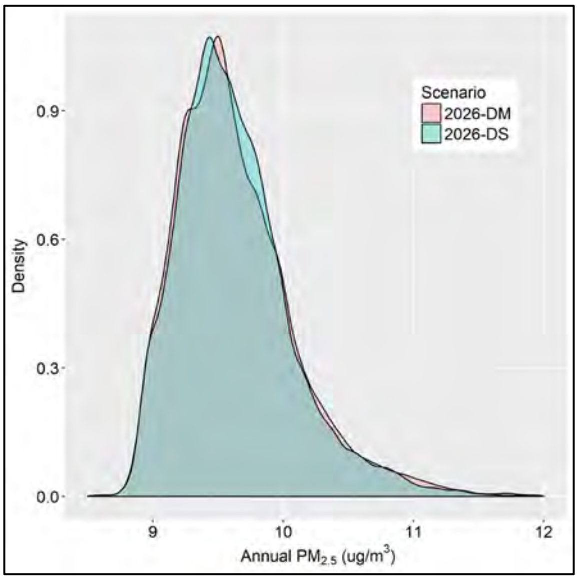

Figure 9-47 Density plot for annual mean $PM_{2.5}$ in 2026 with the project (2026-DM and 2026-DS)

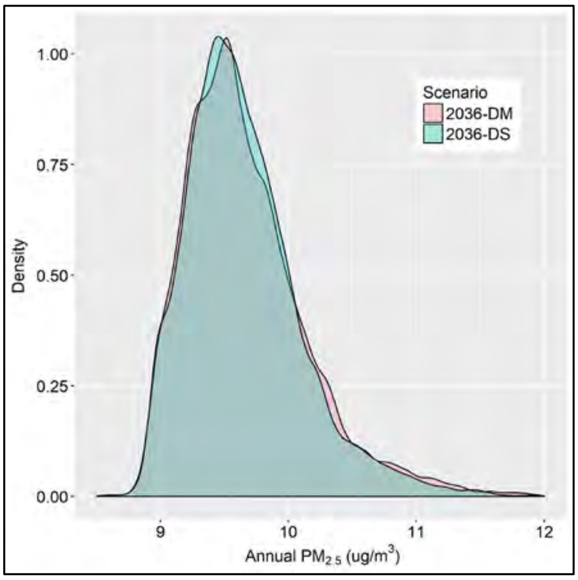

Figure 9-48 Density plot for annual mean $PM_{2.5}$ in 2036 with the project (2036-DM and 2036-DS)

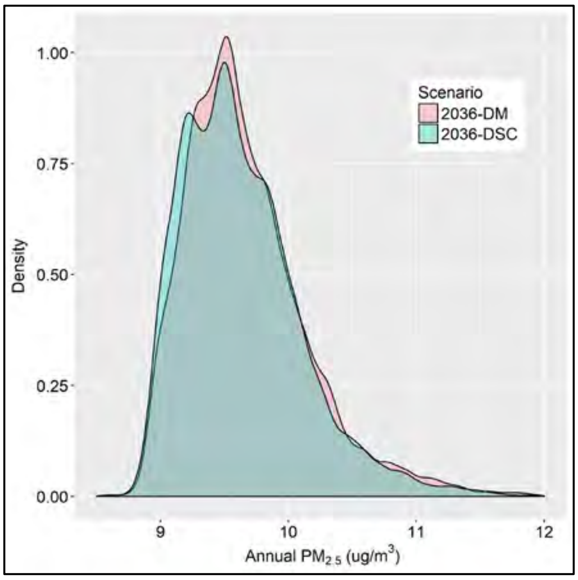

Figure 9-49 Density plot for annual mean $PM_{2.5}$ in the 2036 cumulative scenario (2036-DM and 2036-DSC)

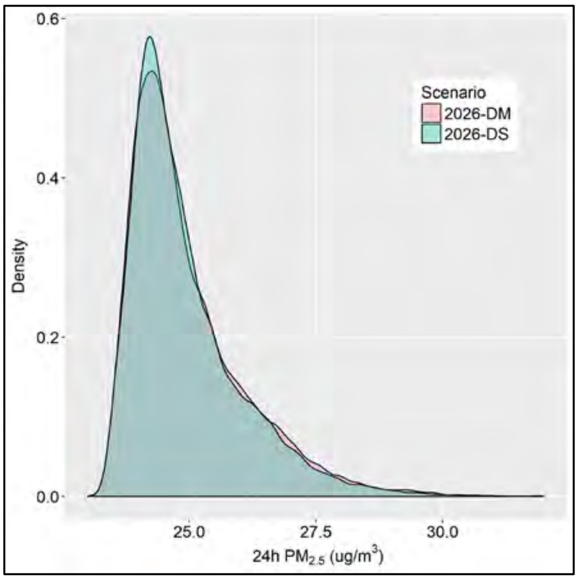

Figure 9-50 Density plot for maximum 24-hour $PM_{2.5}$ in 2026 with the project (2026-DM and 2026-DS)

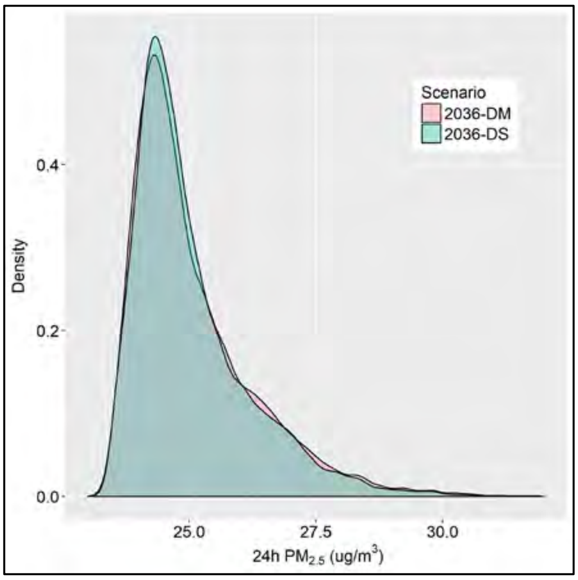

Figure 9-51 Density plot for maximum 24-hour $PM_{2.5}$ in 2036 with the project (2036-DM and 2036-DS)

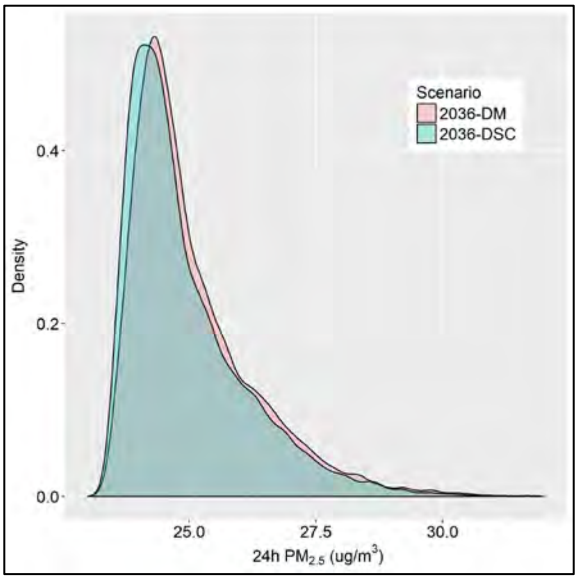

Figure 9-52 Density plot for maximum 24-hour $PM_{2.5}$ in the 2036 cumulative case (2036-DM and 2036-DSC)

9.6.8 Regional air quality

The changes in the total emissions resulting from the project were given in **Table 9-34**. These changes can be viewed as a proxy for the project's regional air quality impacts which, on the basis of the results, are likely to be negligible. For example:

- The changes in NO_X emissions for the assessed road network in a given year ranged from a decrease of 39 tonnes per year to an increase of 27 tonnes per year. The largest increase equated to a very small proportion (around 0.05 per cent) of anthropogenic NO_X emissions in the Sydney airshed in 2016 (around 53,700 tonnes)
- The increase in NO_X in a given year was much smaller than the projected reduction in emissions between 2015 and 2036 (around 690 tonnes per year).

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

The results in **Table 9-34** show that the largest increase in NO_X emissions (27 tonnes per year in the 2036-DSC scenario) was well below the 90 tonnes/year threshold for assessment. Indeed, this was the only scenario with an increase in overall NO_X emissions. THC emissions decreased in all scenarios.

Table 9-34 Absolute changes in total traffic emissions in the GRAL domain

Scenario comparison	Change in total emissions (tonnes/year)				
	CO	NO_x	PM_{10}	$PM_{2.5}$	THC
Underlying changes in emissions with time[(a)]					
2026-DM vs 2016-BY	-1,369	-610	1.7	-5.2	-174
2036-DM vs 2016-BY	-1,838	-689	5.8	-4.2	-221
Changes due to the project in a given year					
2026-DS vs 2026-DM	-42	-39	-2.8	-1.8	-3.4
2036-DS vs 2036-DM	31	12	1.3	0.8	-0.4
2036-DSC vs 2036-DM	56	27	2.8	1.8	-2.8

The 2026-DM and 2036-DM scenarios include the WestConnex and Sydney Gateway projects. The 2016-BY scenario does not.

The changes in total traffic emissions for the project scenarios are shown in **Figure 9-53**.

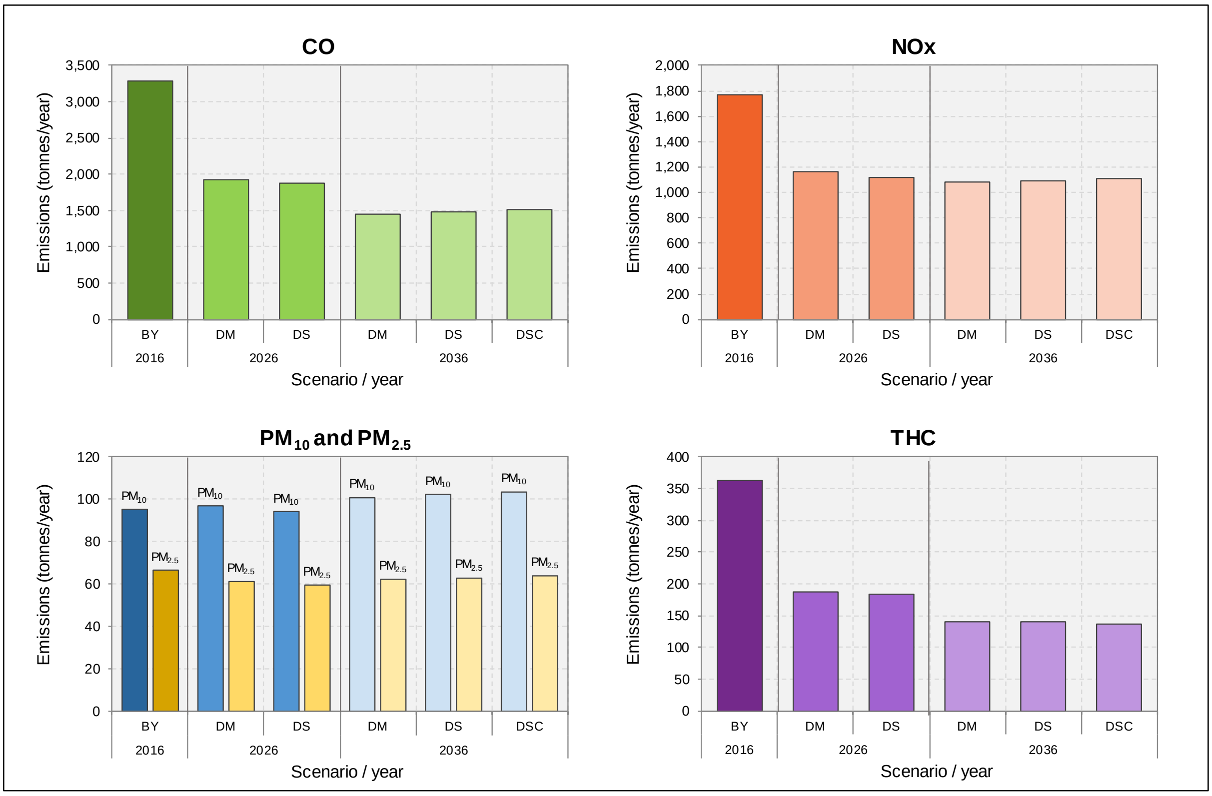

Figure 9-53 Total traffic emissions in the GRAL domain

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

9.6.9 Odour

The changes in the levels of three odorous pollutants as a result of the project, and the corresponding odour assessment criteria from the Approved Methods, are given in **Table 9-35**. It can be seen that the change in the maximum 1-hour concentration of each pollutant was an order of magnitude below the corresponding odour assessment criterion in the Approved Methods.

Table 9-35 Comparison of changes in odorous pollutant concentrations with criteria in Approved Methods (RWR receptors)

Scenario	Largest increase in maximum 1 hour THC concentration relative to Do Minimum scenario (μg/m³)	Largest increase in maximum 1 hour concentration for specific compounds		
		Toluene (μg/m³)	Xylenes (μg/m³)	Acetaldehyde (μg/m³)
2026-DS	65.0	4.7	3.9	1.0
2036-DS	45.6	2.8	2.3	0.9
2036-DSC	41.9	2.5	2.1	0.8
Odour criterion (μg/m³)		360	190	42

9.6.10 Cumulative impacts

For the cumulative scenario (2036-DSC) there were changes associated with the introduction of the later stages F6 Extension. These included reductions in $PM_{2.5}$ concentration along The Grand Parade to the south of President Avenue, Sandringham Street and Rocky Point Road. In addition, the increase in concentration on Princes Highway in the Do Something (the project) scenarios changed to a reduction in concentration in the Cumulative scenario.

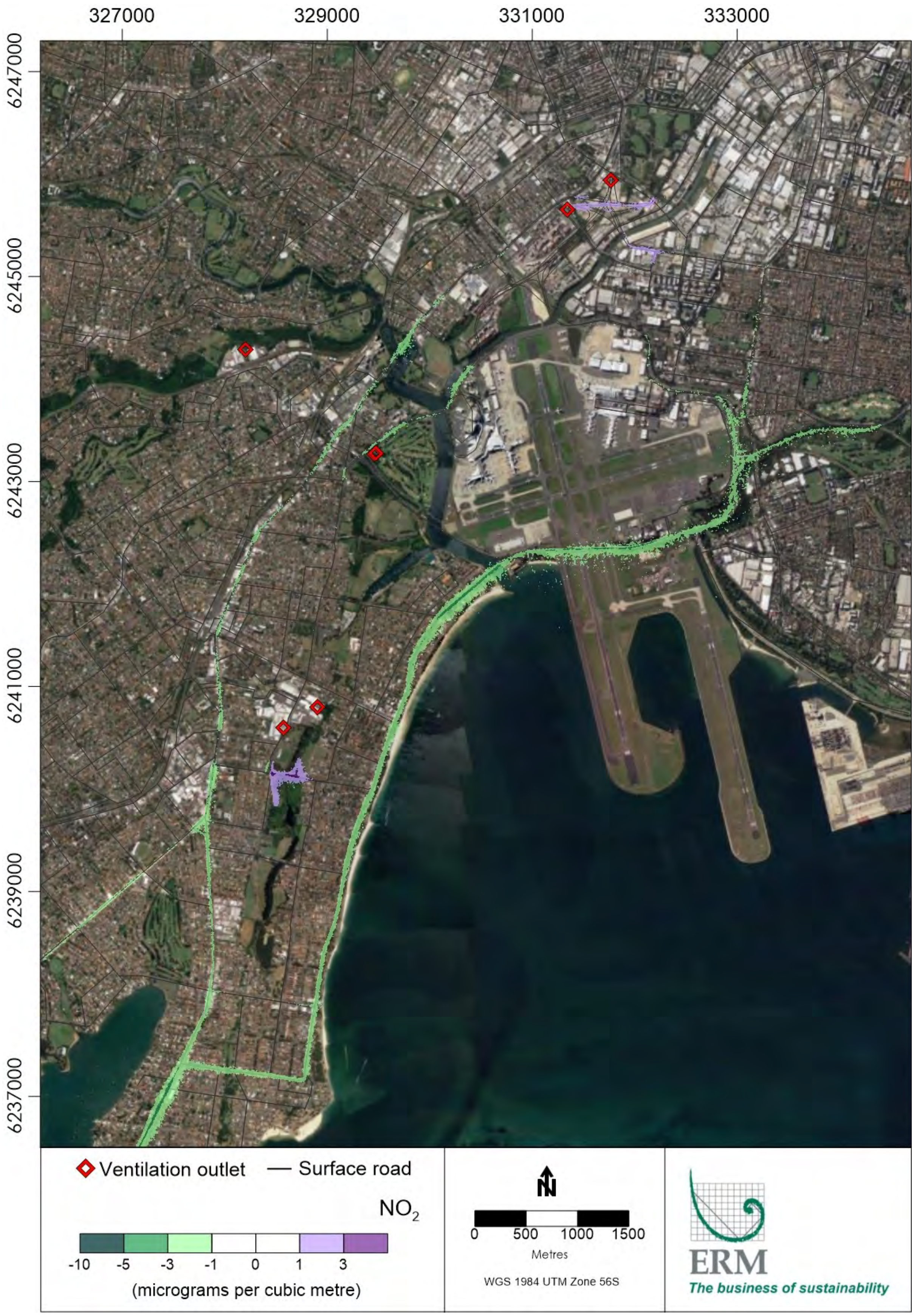

Figure 9-54 Contour plot of change in annual mean NO_2 concentration in the 2036 cumulative scenario (all sources, 2036-DSC minus 2036-DM)

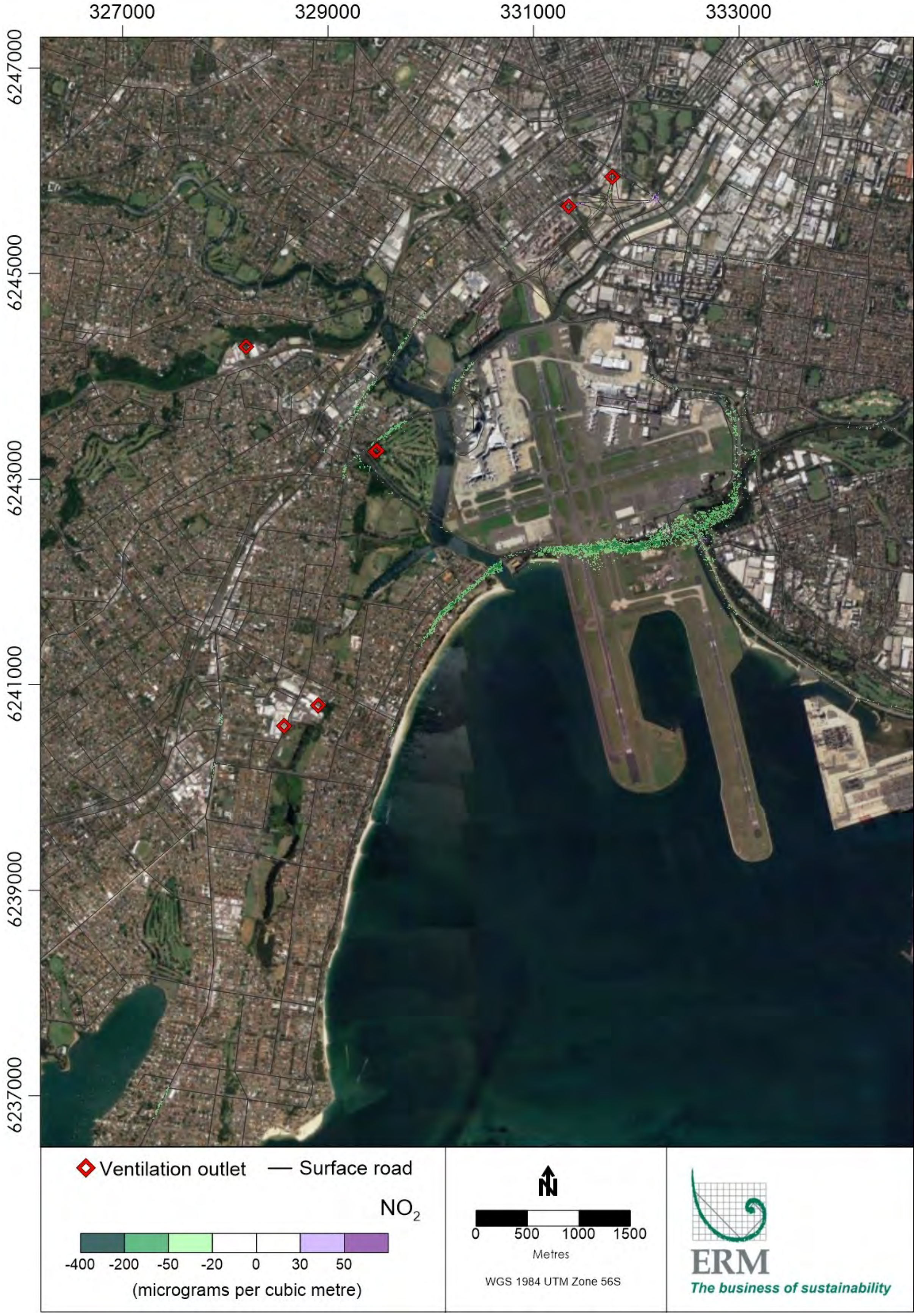

Figure 9-55 Contour plot of change in maximum one-hour mean NO_2 concentration in the 2036 cumulative scenario (all sources, 2036-DSC minus 2036-DM)

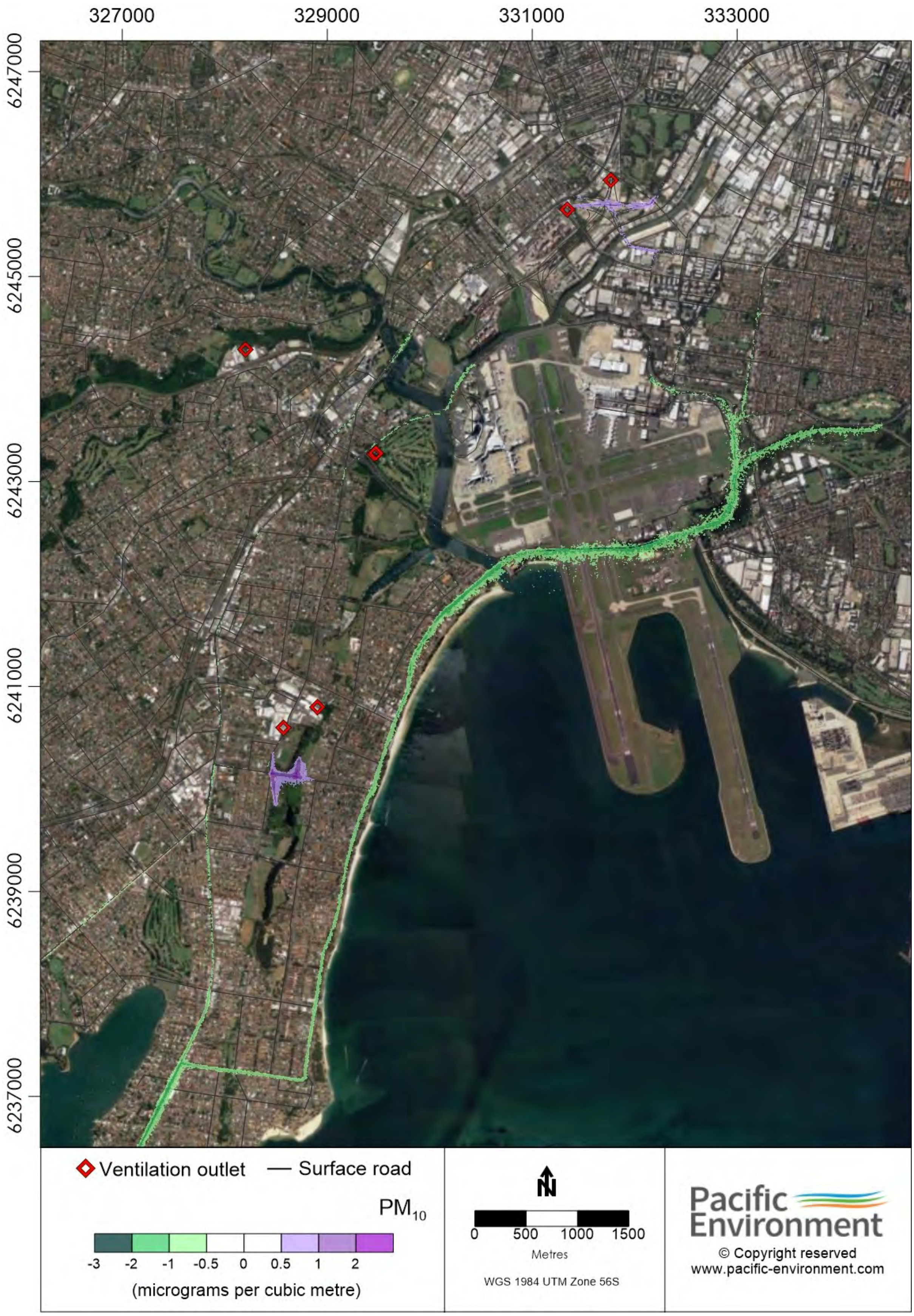

Figure 9-56 Contour plot of change in annual mean PM_{10} concentration in the 2036 cumulative scenario (2036-DSC minus 2036-DM)

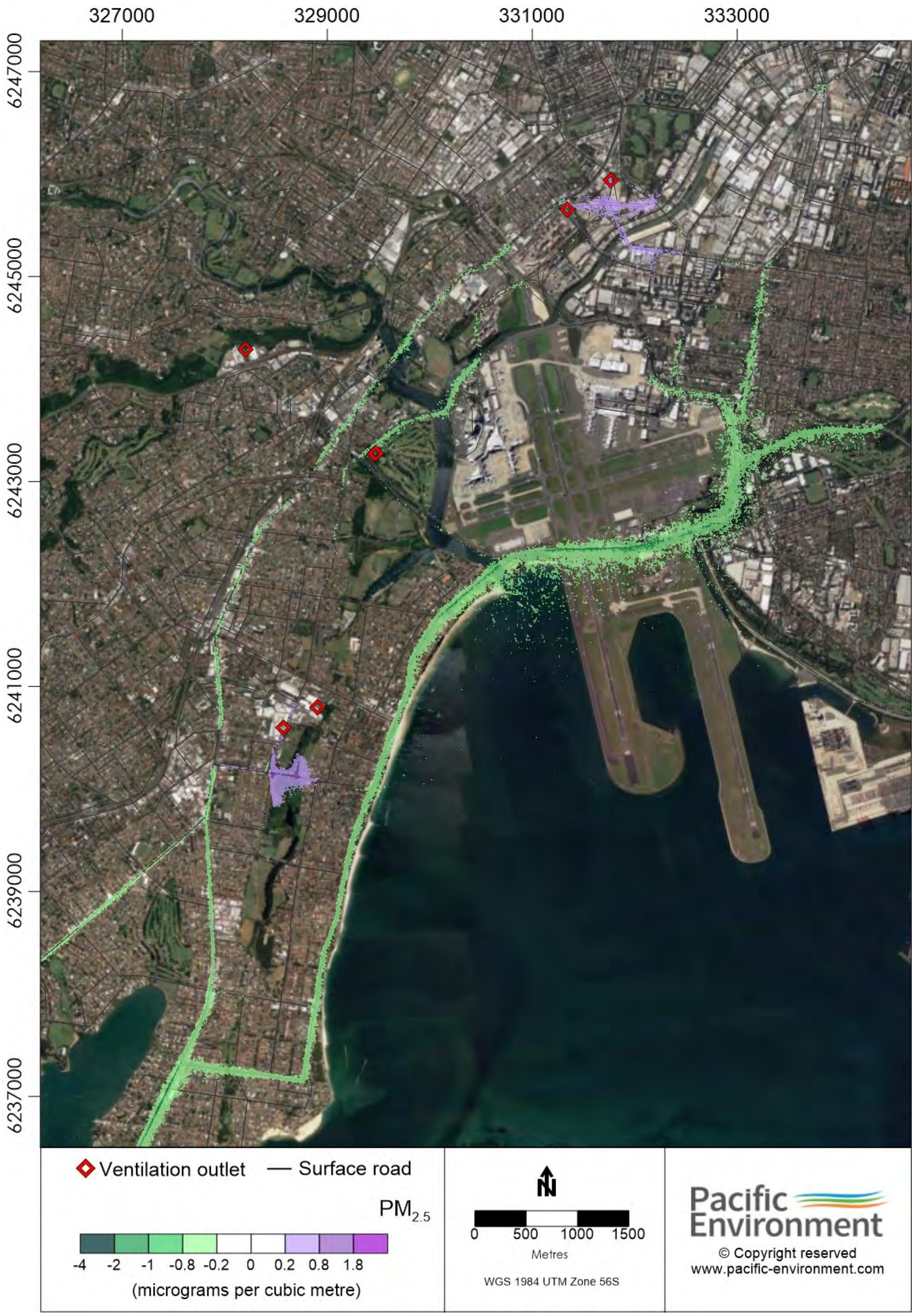

Figure 9-57 Contour plot of change in annual mean $PM_{2.5}$ concentration in 2036 cumulative scenario (all sources, 2036-DSC minus 2036-DM)

9.7 Management of impacts

Table 9-36 Environmental management measures –Air quality

Impact	Reference	Environmental management measures	Timing
Impacts from ambient air quality from dust generation and deposition during construction	AQ1	A Construction Air Quality Management Plan will be developed and implemented to monitor and manage potential air quality impacts associated with the construction of the project and activities at construction ancillary facilities. The management plan will identify project construction activities with the potential to have air quality impacts and the controls required to avoid, minimise and mitigate these impacts. The plan will include measures to: • Minimise project and cumulative dust generation from stockpiles, haulage routes, work activities, exposed ground surfaces and acoustic sheds • Minimise generator and vehicle emissions during construction of the tunnel • Inspect and address corrective actions • Modify or cease dust generating works during unfavourable weather conditions. The Plan will be implemented for the duration of construction.	Prior to construction
	AQ2	Demolition activities, including removal of hazardous building materials will be planned and carried out in a manner that minimises the potential for dust generation. Removal of hazardous building materials will be completed prior to the commencement of general demolition works.	Construction
Odour impacts	AQ3	Odorous material would be treated immediately on-site, and removed from site where necessary. Areas of odorous materials would be excavated in a staged process to allow for treatment and handling. Exposed areas of odorous material would be kept to a minimum to reduce the total emissions from the site. On-site odour measurements would be carried out during excavation works to determine odour emission rates. Results from the monitoring would be used to inform future excavation and treatment activities on site.	Construction
Impacts on air quality within project tunnels during operation	AQ4	Tunnel infrastructure will be designed in such a way that the generation of pollutant emissions by the traffic using the tunnel is minimised. In-tunnel air quality will be managed through monitoring and management of the ventilation systems and, where necessary, traffic management.	Detailed design
	AQ5	An in-tunnel air quality monitoring system will be included in the detailed design to monitor and assess ambient and in-tunnel air quality against relevant criteria. This will require sufficient, appropriately placed monitors to calculate a journey average.	Construction and operation

9.8 Environmental risk analysis

An environmental risk analysis was undertaken for air quality and is provided in **Table 9-37**.

A level of assessment was undertaken commensurate with the potential degree of impact the project may have on that issue. This included an assessment of whether the identified impacts could be avoided or minimised (for example, through design amendments). Where impacts could not be avoided, environmental management measures have been recommended to manage impacts to acceptable levels.

The residual risk is the risk of the environmental impact after the proposed mitigation measures have been implemented. The methodology used for the environmental risk analysis is outlined in **Appendix O** (Methodologies).

Table 9-37 Environmental risk analysis – Air quality

Summary of impact	Construction/ operation	Management and mitigation reference	Likelihood	Consequence	Residual risk
Fugitive dust emissions from construction activities including emissions from construction plant and equipment	Construction	AQ1, AQ2, AQ3	Likely	Minor	Low
Effects of poor in-tunnel air quality on human health	Operation	AQ4, AQ5	Unlikely	Minor	Low
Impacts on ambient air quality	Operation	-	Unlikely	Minor	Low
Potential increase in pollutant concentrations on some parts of the network, particularly within the vicinity of the new President Avenue intersection as a result of increase in traffic	Operation	-	Likely	Minor	Low

10 Health, safety and hazards

This chapter identifies potential hazards that could pose a risk to human health, the surrounding community or the human environment and outlines measures to avoid, mitigate or manage those risks. The construction and operation of the project has the potential to create a number of environmental hazards. This chapter is informed by **Appendix F** (Human health technical report) which provides greater detail of the human health risk assessment and results.

Table 10-1 sets out the SEARs relevant to health safety and hazards, and identifies where the requirements have been addressed in this EIS.

Table 10-1 SEARs - Health, safety and hazards

Assessment requirements	Where addressed
3. Health and Safety	
1. The Proponent must assess the potential health impacts from the construction and operation of the project. The assessment must:	
(a) describe the current known health status of the potentially affected population;	Section 10.2.
(b) describe how the design of the proposal minimises adverse health impacts and maximises health benefits;	Section 3.3 of Appendix F (Human health technical report).
(c) assess human health impacts from the operation and use of the tunnel under a range of conditions, including worst case operating conditions and the potential length of existing and committed future motorway tunnels in Sydney;	Section 10.4.1.
(d) human health risks and costs associated with the construction and operation of the proposal, including those associated with air quality, groundwater quality, odours, noise and vibration (including residual noise following application of mitigation measures), construction fatigue and social impacts (including from acquisitions) on the adjacent and surrounding areas, as well as opportunity costs (such as those from social infrastructure and active transport impacts) during the construction and operation of the proposal;	Section 10.3 and section 10.4. Chapter 9 (Air quality), Chapter 11 (Noise and vibration), Chapter 15 (Social and economic), and Chapter 17 (Geology and groundwater).
(e) include both incremental changes in exposure from existing background pollutant levels and the impacts of project specific pollutant levels at the location of the most exposed receivers and other sensitive receptors (including public open space areas, sportsgrounds, child care centres, schools, hospitals and aged care facilities);	Section 10.3.1 and section 10.4.2.
(f) assess the likely risks of the project to public safety, paying particular attention to pedestrian safety, subsidence risks, flood risks and the handling and use of dangerous goods;	Section 10.3.4 and 10.4.5 Chapters 8, 13, 14
(g) assess the opportunities for health improvement;	Section 10.3 and section 10.4 and Appendix F (Human health technical report).
(h) assess the distribution of the health risks and benefits;	Section 10.4.6
(i) include a cumulative human health impact assessment inclusive of in-tunnel users, local and regional impacts due to the operation of and potential continuous travel through existing and committed future motorway tunnels and surface road	Section 10.4.1 and section 10.4.2
17. Hazards	
The Proponent must describe the process for assessing the risk of emissions from ventilation facilities on aircraft operations taking into consideration the requirements of the *Airports Act 1996* (Commonwealth) and the Airport Regulations 1997.	Section 10.4.5.

10.1 Assessment approach

10.1.1 Human health risk assessment

The assessment approach for the human health risk assessment is detailed in **Appendix F** (Human health technical report). The assessment is informed by the air quality impact assessment and noise and vibration assessment undertaken for the project. The assessment approach for these assessments is outlined in **Chapter 9** (Air quality) and **Chapter 11** (Noise and vibration).

The assessment approach is in accordance with national and international guidance that is endorsed or accepted by Australian health and environmental authorities, and includes, but is not limited to:

- Air Quality in and Around Traffic Tunnels (National Health and Medical Research Council (NHMRC) 2008)
- *Environmental Health Risk Assessment: Guidelines for Assessing Human Health Risks from Environmental Hazards: 2012* (enHealth 2012b)
- *Health Impact Assessment Guidelines* (enHealth 2001)
- *Health Impact Assessment: A Practical Guide* (NSW Health 2007)
- *Australian Exposure Factors Guide* (enHealth 2012a)
- *Schedule B8 Guideline on Community Engagement and Risk Communication (National Environment Protection Council Schedule (NEPC) 1999* amended 2013a)
- *National Environmental Protection (Air Toxics) Measure, Impact Statement for the National Environment Protection (Air Toxics) Measure* (NEPC 2003)
- *Risk Assessment Guidance for Superfund: Volume I Human Health Evaluation Manual (Part F, Supplemental Guidance for Inhalation Risk Assessment) (United States Environmental Protection Agency* (USEPA) 2009b)

In addition, the following have been considered:

- *Methodology for Valuing the Health Impacts of Changes in Particle Emissions* (NSW EPA 2013)
- NSW Health, Building Better Health, Health considerations for urban development and renewal in the Sydney Local health District (LHD) (NSW Health, 2016)
- Air Quality in and Around Traffic Tunnels (National Health and Medical Research Council (NHMRC), 2008)
- NSW Health, Healthy Urban Development Checklist, A guide for health services when commenting on development policies, plans and proposals, 2009
- *State Environmental Planning Policy No. 33* (SEPP 33) – Hazardous and Offensive Development (NSW).

This chapter considers the following issues in relation to the assessment of human health impacts:

- Existing conditions (in relation to air quality and noise) (refer to **section 10.2.4**)
- Human health risks and costs associated with the project, including those associated with air quality, noise and vibration, groundwater, contamination, and social impacts, during the construction and operation of the project and estimation of short-term (acute) and long-term (chronic) impacts during construction and operation of the project
- Human health impacts on users of the tunnels and external receptors of air and noise emissions from the operation of the tunnels under a range of conditions, including a worst case operating condition
- Consideration of cumulative impacts resulting from the project and other related projects comprising the New M5 and M4M5 Link projects.

The detailed principles, methodology and limitations of the toxicity and risk assessment, as well as how the design of the project minimises adverse health impacts are provided in **Appendix F** (Human health technical report).

During community consultation undertaken prior to the EIS, some members of the community raised concern over the effect of air quality impacts on individuals with respiratory diseases such as asthma.

The potential for the project to result in respiratory effects for individuals is discussed in **section 10.4.1** and **section 10.4.2** of this chapter.

Study area

The study area, illustrated in **Figure 10-1**, identifies the area over which impacts to air quality has been considered (referred to as GRAL domain, as discussed in **Chapter 9** (Air quality)).

The operational modelling considered meteorology relevant to a larger area (red box, or GRAMM (Graz Mesoscale Model) domain, on **Figure 10-1**) that includes the study area, local terrain, and project-specific emission sources.

A smaller area, within this larger area, has been considered for the assessment of noise, soil and vibration impacts.

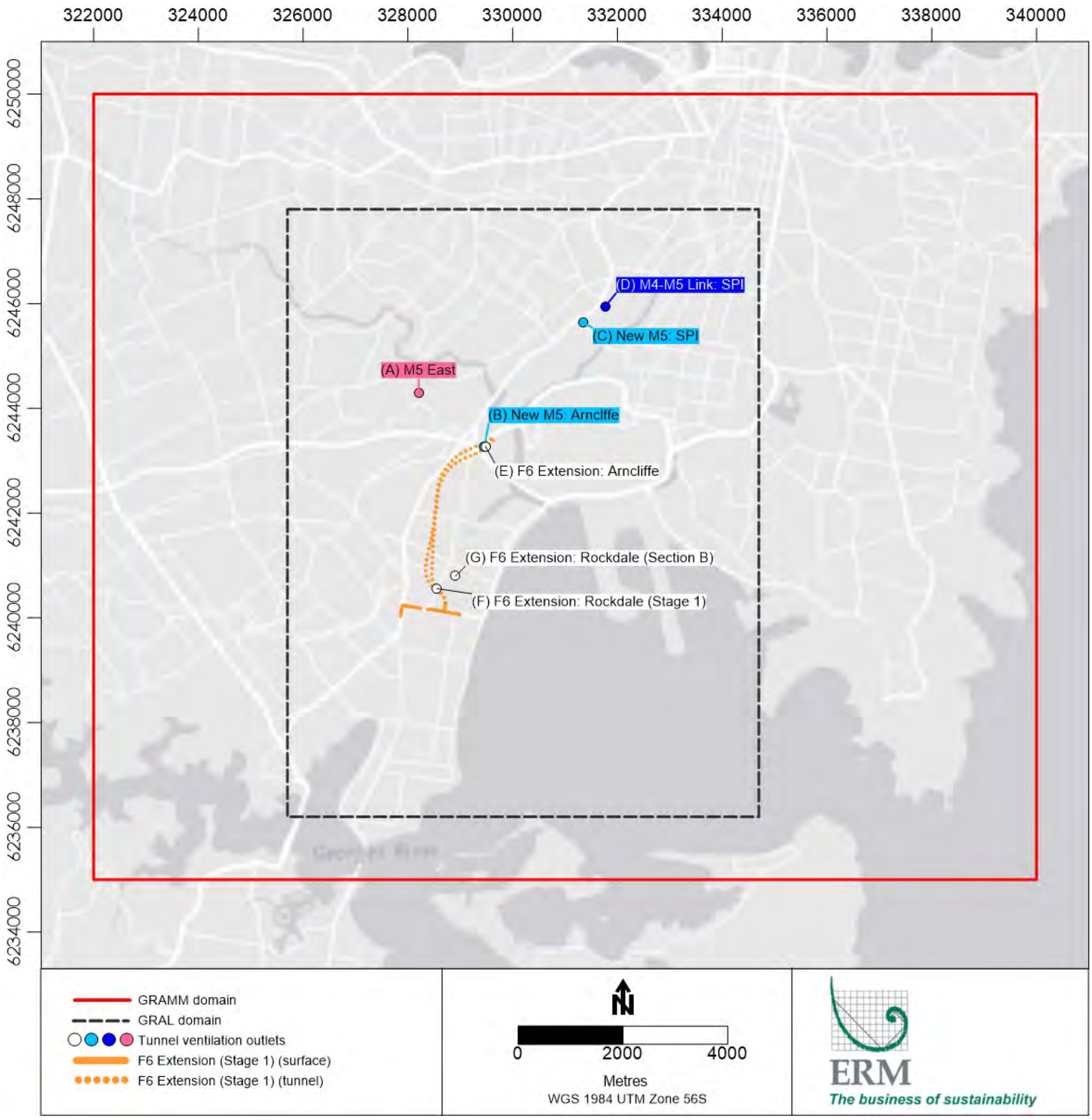

Figure 10-1 Air quality health impact assessment study area (ERM, 2018)

10.1.2 Assessment of other hazards and risks

A qualitative assessment of potential hazards and risks was undertaken for the project. The assessment identified potential hazards and risks based on those experienced on other recent NSW tunnelling projects.

10.2 Existing environment

Relevant information on the existing health aspects of the population has been obtained from the Australian Bureau of Statistics (ABS) Census 2011, information relevant to local government areas (LGAs) and health districts (in particular South Eastern Sydney and Sydney LHDs (LHD)). In some cases, where local data was lacking, information has been obtained (or compared with) data from larger populations areas of Sydney and/or NSW.

The population considered includes those who live or work within the vicinity of the construction ancillary facilities, surface works and intersection upgrades, ventilation facilities and the surrounding road network.

The study area covers several suburbs across the Bayside, City of Sydney, Inner West, Canterbury – Bankstown and Georges River LGAs.

10.2.1 Sensitive receptors

Sensitive 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 include medical facilities, child care facilities, educational facilities and aged care homes/facilities.

Table 10-2 presents a list of the key community receptors included in the air quality assessment, for which a more detailed quantitative assessment of health impacts has been undertaken, compared to the remainder of the 17,509 receptor locations assessed for air quality (refer to **Chapter 9** (Air quality)). It is noted that these 30 locations are representative only and are not intended to comprise an exhaustive list of community receptors in the study area. The location of the 30 selected sensitive or community receptors is shown in **Figure 10-2**.

In addition to these community receptors, 17,509 individual receptors (residential, workplace and recreational (RWR) receptors also shown in **Figure 10-2**) have been modelled in the suburbs located in the study area. These individual RWR receptor locations represent a range of land uses including residential, commercial or recreational (open space) areas in the surrounding community, as detailed in **Table 10-3**. The RWR include all other community receptors located in the study area, not just those included in **Table 10-2**.

Table 10-2 Community receptors included in health risk assessment

	Receptor name	Type of receptor	Suburb	LGA
CR1	St Finbar's Primary School	Primary School	Sans Souci	Georges River
CR2	St George Christian School Infants	Primary School	Sans Souci	Georges River
CR3	Ramsgate Public School	Primary School	Ramsgate Beach	Bayside
CR4	Estia Health	Community Home	Kogarah	Bayside
CR5	Wesley Hospital Kogarah	General Hospital	Kogarah	Georges River
CR6	St George School	Special School	Kogarah	Bayside
CR7	St George Hospital	General Hospital	Kogarah	Georges River
CR8	Brighton-Le-Sands Public School	Primary School	Brighton Le-Sands	Bayside
CR9	Kogarah Public School	Primary School	Kogarah	Georges River
CR10	St George Girls High School	High School	Kogarah	Georges River
CR11	St Thomas More's Catholic School	Primary School	Brighton Le-Sands	Bayside
CR12	Jenny-Lyn Nursing Home	Community Home	Brighton Le-Sands	Bayside
CR13	Huntingdon Gardens Aged Care Facility	Community Home	Bexley	Bayside
CR14	Rockdale Public School	Primary School	Rockdale	Bayside
CR15	Scalabrini Village Nursing Home-Bexley	Community Home	Bexley	Bayside
CR16	Rockdale Nursing Home	Community Home	Rockdale	Bayside
CR17	Arncliffe Public School	Primary School	Arncliffe	Bayside

	Receptor name	Type of receptor	Suburb	LGA
CR18	Athelstane Public School	Primary School	Arncliffe	Bayside
CR19	Al Zahra College	Combined Primary-Secondary School	Arncliffe	Bayside
CR20	Cairnsfoot School	Special School	Brighton Le-Sands	Bayside
CR21	Undercliffe Public School	Primary School	Earlwood	Canterbury-Bankstown
CR22	Ferncourt Public School	Primary School	Marrickville	Inner West
CR23	Tempe High School	High School	Tempe	Inner West
CR24	St Peters Public School	Primary School	St Peters	Inner West
CR25	St Pius' Catholic Primary School	Primary School	Enmore	Inner West
CR26	Frobel Alexandria Early Learning Centre	Child Care Centre	Alexandria	Sydney
CR27	Little Learning School - Alexandria	Child Care Centre	Alexandria	Sydney
CR28	Active Kids Mascot	Child Care Centre	Mascot	Bayside
CR29	Mascot Public School	Primary School	Mascot	Bayside
CR30	Hippos Friends	Child Care Centre	Botany	Bayside

Table 10-3 Summary of RWR receptor types

Receptor type	Number	% of total
Aged care	32	0.18%
Child care / pre-school	21	0.12%
Commercial	1,359	7.77%
Community	3	0.02%
Further education	4	0.02%
Hospital	7	0.04%
Industrial	355	2.03%
Mixed use	617	3.52%
Other	445	2.54%
Park / sport / recreation	174	0.99%
Residential	14,408	82.28%
School	84	0.48%
Total	17,509	100.00%[1]

1 Total of receptor types does not add up to exactly 100 per cent due to rounding.

Figure 10-2 Community receptors and RWR receptors evaluated in health impact assessment

10.2.2 Demographic profile

The population within the study area consists of residents and workers as well as those attending educational and child care facilities, medical facilities and recreational areas. The composition of the populations located within the study area is expected to be generally consistent with statistics for the larger individual suburbs that are wholly or partially included in the study area.

Population statistics for the LGAs are available from the ABS for the Census year 2016 and are summarised in **Table 10-4**. For the purpose of comparison, the population statistics presented also include the statistics for larger statistical population groups in the area (defined by the ABS SA4) and the larger statistical areas of Greater Sydney and the rest of the NSW (excluding Greater Sydney) (as defined by the ABS).

Table 10-4 Summary of demographic statistics in the study area

Location	Total population		% Population of key age groups					
	Male	Female	0 4	5 19	20 64	65+	1–14[1]	30+[1]
Local government areas								
Botany[2]	23,229	23,420	6.2	16.5	64.3	13.0	15.7	59.8
Rockdale[2]	54,079	55,325	6.1	14.8	63.8	15.3	14.6	61.5
Sydney	107,852	100,530	3.3	7.4	81.0	8.2	5.9	57.6
Inner West	88,736	93,302	5.9	13.2	68.7	12.2	14.1	63.8
Canterbury – Bankstown	172,327	173,977	7.2	19.6	59.2	13.9	19.2	58.4
Georges River	71,755	75,086	5.8	17.0	61.8	15.3	15.7	60.8
Larger local statistical areas (SA4 – includes local government areas)								
Sydney – City and Inner South	161,061	154,483	4.1	9.6	76.9	9.4	8.6	58.9
Sydney – Inner West	142,436	150,867	5.9	14.5	66.1	13.5	14.6	61.9
Sydney – Inner South West	282,753	288,670	6.7	18.1	60.7	14.6	17.5	59.6
Statistical areas of Sydney and NSW								
Greater Sydney	2,376,766	2,447,221	6.4	18.2	61.4	13.9	17.4	60.4
Rest of NSW (excluding Greater Sydney)	1,301,717	1,341,813	5.8	18.5	55.1	20.6	17.3	64.6

Ref: Australian Bureau of Statistics, Census Data 2016
SA = statistical area
[1] Age groups specifically relevant to the characterisation of risk
[2] (Now amalgamated and known as Bayside Council)

When comparing the statistics of the study area to that of Greater Sydney:

- Sydney – City and Inner South have a lower proportion of children (0-19 years), a higher proportion of working aged individuals and a lower proportion of individuals aged over 65 years
- Sydney – Inner West have a slightly lower proportion of children and slightly higher proportion of working age individuals
- At a local government area level:
  - Sydney has a lower proportion of young children (0-4 years)
  - Botany, Rockdale, Sydney, Inner West, and Georges River have a lower proportion, while Canterbury-Bankstown have a higher proportion of children (5-19 years)
  - Canterbury-Bankstown have a lower proportion while Botany, Rockdale, Sydney and Inner West, have a higher proportion of working age individuals
  - Sydney and Inner West have a lower proportion while Rockdale and Georges River have a higher proportion of individuals aged over 65 years.

The estimated population growth from 2011 to 2036 for the relevant LGAs are (NSW Planning & Environment 2016) are shown in **Figure 10-3**.

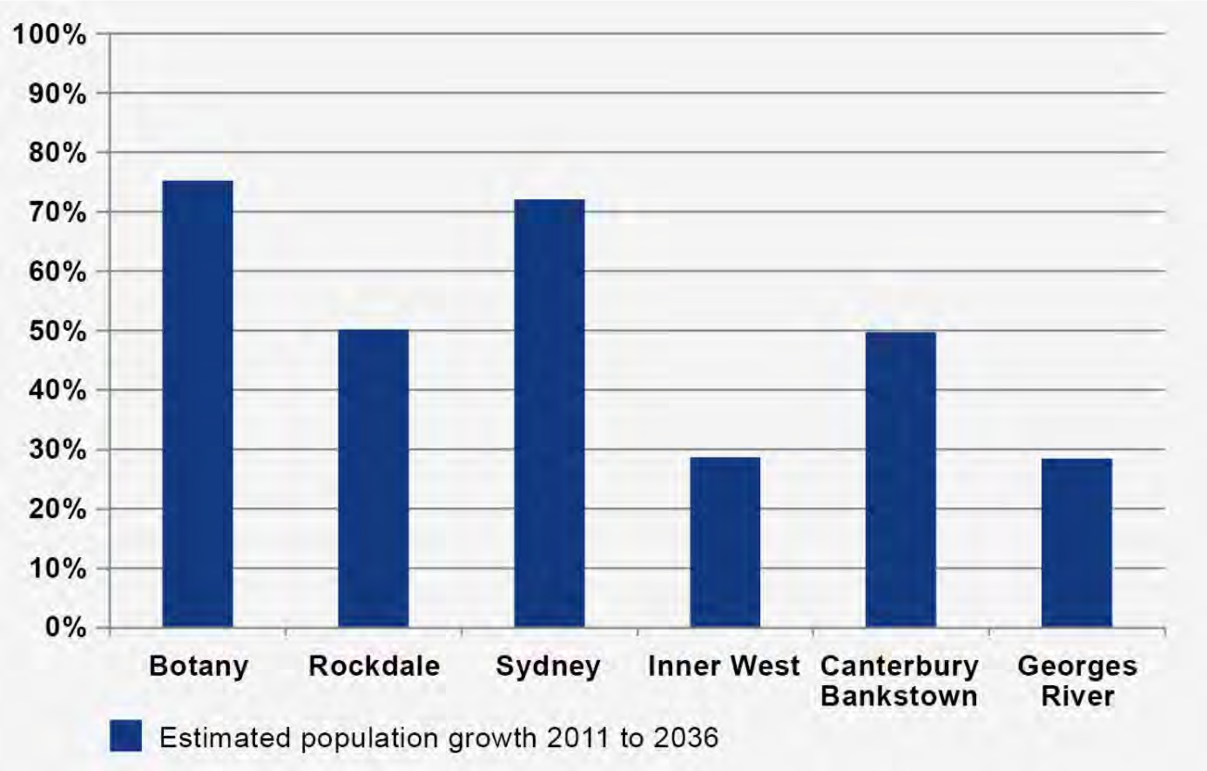

Figure 10-3 Estimated population growth from 2011 to 2036

Table 10-5 presents a summary of a selected range of demographic measures (including income) relevant to the population of interest with comparison to statistical areas of Greater Sydney and the rest of NSW (excluding Greater Sydney).

Table 10-5 Selected income 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 government areas						
Botany #	35	1,626	2,400	460	2.7	5.6
Rockdale #	35	1,575	2,167	460	2.7	6.2
Sydney	32	1,926	2,499	565	2.0	6.0
Inner West	36	2,048	2,600	480	2.4	4.8
Canterbury – Bankstown	35	1,298	2,000	380	3.0	8.2
Georges River	37	1,654	2,167	450	2.9	6.5
Larger local statistical areas (SA4 – includes local government areas)						
Sydney - City and Inner South	33	1,894	2,500	550	2.2	5.7
Sydney – Inner West	36	1,964	2,500	500	2.6	5.5
Sydney – Inner South West	35	1,431	2,167	415	2.9	7.4
Statistical areas of Sydney and NSW						
Greater Sydney	36	1,750	2,167	440	2.8	6.0
Rest of NSW (excluding Greater Sydney)	43	1,168	1,590	270	2.4	6.6

The social and income demographics of an area have some influence on the health of the existing population. As shown in **Table 10-5**, when comparing the populations of the study area to that of Greater Sydney:

- Botany, Rockdale, Canterbury-Bankstown and Georges River have a lower median income, while Sydney, and Inner West have a higher median income
- Botany, Sydney and Inner West have higher, while Canterbury-Bankstown has lower monthly mortgage repayments
- Sydney has higher and Canterbury-Bankstown has lower median weekly rental costs
- Sydney and Inner West have a smaller average household size
- Canterbury-Bankstown has higher and Inner West has lower unemployment rates.

10.2.3 Existing health of population

General

Full details of the existing health of the population and the assessment undertaken is provided in **Appendix F** (Human health technical report).

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, it is not possible or appropriate to be able to identify a causal source, particularly individual or localised sources.

The project is located across the South Eastern Sydney LHD and Sydney LHD. Not all of the health data is available for all of these areas.

The assessment presented in the human health impact assessment (refer to **Appendix F** (Human health technical report) has focused on key pollutants that are associated with construction and combustion sources (e.g. 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 works. Other aspects that affect the health of an individual include personal exposures (such as smoking) and risk taking behaviours.

Health related behaviours

Information in relation to health related behaviours that are linked to poorer health status and chronic disease, such as cardiovascular and respiratory diseases, cancer, is available for the larger populations within the LHDs in Sydney and NSW. These behaviours include risky alcohol drinking, smoking, consumption of fruit and vegetables, being overweight or obese, and adequate physical activity. The incidence of these health-related behaviours in the South Eastern and Sydney LHDs, compared with other districts in NSW, and the state of NSW (based on NSW Health data from 2015 and 2016) is provided in **Appendix F** (Human health technical report).

Review of this data indicates the population in the South Eastern Sydney and Sydney LHDs (that include the study area) have lower rates of physical inactivity and of being overweight and obese compared with NSW.

Health indicators

Appendix F (Human health technical report) provides the rates of the key mortality indicators (such as cardiovascular disease, lung cancer and chronic obstructive pulmonary disease (COPD), hospitalisations and mental health indicators for the study area compared to Greater Sydney and NSW as a whole.

The data indicates that the rate of mortality indicators in the South Eastern Sydney and Sydney LHDs are significantly lower than the NSW average, except for lung cancer for the Sydney LHD which was around the same as the NSW average.

The rate of hospitalisations for the key mortality indicators in the South Eastern Sydney and Sydney LHDs is significantly lower than NSW as whole, with the exception of cardiovascular disease hospitalisations in South Eastern Sydney, which is similar to the rate for 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 LHD (13.9 per cent) is a little higher, and South Eastern Sydney LHDs (9.3 per cent) a little lower than the state average (11.8 per cent), however none were significantly different
- The rate of high or very high psychological distress in Sydney LHD has varied between 10 and 15 per cent between 2003 and 2015 while in the South Eastern Sydney LHD, the rate has declined from around 14 per cent in 2003 to less than 10 per cent in 2015.

Details on specific health indicators relevant to the quantification of exposure to nitrogen dioxide and particulate matter for the study area are provided in **Appendix F** (Human health technical report). This includes data on mortality and hospitalisations due to respiratory diseases such as asthma. A review of this data generally indicates that for the population in study 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 LHDs of South Eastern Sydney, Sydney and the wider Sydney metropolitan area and slightly lower than the whole of NSW.

10.2.4 Existing air quality environment

Full details of the existing air quality environment and assessment undertaken is provided in **Appendix E** (Air quality technical report).

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. A summary of the assessment of background air quality is presented in **Chapter 9** (Air quality) and detailed in **Appendix E** (Air quality technical report).

The following is noted for the human health assessment in relation to background air quality:

- Carbon monoxide: background air concentrations (as one hour and eight hour averages) were below the current air quality guidelines both at any of the background air monitoring stations. 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 stations and at roadside monitoring locations. The concentration of nitrogen dioxide has been observed to be generally stable to trending downward over time.
- Ozone: background air concentrations (as one hour and four hour averages) exceeded the current air quality guidelines on a few occasions. The most number of times a station exceeded the guideline per year was eighteen, with many of the stations not exceeding more than 5 times per year. Annual ozone concentrations were stable between 2004 and 2016.
- 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
- $PM_{2.5}$: Long term measurement of annual $PM_{2.5}$ concentrations has only occurred at three OEH stations Chullora, Earlwood and Liverpool. Concentrations at these stations 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
- Air toxics: A number of measurement campaigns have been undertaken to determine the levels of air toxics around Sydney. All have found the concentrations remain low and under the respective Air Toxic NEPM investigation levels.

10.2.5 Existing noise environment

The study area for the noise assessment (refer to **Chapter 11** (Noise and vibration) includes a mixture of residential development, commercial and industrial properties, and major roads and railway lines.

Noise sensitive receptors

Throughout the study area, receptors which are potentially sensitive to noise and vibration include residential dwellings, schools, community centres, recreation areas, hospitals, libraries, commercial and industrial properties and places of worship.

A list of the noise sensitive receptors identified within the study area (excluding residential receptors) is provided in **Appendix G** (Noise and vibration technical report).

Existing noise levels

The results of the unattended ambient noise surveys undertaken in June 2015 (as part of the New M5 Motorway project) and November/December 2017 and February 2018 (specifically for this project) are provided in **Appendix G** (Noise and vibration technical report).

The background noise levels derived from monitoring indicate that the existing noise environment at the measurement locations is typical of major transport corridors in suburban/urban areas. In these locations daytime and evening background levels are generally high due to heavy and continuous traffic flows, with night time levels tending to decrease as a result of a reduction in these flows.

For the assessment of noise and vibration impacts, a range of guidelines and criteria have been adopted for the assessment.

The *Interim Construction Noise Guideline* (ICNG)[1] has been adopted for the assessment of noise during construction works. 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.

Intermittent vibration has been evaluated on the basis of the NSW EPA guideline *Assessing Vibration: A Technical Guideline*[2].

Operational noise impacts have been evaluated on the basis of the *NSW Road Noise Policy*[3], with additional guidance and criteria provided within Roads and Maritime's *Noise Criteria Guideline*[4] (NCG) and *Noise Mitigation Guideline* (NMG)[5].

[1] NSW DECC, 2009. *Interim Construction Noise Guideline.*
[2] NSW DEC, 2006. *Assessing Vibration: ATechnical Guideline.*
[3] NSW DECCW, 2011. *NSW Road Noise Policy.*
[4] NSW Roads and Maritime 2015. *Noise Criteria Guideline.*
[5] NSW Roads and Maritime 2015. *Noise Mitigation Guideline.*

10.3 Potential impacts – construction

During construction, the following hazards may be associated with the project:

- Potential hazards resulting from accidental releases or improper handling and storage of dangerous goods and hazardous substances within construction ancillary facilities
- Potential hazards resulting from release of hazardous substances from vehicles transporting them to and from the construction ancillary facilities in the event of an accident
- Potential safety hazards, such as dangers to construction workers, road users and the community, associated with the potential risk of tunnel collapse, tunnel fires or explosions, rock falls at cuttings and mobile plant (including plant overturning and plant collisions with workers or other plant)
- Potential hazards associated with encountering acid sulfate soils, asbestos and contaminated soils during construction activities
- Potential accidental spills or leaking of fuels, chemicals or other hazardous substances during construction activities, including during refuelling of construction vehicles and machinery
- Potential hazards associated with mobile construction plant
- Potential hazards relating to flooding
- Potential rupture of, or interference with, utilities
- Potential hazards relating to bushfires.

The following risks have been assessed for the construction of the project:

- Human health risks
- Social impacts (including from acquisitions) (discussed in **Chapter 15** (Social and economic)
- Pedestrian safety risks (discussed in **Chapter 8** (Traffic and transport))
- Subsidence (ground settlement) risks (discussed in **Chapter 14** (Property and land use) and **Chapter 17** (Geology and groundwater))
- Bushfire risks
- Risks associated with the storage and handling of dangerous goods
- Potential risk of encountering acid sulfate soils, asbestos and contaminated soils during construction activities (discussed in **Chapter 16** (Surface water) and **Chapter 17** (Soils and contamination))
- Potential risks associated with the impact of project construction and operational activities on air quality (refer to **Chapter 9** (Air quality))
- Potential risks associated with climate change impacts, including changes in the frequency of air temperature extremes, changes in mean and extreme rainfall, and changes in the frequency and intensity of storm events (discussed in **Chapter 25** (Climate change risk and adaption)).

10.3.1 Air quality impacts on community health

Appendix E (Air quality technical report) 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 semi quantitative assessment approach. The assessment was split into two different construction ‘zones’ (refer to **Figure 10-4**).

The assessment identified the range of activities during construction, potential emissions from these activities and the location of these activities in relation to sensitive receptors. **Figure 10-4** shows the location of the sensitive receptors considered in the air quality impact assessment during construction works. The figure also shows the location of the zones considered in each of the construction sites.

Figure 10-4 Location of sensitive human receptors in proximity to construction works

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 E** (Air quality technical report). In relation to health impacts, the following levels of risk were identified for the two zones:

- Zone 1: Low risk for construction, medium risk for earthworks and track-out with no applicable risk for demolition
- Zone 2: High risk for all activities.

On this basis, appropriate mitigation measures would be required to minimise impacts on the local community during construction. Experience from similar construction projects shows that significant impacts to community receptors can be avoided through the use of effective mitigation.

Hence, where mitigation measures are appropriately implemented, **Appendix E** (Air quality technical report) concluded that the residual risk level would normally be 'not significant'.

However, even with a rigorous Dust Management Plan in place, 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'.

Appendix E (Air quality technical report) did not identify the construction of the powerline as a significant source of dust that required impact assessment.

A Construction Air Quality Management Plan will be produced to cover all construction stages of the project. These measures include site management, monitoring, preparing and maintaining the construction sites, maintenance and controls on vehicles and machinery and construction. **Chapter 9** (Air quality) provides the dust management measures proposed for the project.

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 10.3.6**

Odour impacts

The potential source of odour for the project is the release of hydrogen sulphide gas when excavation activities for the construction of the cut and cover structures disturb a historical landfill site, which may contain contaminated acid sulfate soils. These soils have the potential to be exposed to air. This has the potential to release odorous hydrogen sulphide gas (H_2S) into the atmosphere impacting nearby receptors.

Chapter 9 (Air quality) outlines the NSW EPA criteria for community exposure to H_2S odour and the results of the assessment undertaken for odour impacts during construction activities.

The results indicate that the predicted 99th percentile H_2S concentration at the nearest receptors are well below the criterion and likely to be below the level of detection. Therefore this assessment did not find that there would be significant odour impacts. However on-site odour measurements would be carried out during excavation works to determine odour emission rates (refer to environmental management measure AQ3 in **Chapter 9** (Air quality)). Results from the monitoring would be used to inform future excavation and treatment activities on site. Odorous material would be treated immediately on-site, and removed from site where necessary. Areas of odorous materials would be excavated in a staged process to allow for treatment and handling. Exposed areas of odorous material would be kept to a minimum to reduce the total emissions from the site.

10.3.2 Noise and vibration impacts on community health

Air-borne construction noise

A detailed assessment of noise and vibration impacts associated with the project is presented in **Appendix G** (Noise and vibration technical report). **Appendix G** (Noise and vibration technical report) 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 during construction and operations involved consideration of impacts at 17 noise catchment areas (NCAs) presented in **Appendix G** (Noise and vibration technical report). An NCA is defined by what is considered a similar noise environment. Thus receptors belonging to the same NCA are assigned the same background noise level and noise management level.

Potential noise impacts of the project have been assessed against Australian or NSW criteria, including the ICNG and the Road Noise Policy.

The criteria of these guidelines have been established on the basis of noise annoyance or specific health effects such as sleep disturbance, which are considered to be the effects that precede physiological effects. As a result, these guidelines are designed to be protective and indicative of adverse health effects and have been used to assess construction and operational noise impact associated with the project.

Where the guidelines cannot be met then there is the potential for the above adverse health effects to occur for the receptors in the vicinity of the project, such as sleep disturbance and annoyance.

A number of receptors have been identified as highly affected from standard and out of hours construction noise, especially around C2, C3, the cut-and-cover works at West Botany Street, the President Avenue surface works and the C6 construction ancillary facility for the Princes Highway and President Avenue intersection upgrade. Construction noise is also predicted to cause sleep disturbances for several receptors during out of hours works. Construction road traffic noise was estimated to be generally compliant with the relevant guidelines except for some roads around C2 (especially Wickham Street) during night time periods where increased traffic noise was predicted to be up to 7.3 dB(A) above the existing level of road traffic noise. Night-time haulage would be avoided during night time off-peak traffic periods to minimise noise impacts where feasible. Sensitive receptors are likely to be highly affected by construction of the permanent power supply when the works are directly opposite the receptor location. As the works move further away from receptors, noise levels would reduce significantly. High noise impacts at any one receptor are unlikely to last for more than a few days for each sensitive receptor.

The detailed design for the mitigation measures will be outlined in the Construction Noise and Vibration Management Plan (CNVMP) as discussed in **Appendix G** (Noise and vibration technical report). The mitigation measures would including temporary noise walls or hoarding, respite periods, plant and equipment selection, an out of hours protocol and traffic management. The aim of the measures would be to reduce noise and vibration to levels that comply with the management goals established in this assessment.

Receptors identified as requiring at-property operational noise mitigation would be identified and offered treatment prior to commencement of construction works that would affect them.

The assessment has also addressed the impact of simultaneous construction noise resulting from the construction of a number of different infrastructure projects in the vicinity of the project. An identification of developments planned in the area along with current developments was undertaken. It was estimated that the cumulative construction noise impact may increase by as much as 3 dB(A). A discussion on the impacts of consecutive construction works was also undertaken and is further discussed in **section 10.3.6**.

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. When vibrations reach a building they enter the foundations, it can be transmitted into the walls and ceiling. The vibration of the walls and ceiling could result in the generation of low-frequency noise (or ‘rumble) which could be audible if the vibration levels are high enough.

Vibration would be generated during tunnelling works for the project from the operation of road headers. Blasting is not proposed as a core tunnelling activity but may be required. Tunnelling activities are expected to occur 24 hours per day. Associated surface activities would generally be carried out in acoustic sheds.

Tunnelling would typically progress around a maximum of seven metres per day. It is likely that ground-borne noise would be discernible for up to five days at each affected receptor with exceedances occurring for up to two days. Only one receptor is predicted to exceed the ground-borne noise criteria. This exceedance would be up to 1 dB(A) during the night-time period, which is considered to have negligible health impacts.

Vibration impacts

A range of construction equipment has the potential to result in vibration impacts. These potential impacts can be managed by ensuring suitable separation distances between the equipment and receptor locations.

The noise and vibration assessment did not identify any receptors that would exceed the vibration criteria for human comfort, and concluded that the structural damage criteria would not be exceeded by the tunnelling activities.

10.3.3 Dangerous goods and substances

Storage and handling

The storage, handling and use of dangerous goods and hazardous substances would be undertaken in accordance with:

- *Work Health and Safety Act 2011* (NSW) (WHS Act)
- Storage and Handling of Dangerous Goods Code of Practice (WorkCover NSW 2005)
- Environment Protection Manual for Authorised Officers: Bunding and Spill Management, technical bulletin (NSW Environment Protection Authority (NSW EPA) 1997)
- *Dangerous Goods (Road and Rail Transport) Act 2008* (NSW)
- *Dangerous Goods (Road and Rail Transport) Regulation 2014* (NSW)
- Other relevant Australian Standards.

The types and estimated quantities of dangerous goods and hazardous substances that would be stored within the construction ancillary facilities, and used for construction activities, are outlined in **Table 10-6**. Minor quantities of other hazardous materials may also be used at the construction ancillary facilities from time to time.

SEPP 33 is not strictly applicable to the project given it is State significant infrastructure. Nevertheless, the principles which are applied in relation to SEPP 33 have been followed to consider potential hazards associated with the use and transport of dangerous goods for the project, as outlined below.

The thresholds specified in *Hazardous and Offensive Development Application Guidelines: Applying SEPP 33*[6] (SEPP 33 Guidelines) have been applied to the inventories of dangerous goods to be transported to and stored at each construction ancillary facility. These screening thresholds represent the level at which dangerous goods may present a credible offsite hazard that requires a further, more detailed assessment of risks. Application of the screening thresholds specified in the SEPP 33 Guidelines is included in **Table 10-6**.

[6] Hazardous and Offensive Development Application Guidelines: Applying SEPP 3 NSW Department of Planning 2011

Table 10-6 Indicative dangerous goods (DG) and hazardous substances used on site during the construction period (quantities are indicative only)

Material and Australian DG Code class	C1	C2	C3	C4	C5	C6	Assessment against inventory thresholds in the SEPP 33 Guidelines
Acetylene (litres) DG class 2.1	Y	Y	Y	Y	Y	Y	Individual cylinders containing acetylene would not trigger the threshold in the SEPP 33 Guidelines (100 kilograms). Maximum stored inventories (1,040 litres) would also be located more than 50 metres away from the nearest construction ancillary facility boundary and would also not trigger the threshold in the SEPP 33 Guidelines if considered in aggregate.
Ammonium nitrate emulsion DG class 5.1	Y	Y	N	N	N	N	Ammonium nitrate would not trigger the threshold in the SEPP 33 Guidelines (five tonnes) if considered as individual containers or in aggregate.
Concrete bonding agent base (litres) DG class N/A	Y	Y	Y	N	N	Y	Concrete bonding agent bases are not dangerous goods and therefore do not trigger the thresholds in the SEPP 33 Guidelines.
Concrete bonding agent hardener (litres) DG class 8	Y	Y	Y	N	N	Y	Concrete bonding agent hardener would not trigger the threshold in the SEPP 33 Guidelines (25 tonnes) if considered as individual containers or in aggregate.
Concrete surface retarder (litres) DG class 3 PGIII	Y	Y	Y	N	N	Y	Concrete surface retarder would not trigger the threshold in the SEPP 33 Guidelines (five tonnes) if considered as individual containers or in aggregate.
Construction grout (kilograms) DG class N/A	Y	Y	Y	Y	Y	Y	Construction grout is not a dangerous good and therefore does not trigger the threshold in the SEPP 33 Guidelines.
Curing compound (litres) DG class N/A	Y	Y	Y	Y	Y	Y	Curing compounds are not dangerous goods and therefore do not trigger the thresholds in the SEPP 33 Guidelines.
Diesel DG class C1 PGIII	Y	Y	Y	Y	Y	Y	Diesel would not be stored with Class 3 materials and would therefore not be subject to the thresholds in the SEPP 33 Guidelines.
Epoxy paste part A (litres) DG class 3 PGIII	Y	Y	Y	N	N	Y	Epoxies would not trigger the threshold in the SEPP 33 Guidelines (five tonnes) if considered as individual containers or in aggregate.
Epoxy paste part B (litres) DG class 3 PGIII	Y	Y	Y	N	N	Y	Epoxies would not trigger the threshold in the SEPP 33 Guidelines (five tonnes) if considered as individual containers or in aggregate.
Form oil (litres) DG class C2	Y	Y	Y	Y	Y	Y	Form oil would not be stored with Class 3 materials and would therefore not be subject to the thresholds in the SEPP 33 Guidelines.
Grease (kilograms) DG class C2	Y	Y	Y	Y	Y	Y	Grease would not be stored with Class 3 materials and would therefore not be subject to the thresholds in the SEPP 33 Guidelines.
Hydraulic oil (litres) DG class C2	Y	Y	Y	N	N	Y	Hydraulic oil would not be stored with Class 3 materials and would therefore not be subject to the thresholds in the SEPP 33 Guidelines.

Material and Australian DG Code class	C1	C2	C3	C4	C5	C6	Assessment against inventory thresholds in the SEPP 33 Guidelines
Injectable mortar (kilograms) DG class N/A	Y	Y	Y	N	N	Y	Injectable mortar is not a dangerous good and therefore does not trigger the thresholds in the SEPP 33 Guidelines.
Joint sealant (kilograms) DG class N/A	Y	Y	Y	Y	Y	Y	Joint sealant is not a dangerous good and therefore does not trigger the thresholds in the SEPP 33 Guidelines.
Line marking aerosol (kilograms) DG class 2.1	Y	Y	Y	Y	Y	Y	Individual cylinders containing line marking aerosol would not trigger the threshold in the SEPP 33 Guidelines (100 kilograms).
Liquid nails (kilograms) DG class 3 PGII	Y	Y	Y	Y	Y	Y	Liquid nails would not trigger the threshold in the SEPP 33 Guidelines (five tonnes) if considered as individual containers or in aggregate.
Oxygen (litres) DG class 2.2	Y	Y	Y	N	N	Y	Industrial grade oxygen is a Class 2.2 dangerous good and is therefore not subject to the thresholds in the SEPP 33 Guidelines. Oxygen has a subsidiary risk of Class 5.1. Oxygen would not trigger the threshold in the SEPP 33 Guidelines (five tonnes) if considered as individual containers or in aggregate.
Polyurethane foam (kilograms) DG class 2.1	Y	Y	Y	Y	Y	Y	Individual cylinders containing polyurethane foam would not trigger the threshold in the SEPP 33 Guidelines (100 kilograms) if considered as individual containers or in aggregate.
Sodium hydroxide (litres) DG class 8 PGII	Y	Y	Y	N	N	Y	Sodium hydroxide would not trigger the threshold in the SEPP 33 Guidelines (25 tonnes) if considered as individual containers or in aggregate.
Sulfuric acid (litres) DG class 8 PGII	Y	Y	Y	N	N	Y	Sulfuric acid would not trigger the threshold in the SEPP 33 Guidelines (25 tonnes) if considered as individual containers or in aggregate.
Unleaded Petrol (litres) DG class 3 PGII	Y	Y	Y	Y	Y	Y	Epoxies would not trigger the threshold in the SEPP 33 Guidelines (five tonnes) if considered as individual containers or in aggregate.

Table 10-6 demonstrates that the dangerous goods and hazardous substances proposed to be stored and used for construction activities would not exceed the inventory thresholds in the SEPP 33 Guidelines. This indicates that the proposed storage of dangerous goods and hazardous substances at construction ancillary facilities would not pose a material off-site hazard, in the unlikely event of an incident at the proposed construction ancillary facility locations.

At each construction ancillary facility:

- Liquid dangerous goods and hazardous chemicals would be stored within a bunded storage container or spill tray
- Gases would be secured and stored in a storage cage in a well ventilated area
- Storage areas would be located away from natural or built drainage lines, to minimise the likelihood of pollutants entering adjacent watercourses in the event of a spill or leak escaping the bunded area
- Self-bunded fuel storage areas would be located within or adjacent to acoustic sheds.

A register and inventory of the dangerous goods and hazardous substances to be stored at each construction ancillary facility would be kept as part of the Incident Response Plan for the project. Material Safety Data Sheets would also be kept on site for each relevant material.

Implementation of environmental management measures for the storage and handling of dangerous goods and hazardous substances, as detailed in **Table 10-34**, would reduce the risk to the environment, construction personnel and the public. Safety hazards associated with the use of hazardous materials during construction, including within enclosed tunnel environments, are discussed in **section 10.3.4**.

Transport of dangerous goods and substances

Transportation of dangerous goods would not exceed the thresholds in the SEPP 33 Guidelines and would be undertaken in accordance with suppliers' instructions as well as the WHS Act, the Storage and Handling of Dangerous Goods Code of Practice[7], *Dangerous Goods (Road and Rail Transport) Act 2008* (NSW), *Dangerous Goods (Road and Rail Transport) Regulation 2014* (NSW) and relevant Australian Standards.

Table 10-7 outlines the dangerous goods and hazardous substances that would be transported to construction ancillary facilities. Potential hazards and risks associated with the transportation of dangerous goods and hazardous substances have been considered by comparing the type, quantity and frequency of delivery of dangerous goods and hazardous substances with the thresholds presented in the SEPP 33 Guidelines.

[7] WorkCover NSW (2005) Storage and Handling of Dangerous Goods

Table 10-7 Dangerous goods and hazardous substances transported to construction sites

Material and Australian Dangerous Goods Code class	Transport quantity and frequency of delivery to each facility (indicative only)	Construction ancillary facility destination	Transportation thresholds in the SEPP 33 Guidelines	Assessment against transportation thresholds in the SEPP 33 Guidelines
Acetylene DG class 2.1	20 litres per month	All construction ancillary facilities	Minimum transport load or transport frequency of two tonnes more than 30 times per week	Industrial grade acetylene would not trigger the transportation thresholds in the SEPP 33 Guidelines.
Ammonium nitrate emulsion DG class 5.1	2,000 litres once during the project	Arncliffe construction ancillary facility (C1) and Rockdale construction ancillary facility (C2)	Minimum transport load or transport frequency of two tonnes more than 30 times per week	Ammonium nitrate emulsion would trigger the minimum transport load threshold of two tonnes. However, it would not trigger the threshold for transport frequency and thus is unlikely to be significant.
Concrete bonding agent base DG class N/A	15 litres per month	All construction ancillary facilities	N/A	Concrete bonding agent base is not subject to the transportation thresholds in the SEPP 33 Guidelines.
Concrete bonding agent hardener DG class 8	15 litres per month	All construction ancillary facilities	Minimum transport load or transport frequency of two tonnes more than 30 times per week	Concrete bonding agent hardener would not trigger the transportation thresholds in the SEPP 33 Guidelines.
Concrete surface retarder DG class 3 PGIII	180 litres per month	All construction ancillary facilities	Minimum transport load or transport frequency of 10 tonnes more than 60 times per week	Concrete surface retarder would not trigger the transportation thresholds in the SEPP 33 Guidelines.
Construction grout DG class N/A	50 kilograms per month	All construction ancillary facilities	N/A	Construction grout is not subject to the transportation thresholds in the SEPP 33 Guidelines.
Curing compound DG class N/A	200 litres per month	All construction ancillary facilities	N/A	Curing compounds are not subject to the transportation thresholds in the SEPP 33 Guidelines.

Material and Australian Dangerous Goods Code class	Transport quantity and frequency of delivery to each facility (indicative only)	Construction ancillary facility destination	Transportation thresholds in the SEPP 33 Guidelines	Assessment against transportation thresholds in the SEPP 33 Guidelines
Diesel DG class C1 PGIII	1,500 litres per day	All construction ancillary facilities	N/A	Diesel would not be transported with Class 3 dangerous goods. Therefore, it would not be subject to the transportation thresholds in the SEPP 33 Guidelines.
Epoxy paste part A DG class 3 PGIII	15 litres per month	C1, C2, President Avenue construction ancillary facility (C3) and Prince Highway construction ancillary facility (C6)	Minimum transport load or transport frequency of 10 tonnes more than 60 times per week	Epoxies would not trigger the transportation thresholds in the SEPP 33 Guidelines.
Epoxy paste part B DG class 3 PGIII	15 litres per month	C1, C2, C3 and C6	Minimum transport load or transport frequency of 10 tonnes more than 60 times per week	Epoxies would not trigger the transportation thresholds in the SEPP 33 Guidelines.
Form oil (litres) DG class C2	180 litres per month	C1, C2 and C3	N/A	Form oil is not a dangerous good and would not be transported with Class 3 dangerous goods. Therefore, it would not be subject to the transportation thresholds in the SEPP 33 Guidelines.
Grease DG class C2	10 kilograms per month	C1, C2, C3 and C6	N/A	Grease is not a dangerous good and would not be transported with Class 3 dangerous goods. Therefore, it would not be subject to the transportation thresholds in the SEPP 33 Guidelines.
Hydraulic oil DG class C2	200 litres per month	All construction ancillary facilities	N/A	Hydraulic oil is not a dangerous good and would not be transported with Class 3 dangerous goods. Therefore, it would not be subject to the transportation thresholds in the SEPP 33 Guidelines.
Injectable mortar DG class N/A	8 kilograms per month	All construction ancillary facilities	N/A	Injectable mortar is not subject to the transportation thresholds in the SEPP 33 Guidelines.

Material and Australian Dangerous Goods Code class	Transport quantity and frequency of delivery to each facility (indicative only)	Construction ancillary facility destination	Transportation thresholds in the SEPP 33 Guidelines	Assessment against transportation thresholds in the SEPP 33 Guidelines
Joint sealant DG class N/A	10 kilograms per month	All construction ancillary facilities	N/A	Joint sealant is not subject to the transportation thresholds in the SEPP 33 Guidelines.
Line marking aerosol DG class 2.1	20 kilograms per month	All construction ancillary facilities	Minimum transport load or transport frequency of two tonnes more than 30 times per week	Line marking aerosol would not trigger the transportation thresholds in the SEPP 33 Guidelines.
Liquid nails DG class 3 PGII	10 kilograms per month	All construction ancillary facilities	Minimum transport load or transport frequency of three tonnes more than 45 times per week	Liquid nails would not trigger the transportation thresholds in the SEPP 33 Guidelines.
Oxygen DG class 2.2	150 litres per month	C1, C2, C3 and C6	N/A	Industrial grade oxygen is not subject to the transportation thresholds in the SEPP 33 Guidelines.
Oxygen subsidiary risk DG class 5.1	180 litres per month	C1, C2, C3 and C6	Minimum transport load or transport frequency of two tonnes more than 30 times per week	Oxygen has a subsidiary risk class of 5.1. Oxygen would not trigger the transportation thresholds in the SEPP 33 Guidelines.
Polyurethane foam DG class 2.1	7 kilograms per month	All construction ancillary facilities	Minimum transport load or transport frequency of two tonnes more than 30 times per week	Polyurethane foam would not trigger the transportation thresholds in the SEPP 33 Guidelines.
Sodium hydroxide DG class 8 PGII	2,000 litres per month	C1, C2, C3 and C6	25 tonnes as individual containers or in aggregate	Sodium hydroxide would not trigger the transportation threshold in the SEPP 33 Guidelines.
Sulfuric acid DG class 8 PGII	2,000 litres per month	C1, C2, C3 and C6	25 tonnes as individual containers or in aggregate	Sulfuric acid would not trigger the transportation threshold in the SEPP 33 Guidelines.

Material and Australian Dangerous Goods Code class	Transport quantity and frequency of delivery to each facility (indicative only)	Construction ancillary facility destination	Transportation thresholds in the SEPP 33 Guidelines	Assessment against transportation thresholds in the SEPP 33 Guidelines
Unleaded Petrol DG class 3 PGII	180 litres per month	All construction ancillary facilities	Minimum transport load or transport frequency of three tonnes more than 45 times per week	Unleaded petrol would not trigger the transportation thresholds in the SEPP 33 Guidelines.

Note:

1 For some construction ancillary facilities, the quantity of diesel and unleaded petrol delivered to site would be greater than the quantity stored within the facility at any time, because the delivery volume takes into the account fuel which is brought to the facility by mini-tanker and used to directly refuel plant. As this fuel is ‘in use’ in the plant it is not classified as ‘stored’

10.3.4 Public safety risks to the community

A range of potential hazards have been identified that have the potential to affect public safety during construction. These are outlined in the following sections.

On the basis of the conclusions drawn in this section, there are no issues related to construction of the project that have the potential to result in significant safety risks to the community.

Tunnel collapse

The project tunnels would generally be excavated in good quality Hawkesbury sandstone, with poorer geological conditions present in the vicinity of the President Avenue intersection. A number of major design and construction method reviews have been undertaken to better understand historical tunnel collapses. Consequently, the risks of a similar incident occurring during a Sydney tunnelling project are extremely low. The reasons for this include:

- Vastly improved geotechnical assessment and modelling
- Improved predictive two dimensional and three dimensional modelling of geology, excavation spans, temporary and permanent loads
- Fit for purpose design to develop the appropriate type of ‘support’ to match the ground conditions on a day to day basis as the excavation progresses
- Continuous independent review of the temporary and permanent works design and construction methods by experts
- Continual construction verification that tunnel support is installed and performing as per design
- Robust change management processes for conditions that are out of the ordinary or unexpected, including probe drilling and ground treatment through suspected poor ground zones
- Continuous assessment of likely excavation and groundwater conditions
- Detailed survey monitoring of surface roads, buildings and structures in the tunnel vicinity.

Construction of the tunnels would be undertaken in sections. A ‘permit to tunnel’ system would be implemented, which would require authorisation from the tunnel construction manager (or authorised delegate) and geotechnical engineer before tunnelling is allowed to continue to the next section. The 'permit to tunnel' authorisation considers the anticipated and observed ground support performance, and geotechnical and groundwater conditions. This would minimise the risk of tunnel collapse.

Tunnel fires or explosions

Combustible materials within a tunnel have the potential to cause tunnel fires and explosions. Diesel equipment fire precautions, hot work procedures and electrical equipment procedures would be followed and adequate training would be provided to minimise risks associated with fire and explosion. Construction ancillary facilities would be maintained in a tidy and orderly condition, with the aim of minimising potential fuel loads and isolating fuel sources from ignition sources.

Rock falls at cuttings

Rock falls can occur during excavation of a tunnel portal, if the portal breakthrough areas are not secured before excavation. Rock falls have the potential to injure construction workers and cause damage to construction equipment. The intersection dive structures have the potential to create rock fall hazards as steep slope sites have the potential to pose slip, fall and unsecured equipment hazards.

Standard construction and mitigation measures would be applied to manage rock fall risk, including the use of appropriate personal protective equipment, frequent tunnel inspections, scaling, progressive installation of properly secured ground support, safety fencing and overhead protection.

Exposure to airborne pollutants

During construction and demolition activities, airborne pollutants have the potential to be generated, including dust and toxic gas. If this were to occur, it may result in oxygen deficient or toxic environments and other potential health risks for construction workers and local community members. The operation of diesel and petrol-fuelled equipment and the use of hazardous materials also have the potential to produce a range of air contaminants, including diesel particulate matter from diesel combustion. Dust generation in the tunnels would be minimised by wetting down the cutting face and by using temporary fans and dry dust scrubbers. Standard ventilation, dust extraction and monitoring procedures would be carried out when appropriate.

Acid sulfate soils

Acid sulfate soils are naturally occurring soils that contain iron sulfides. When acid sulfate soils are exposed to the air, they oxidise and create sulfuric acid. This increase in acidity can result in the mobilisation of aluminium, iron and manganese from the soils. Other impacts include the de-oxygenation of water. Potential acid sulfate soils are waterlogged soils rich in pyrite that have not been oxidised. Disturbance of potential acid sulfate soils during construction causing exposure to oxygen would lead to the development of actual acid sulfate soil layers.

For construction workers, physical contact with ground and water containing toxic concentrations of acid and metal contaminants is a health risks. Standard construction and mitigation measures would be applied to mitigate the potential risks associated with the disturbance of acid sulfate soils, including the use of appropriate personal protective equipment.

Further information regarding acid sulfate soils is provided in **Chapter 16** (Soils and contamination).

Contamination

Appendix J (Contamination technical report) has considered the location of the construction activities in relation to known areas of contamination in soil, as well as issues associated with the impact of construction on the environment, where the community may be exposed.

Acid sulfate soils, asbestos and other contamination is known to be present within the construction boundary. Exposure to asbestos, landfill gas associated with historic landfill areas adjacent to President Avenue intersection, and other contaminants during construction may result in health risks for construction workers, as well as people and waterways in neighbouring communities.

Appendix J (Contamination technical report) also outlines the measures required to be adopted during construction to manage soil and surface water contamination. These would be detailed in the Construction Environmental Management Plan (CEMP). The proposed surface water management measures for the project (refer to **Chapter 18** (Surface water and flooding)) aim to minimise short term impacts on the receiving waterways during construction. With the implementation of the management measures, and in the context of the overall catchment, any potential short term impacts are unlikely to have a material impact on ambient water quality within the receiving waterways and therefore the health of the surrounding community.

Standard mitigation measures would be applied to manage potential risks to the construction workers from exposure contaminated material including the use of appropriate personal protective equipment.

Removal of asbestos containing material would be undertaken in accordance with the relevant procedures and guidelines, and by suitably qualified experts in accordance with the Work Health and Safety Plan and would include notification requirements to communities and relevant stakeholders. Refer to **Chapter 17** (Soils and contamination) and **Chapter 21** (Waste management) for further information on asbestos management.

Groundwater quality

During tunnelling works, groundwater would be extracted and would be collected, and groundwater along the tunnel alignment has the potential to be contaminated.

Should contaminated groundwater be encountered, it would be treated and discharged in accordance with the appropriate discharge criteria (refer to **Chapter 18** (Surface water and flooding). Meeting these guidelines would ensure that discharged water would not affect the health of the community using these waterways for recreation.

There is also the potential to contaminate groundwater through incidents within the construction ancillary facilities associated with the storage of hazardous materials or refuelling operations. Groundwater could become contaminated via fuel and chemical spills, petrol, diesel, hydraulic fluids and lubricants, particularly if a leak or incident occurs over the alluvium, a palaeochannel or fractured sandstone. Stockpiling of construction materials may also introduce contaminants that could potentially leach into and contaminate local groundwater. The risks to groundwater as a result of such incidents would be managed through standard construction management procedures in accordance with site specific environmental management plans developed for the project as outlined in **Chapter 16** (Soils and contamination).

Spills and leaks from construction vehicles and machinery

There is potential for fuel spills to occur during refuelling of construction vehicles and machinery, and for oil spills or the emission of other hazardous substances as a result of mechanical or other failures of construction plant. For construction workers, physical contact with fuels, oils and other hazardous materials is associated with health risks.

All materials will be stored in accordance with appropriate legislation and guidelines, including the thresholds prescribed under SEPP 33 (refer to **section 10.3.3**) that includes the use of bunding and ventilation of areas where gases are stored, maintaining a register and inventory. All materials would also be transported in accordance with the appropriate legislation and guidelines, including the thresholds prescribed under SEPP 33 (refer to **section 10.3.3**).

Spills and leaks and accidental handling of materials by workers would be managed by the implementation of standard construction environmental measures, including measures for fuel and chemical handling, spill containment and the use of appropriate personal protective equipment. These measures would form part of the Construction Environmental Management Plan (CEMP) for the project. Therefore, the risk to public safety is considered to be low.

Mobile plant

The operation of powered mobile plant during construction would be associated with a number of safety hazards including:

- The plant overturning
- Objects falling on the operator of the plant
- The operator being ejected from the plant
- The plant colliding or coming into contact with any person or object (e.g. workers, other vehicles or plant, energised powerlines).

In order to manage these hazards, mobile plant on construction sites would be operated in accordance with *Moving Plant on Construction Sites: Code of Practice*[8].

Flooding

Flooding during construction of the project could potentially impact areas within and near the construction sites. Flood related impacts during construction could include:

- Inundation of excavated tunnels
- Damage to facilities, infrastructure, equipment, stockpiles and downstream sensitive areas caused by inundation from floodwaters
- Release of contamination due to flooding of bunded areas
- Increased risk of flooding of adjacent areas due to temporary loss of floodplain storage (due to displacement of water) or impacts on the conveyance of floodwaters.

The project proposes permanent tunnel portals at the President Avenue intersection. These would be created using cut-and-cover techniques. Tunnelling would also occur through temporary shafts at the Arncliffe construction ancillary facility (C1) and a decline access at the Rockdale construction ancillary facility (C2).

[8] SafeWork NSW (2004) Moving Plant on Construction Sites: Code of Practice

Ingress of floodwater into the shafts or portals during construction would pose significant risk to personal safety for those working in the tunnel. Where these facilities occur within the floodplain or other areas that are flood prone, protection measures such as bunding or floodwater barriers would be provided to ensure floodwaters do not enter shafts or portals. Other flooding impacts during construction, such as flooding of stockpiles and erosion of cleared areas, are expected to be minor.

These impacts would be mitigated by planning sites to recognise the identified flood conditions and minimise the potential for off-site flood impacts. Mitigation measures that would be employed are outlined in **Chapter 18** (Surface water and flooding).

Road and pedestrian safety risks

Impacts to pedestrian safety are discussed in **Chapter 8** (Traffic and transport). An increase in the number of heavy vehicles during the construction period has the potential to impact walking and cycling amenity and safety. However, construction road traffic volumes are expected to be low compared with existing traffic volumes, and are not expected to substantially impact on road safety.

Pedestrian footways and cycling paths may need to be closed or diverted during construction. Alternate safe pedestrian and cycle access is to be provided where it is practical and safe to do so during construction. This will be addressed in the Construction Traffic Management and Access Plan (CTAMP).

At this stage, the expected changes (including detours) across the active transport network during construction are not expected to have a significant impact on cyclist and pedestrian safety.

Subsidence risks

It is generally accepted that the risk of damage to surface features is negligible when subjected to total settlements of less than 10 mm (refer to **Chapter 17** (Groundwater and geology)). For the majority of the tunnel length, the ground settlement is predicted to be less than 10mm due to the depth of the tunnel. Increased levels of settlement (up to around 30mm) may be observed at the southern end of the project, where the tunnel is shallower.

Monitoring of settlement throughout the construction program would be included as part of the CEMP and may include the installation of settlement markers or inclinometers. Pre-construction condition surveys of property and infrastructure that could be impacted by settlement would be undertaken before the commencement of construction activities. In the event that project settlement criteria (which would be determined in the conditions of approval for the project, if approved) are exceeded during construction for property and infrastructure, measures would be taken to ‘make good’ or to manage the impact (refer to **Chapter 17** (Groundwater and geology) for further information regarding settlement criteria). Environmental management measures to control groundwater inflows (which influence groundwater drawdown and therefore ground movement) during construction are outlined in **Chapter 17** (Groundwater and geology). Utilities

The potential rupture or severing of underground utilities due to construction activities could pose a hazard in the form of loss of service to local communities, electrocution, release of sewage from a sewer main or fire if a gas main is impacted. The risks associated with these hazards would be minimised by undertaking the following activities during the works:

- Utility checks (such as ‘dial before you dig’)
- Consulting with the relevant utility service providers
- Service and utility identification works (where possible by non-destructive means, e.g. vacuum truck)
- Relocating and/or protecting utilities in and around the project before construction begins, if required.

Consultation with utility service providers has commenced and would be ongoing during the detailed design and throughout construction, to mitigate the risk of unplanned or unexpected disturbance of utilities.

Bushfire risks

The project would not be located in or near bushfire-prone land. The construction boundary and surrounding area is highly urbanised and does not contain large areas of vegetation that are associated with bushfire risk. As such, bushfire risks associated with the project are considered to be minor.

Temporary construction ancillary facilities and construction infrastructure would be generally less sensitive to bushfire risks than operational facilities, given the temporary nature of the construction ancillary facilities and the absence of critical infrastructure within the facilities. Notwithstanding the low likelihood of bushfire events within the vicinity of the project, measures to mitigate and manage bushfire risks would be developed and included as part of site specific hazard and risk management measures within the CEMP.

Temporary construction ancillary facilities would be maintained in a tidy and orderly condition to minimise potential fuel loads in the event that the facilities are affected by fire. Storage and management of dangerous goods and hazardous materials would occur in a safe, secure location consistent with the requirements of applicable Australian Standards.

Construction activities involving flammable materials and ignition sources (for example, welding) would be proactively managed to ensure that fire risks are effectively minimised. 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

The *Airports Act 1996* (Commonwealth) (Airports Act) and the *Airports (Protection of Airspace) Regulations 1996* (Commonwealth) (Airspace Regulations) were established for the protection of airspace at and around regulated airports in Australia including Sydney Airport. The Airspace Regulations define the 'prescribed airspace' for Sydney Airport as the airspace above any part of either an obstacle limitation surface (OLS) or procedures for air navigation systems operations (PANS-OPS) surface for the airport. Part 139.370 of the Civil Aviation Safety Regulations 1998 (Commonwealth) provides for determination that a plume is a hazardous object if the vertical velocity exceeds 4.3 metres per second.

The OLS is an invisible surface that defines the height limits to which objects, including turbulence from plumes, may project into the airspace around an airport so that aircraft operations may be conducted safely. PANS-OPS protection surfaces are imaginary surfaces in space that establish the airspace that is to remain free of any potential disturbance (including physical objects and other disturbances such as emissions from ventilation outlets) so that aircraft navigation and operations may be conducted safely. Where structures may (under certain circumstances) be permitted to penetrate the OLS, they would not ordinarily be permitted to penetrate any PANS-OPS surface.

Requirements under section 183 of the *Airports Act 1996* are outlined in **Chapter 2** (Assessment process). Construction activities would be carried out to ensure that equipment such as cranes and materials do not intrude into the OLS or PANS-OPS.

CASA and DIRDC have been consulted during the development of the project design and would be consulted further prior to commencement of construction to ensure that the construction activities proposed at Arncliffe, Rockdale and President Avenue are undertaken in line with the Airspace Regulations and the Airports Act, in a manner that satisfies the requirements of CASA.

CASA, under the *Civil Aviation Regulations 1998* (Commonwealth), also regulates ground lighting where it has the potential to impact airport operations (such as causing confusion or distraction from glare to pilots in the air). The Sydney Airport Master Plan 2033 outlines the requirements for external lighting. Lighting during construction would adhere to established guidelines including *Lighting in the vicinity of aerodromes: Advice to lighting designer*[9] and *National Airports Safeguarding Framework Guideline E: Managing the Risk of Distractions to Pilots from Lighting in the Vicinity of Airports*[10] in relation to the location and permitted intensities of ground lights within a six kilometre radius of Sydney Airport.

10.3.5 Social impacts on community health

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. **Chapter 15** (Social and economic) of the environmental impact statement provides details 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 highlighted for the human health assessment.

[9] CASA (1999) Lighting in the vicinity of aerodromes: Advice to lighting designer

[10] DIRD (2012) National Airports Safeguarding Framework Guideline E: Managing the Risk of Distractions to Pilots from Lighting in the Vicinity of Airports

Traffic and transport

Road network

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 10.3.4**.

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. 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.

Construction of the permanent power supply line would require local traffic changes including partial local road closures. However works would move progressively along the route and therefore receptors would only be impacted for a short period of time. A Traffic Control Plan (TCP) and Road Occupancy Licence (ROL) would be submitted for approval by the relevant authorities prior to works in several construction areas along the route.

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

Shared Cycle and Pedestrian Pathways

Walking and cycling have many health benefits including maintaining a healthy weight and improved mental status[11]. There is currently a network of cycle paths in the vicinity of the project, comprising a mixture of separated cycleways and on road paths in areas of medium to high difficulty for on road cyclists.

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, especially along Presidents Avenue and Rockdale wetlands. While the opportunity to walk or cycle in the project area would be addressed in a Construction Traffic and Access Management Plan (CTAMP), 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.

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. Comprehensive communication of changes to roads or paths to emergency services will be an integral part of the CTAMP.

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[11] Hansson et al. 2011; Lindström 2008; Wen & Rissel 2008; WHO 2000b).

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. 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[12]. 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 may contribute to feelings of community severance and disconnection. The project is not introducing new major roadways that would change existing conditions.

Construction of the project would involve the temporary disruption of pedestrian and cycleway routes especially around Rockdale Bicentennial Park. 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.

Property acquisition

The project requires 15 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 (refer to **Chapter 3** (Consultation)). All acquisition required for the project would be undertaken in accordance with the relevant standards and guidelines (refer to **Chapter 14** (Property and land use)).

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. Studies have shown a positive relationship between green space and health and wellbeing[13], including improved mental health (particularly lower stress levels), reduced morbidity and improved opportunities for physical activity and social interactions. Green spaces that include large trees and shrubs can also protect people from environmental exposures such as air pollution, noise and extreme temperatures (such as the urban heat island effect) due to the cooling effect of vegetation.

During construction, the project would require:

- Acquisition of approximately 1.1 hectares plus the temporary lease of 3.9 hectares of Rockdale Bicentennial Park
- Acquisition of approximately 0.5 hectares plus temporary lease of 0.5 hectares of Scarborough Park North
- Acquisition of approximately 0.7 hectares plus temporary lease of 6.1 hectares of Kogarah Golf Course. The golf course is currently operating with 15 holes instead of 18 holes as it is partially occupied by the Arncliffe construction site for the New M5 Motorway project. The project would result in the golf course continuing to operate with 15 holes during construction.

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[12] WHO 2000b, *Transport, environment and health,* WHO Regional Publications, European Series, No. 89.
[13] de Vries et al. 2003; Health Scotland 2008; Kendal et al. 2016; Maas et al. 2006; Mitchell & Popham 2007.

Works would temporarily restrict access to much of Rockdale Bicentennial Park and the recreational facilities located within the park including the Rockdale Skate Park and disability playground. These impacts to green space during construction of the project may reduce opportunities for physical activity and exercise, social interactions and result in increased levels of stress for members of the community. A reduction in green spaces with trees and shrubs (for example, parts of Rockdale Bicentennial Park) may also reduce the protection offered by these green spaces from air pollution, noise and extreme temperatures.

The Rockdale Bicentennial East soccer fields would be temporarily relocated and the Brighton Memorial Playing Fields may be reconfigured at their current location to allow the community to continue to benefit from their use during the construction period. Roads and Maritime has commenced discussions with Bayside Council regarding the reinstated layout of Rockdale Bicentennial Park following construction and compensatory facilities during construction. The final layout would be determined in consultation with Bayside Council.

Visual impacts

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 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.

Economic impacts

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 brings 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 some local businesses will be adversely impacted by both construction and operational activities, along with other businesses marked for acquisition. This can cause stress for the impacted individuals and lead to health impacts if not appropriately managed. To minimise these impacts the project would include development of a Business Management Plan. This plan should include ways to minimise stress to impacted individuals.

Stress and anxiety

A number of changes within the community (as discussed above and in **section 10.3.6**) have the potential to affect an individual's level of stress and anxiety.

An acute stressful event results in changes to the nervous, cardiovascular, endocrine and immune systems. , more commonly known as the "fight or flight" response . Unless there is an accident or other significant event, such acute stress events are not expected to be associated with construction or operation of the project.

For shorter-term events, stress causes the immune system to release hormones that trigger the production of white blood cells. 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. It will make some individuals more susceptible to infections.

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[14].

[14] Schneiderman et al. 2005 'STRESS AND HEALTH: Psychological, Behavioral, and Biological Determinants', *Annual review of clinical psychology,* vol. 1, pp. 607-628.

Other physiological effects associated with chronic stress include:[15]

- 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
- Chronic activation of stress hormones can raise an individual's heart rate, cause chest pain and increase blood pressure and blood lipid (fat) levels. Sustained high levels of fatty substances can lead to atherosclerosis and other cardiovascular diseases[16].
- Cortisol releases at higher levels of stress and plays 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[17].

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. These impacts are greater where there is urbanisation without improvements in infrastructure to improve equitable access to employment and social areas/communities[18].

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 project, 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 project aims 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.

10.3.6 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 results from continued 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. Construction impacts are no longer considered to be transient and/or short-term.

The assessment of construction fatigue in this report includes the construction impacts of the New M5 Motorway project that may overlap with the timing of the construction of the project. It is noted that construction fatigue is particularly relevant for the community surrounding C1, a facility anticipated to be used for both the New M5 Motorway and the project. Other potential construction fatigue risk areas identified include in the vicinity of C2, C3 and the C6 Princes Highway/President Avenue intersection upgrade, where construction requires extended construction timeframes or coordination with other works such as utility relocations or reconfigurations.

The area is also subject to ongoing urban development, with many of the LGAs in the study area projected to have significant population growth (refer to section 4.4) driven by increased development density in the Arncliffe, Banksia, Rockdale and Kogarah areas, as well as the proposed Cooks Cove development.

Dust management measures identified for the project 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 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.

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[15] Brosschot et al. 2006; McEwen, Bruce S. 2008; McEwen, B.S. & Stellar 1993; Mills et al. 2008; Moreno-Villanueva & Bürkle 2015.
[16] Pimple et al. 2015; Seldenrijk et al. 2015.
[17] Ortego et al. 2016; 'Is there an relationship between psychological stress or anxiety and chronic nonspecific neck-arm pain in adults? A systematic review and meta-analysis', *Journal of Psychosomatic Research,* vol. 90, 2106/11/01/, pp.70-81.
[18] Srivastava, K. 2009, 'Urbanization and mental health', *Industrial Psychiatry Journal,* vol. 18, no. 2, Jul-Dec, pp. 75-76.

Appendix G (Noise and vibration technical report) 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. It identified construction noise of up to 8 years could potentially affect some receptors surrounding the area of the Arncliffe ventilation facility, currently being built as part of the New M5 Motorway project. A number of receptors have been identified as highly affected from standard and out of hours construction noise due to the project, which may result in construction fatigue for some receptors currently experiencing noise impacts due to the construction of the New M5 Motorway project at Arncliffe. However, the scale of construction for this project would be less than for the New M5 Motorway project. The current New M5 Motorway project is expected to operate 60 heavy vehicle movements an hour, whilst the project is expecting 26 heavy vehicle movements an hour.

A strategy would be prepared and implemented to address potential construction fatigue impacts. Discussions with the affected community would occur and where practicable noise attenuation and respite would be provided. Receptors identified as requiring at-property or operational noise mitigation will be identified and offered treatment prior to commencement of construction works that affects them.

10.4 Potential impacts – operation

10.4.1 In-tunnel air quality impacts on community health

Traditionally, the approach to managing air quality within tunnels was based on 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, nitrogen dioxide concentrations are now commonly used for tunnel ventilation design.

The operational in-tunnel limits for carbon monoxide and nitrogen dioxide in several Sydney road tunnels are shown in **Table 10-8**. With the current pollution limits, and for the assessment years of the project, NO_2 would be the pollutant that determines the required air flows and drives the design of ventilation for in-tunnel pollution.

Table 10-8 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 M4 M5 Link	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'[19]. That document further consolidated the approach taken earlier for the NorthConnex, M4 East and New M5 projects. The policy wording requires tunnels to be *'designed and operated so that the tunnel average nitrogen dioxide (NO_2) concentration is less than 0.5 ppm as a rolling 15 minute average'*.

For the project's tunnel 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 north and southbound from the New M5 to President Ave.

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.

A number of factors have been considered in this assessment. Firstly, concentrations in the tunnel are expected to vary depending on the 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. Second, the concentration of pollutants within the vehicle itself would be lower, particularly when all windows are closed when inside the tunnel, as most vehicles have filters on the air intake. When the air conditioning/ventilation in the car is set to recirculation the contribution of air from within the tunnel to the air within the vehicle would be limited. Measurements conducted by NSW Health in relation to the M5 East Tunnel[20] 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[21].

[19] ACTAQ 2016, *In-Tunnel Air Quality (Nitrogen Dioxide) Policy,* NSW Advisory Committee on Tunnel Air Quality.
[20] NSW Health 2003, *M5 East Tunnels Air Quality Monitoring Project,* South Eastern Sydney Public Health Unit & NSW Department of Health.
[21] PEL 2016, *Road tunnels: reductions in nitrogen dioxide concentrations in-cabin using vehicle ventilation systems,* Prepared by Pacific Environment Limited for NSW Road and Maritime Services.

The study involved a range of vehicles 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 study found that recirculation reduced exposures by around 70 per cent. Finally, there may be individuals who use the network of tunnels in the Sydney area on a frequent basis throughout the day. These individuals may include taxi drivers, courier drivers and some truck drivers. More frequent and cumulative exposures in these tunnels are considered below.

Carbon monoxide (CO)

Table 10-9 presents the maximum in-tunnel concentration of carbon monoxide predicted for the project. The table presented is for the year 2036 cumulative scenario, that is with all tunnels in consideration.

Table 10-9 Maximum estimated in-tunnel air quality for CO based on expected traffic in 2036

Time Period	CO (ppm) (one hour average)		30 minute CO criteria (ppm)
	Southbound	Northbound	
7am – 9am	4.3	1.2	48.7*
9am – 3pm	5.1	0.8	48.7
3pm – 6pm	7.8	0.7	48.7
6pm – 7am	2.9	0.5	48.7

* The modelling has been undertaken without consideration of CO background concentrations of 1.3 ppm. Therefore 1.3 ppm is subtracted from the 30 minute criteria of 50 ppm

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 both directions for all times of the day. These concentrations are lower than the health based guideline of 25 ppm (one-hour average) established by the WHO[22] and 34 ppm established by the USEPA[23]. The concentrations are lower than PIARC in-tunnel limits[24].
- 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 (i.e. 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. The predicted hourly average concentration in the project tunnel is within the range reported in other tunnels.

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 F6 Extension Stage 1.

Nitrogen dioxide (NO_2)

Table 10-10 presents the maximum route average concentration of nitrogen dioxide predicted for the project, while travelling in both directions. The table presented is for the year 2036 cumulative scenario, that is with all tunnels in consideration. The previous in-tunnel assessment undertaken for the WestConnex M4-M5 Link EIS, that considered all possible tunnel travel routes (including the then proposed F6 extension) remains valid for the journeys through the WestConnex tunnels (refer to Annexure L to **Appendix F** (Air quality technical report). This assessment showed that the in-tunnel nitrogen dioxide concentrations for all trips fell below the 0.5 ppm criteria.

[22] WHO 2010, *WHO Guidelines for Indoor Air Quality, Selected Pollutants,* WHO Regional Office for Europe.
[23] NHMRC 2008, *Air Quality in and Around Traffic Tunnels, Systematic Literature Review,* National Health and medical Research Council.
[24] Longley, 2014, *TP11: Criteria for in-Tunnel and Ambient Air Quality,* NSW Advisory Committee on Tunnel Air Quality.

Table 10-10 Maximum estimated in-tunnel air quality for NO_2 based on expected traffic in 2036

Time Period	NO_2 route average (ppm)				Criteria (ppm)
	St Peters to President Ave	M4-M5 to President Ave	President Ave to St Peters	President Ave to M4-M5	
7am – 9am	0.14	0.18	0.12	0.11	0.47*
9am – 3pm	0.15	0.20	0.07	0.07	0.47
3pm – 6pm	0.19	0.23	0.05	0.05	0.47
6pm – 7am	0.07	0.10	0.03	0.03	0.47

* The modelling has been undertaken without consideration of NO_2 background concentrations of 0.3 ppm. Therefore 0.03 ppm is subtracted from the 0.5 ppm criteria

In relation to the nitrogen dioxide concentrations predicted within the project's tunnel, the following is noted:

- The maximum concentrations in the project's tunnel vary throughout the day, with the maximum concentration predicted at any time of the day less than 0.5 ppm
- 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 (i.e. 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, i.e. minutes) levels up to 0.8 ppm have been reported.

The concentrations discussed above relate to nitrogen dioxide levels inside the tunnels, not inside the vehicles.

Within existing tunnels utilised in the Roads and Maritime study[25] of in-vehicle nitrogen dioxide levels, 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 0.3ppm was determined for nitrogen dioxide where ventilation is set to recirculate. When ventilation was not set to recirculate the concentration of nitrogen dioxide was higher inside the vehicles, and in some cases accumulated inside the vehicle after travelling through short tunnels.

A summary of the health effects of short-term exposure to NO_2 is provided in **Appendix F** (Human health technical report)

The average concentration of nitrogen dioxide has been calculated for the north and south bound trips through the project. However, users of the tunnel network are likely to travel further in the connecting tunnel networks. A previous in-tunnel assessment undertaken for the WestConnex M4-M5 Link EIS considered all possible tunnel travel routes between the western portal of the M4 East, through the M4-M5 Link to the western portal of the New M5, in both directions.

[25] PEL 2016, *Road tunnels: reductions in nitrogen dioxide concentrations in-cabin using vehicle ventilation systems,* Prepared by Pacific Environment Limited for NSW Road and Maritime Services

In the current in-tunnel assessment (refer to **Appendix E** (Air quality technical report)) it is confirmed that the ventilation system of New M5 and F6 Extension, as outlined in this report, meets or exceeds the functional performance requirements of the M4-M5 Link EIS. As such, the integrated analysis of the overarching tunnel network completed as part of the M4-M5 Link EIS remains valid.

Further information for bus travellers is presented in **Appendix F** (Human health technical report).

Table 10-11 and **Table 10-12** present a summary of the maximum (by time of the day) predicted average concentrations of nitrogen dioxide for the routes of travel with the highest NO_2 concentrations, using the project and different parts of the tunnel system (assuming all motorway 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 predicted worst case in-cabin concentration of nitrogen dioxide, where windows are up and ventilation is on recirculation.

Table 10-11 Average nitrogen dioxide levels for different trips using completed tunnel network 2033: to the project

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 Stage 1*	In-tunnel	In-vehicle (recirculation)		In-tunnel	In-vehicle (recirculation)
1F	M4 East	F6 Extension	19.5 km	X	X	X	X	0.25	0.076	7am		
1M	Concord Rd	F6 Extension	18.4 km	X	X	X	X	0.26	0.079	7am	0.39	0.12
1R	Wattle St	F6 Extension	13 km		X	X	X	0.25	0.074	4pm	0.38	0.11
1U	Western Harbour Tunnel	F6 Extension	13 km		X	X	X	0.23	0.068	4pm	0.34	0.10
1W	St Peters	F6 Extension	6.9 km			X	X	0.22	0.066	4pm		
1AA	Iron Cove	F6 Extension	13.4 km		X	X	X	0.22	0.066	4pm	0.33	0.10
1AD	City West Link	F6 Extension	12.1 km		X	X	X	0.24	0.073	4pm	0.36	0.11
NO2 guideline: 15 minute average = 0.5 ppm												

Table 10-12 Average nitrogen dioxide levels for different trips using completed tunnel network 2033: from the project

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)
2F	F6 Extension Stage 1	St Peters	7.1 km			X	X	0.05	0.02	7am		
2G	F6 Extension	Western Harbour Tunnel	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
2AA	F6 Extension	Iron Cove	13.6 km		X	X		0.13	0.04	7am	0.39	0.12
2AB	F6 Extension	City West Link	12.3 km		X	X		0.12	0.04	7am	0.35	0.11
NO_2 guideline: 15 minute average = 0.5 ppm												

In relation to the trips emanating and exiting from the project these trips including the extreme congestion scenario, these trips have been found to be below the 0.5ppm guideline and therefore it is unlikely that significant health effects would occur.

The NO_2 guideline may not be protective of all health effects for all individuals. There is the potential for severe asthmatic individuals, especially if they use motorbikes, to experience some change in respiratory response after using the tunnels, particularly when congested.

Repeated use of tunnels also requires consideration. The available data on health effects associated with short-duration exposures indicates the effects are transient, i.e. 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.

Particulate matter

There are no health based guidelines available for the assessment of short-duration exposures to particulate matter (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 tyre and break wear and dust from surface road wear and the resuspension of road dust. The modelling of PM and visibility within the tunnel did consider both sources. **Table 10-13** presents a summary of the peak concentrations of PM estimated inside the tunnels in 2023, for the expected traffic conditions.

Table 10-13 Predicted peak concentrations of particulate matter in-tunnel: 2023

Scenario/Tunnel segment	Peak PM concentration (mg/m^3)	
	Exhaust	Non-exhaust sources
	Cumulative	Cumulative
To F6 Extension Stage 1		
New M5 including F6 Extension Stage 1	0.08	0.64
From F6 Extension Stage 1		
New M5 including F6 Extension Stage 1	0.03	0.2

The characteristics of PM derived from exhaust and non-exhaust sources are 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 both exhaust and non-exhaust PM emission factors that relate to PM_{10} and $PM_{2.5}$ from relevant emissions studies. PM_{10} concentrations in the tunnels are dominated by non-exhaust sources. Regular cleaning of the tunnel walls and roadways would reduce these levels.

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).

Specific health effects from the short duration variations in particulate exposures throughout any specific day have not been determined. 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 density of the traffic, the age of the vehicle, the choice of ventilation mode used within the vehicle and the type of fuel used[26]. Levels of $PM_{2.5}$ reported in vehicles in Europe[27] 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[28]
- Keeping windows closed and switching ventilation to recirculate has been shown to reduce exposures to particulates inside the vehicle by up to 80 per cent[29]. While noting no guidelines are available for very short duration exposures, this would further reduce exposure to motorists
- 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 any tunnel, 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.

10.4.2 Ambient air quality impacts on community health

Assessment of volatile organic compounds (VOCs) and polycyclic aromatic hydrocarbons (PAHs)

Appendix E (Air quality technical report) 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 (i.e. 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.

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[26] Knibbs, de Dear & Morawska 2010, ‘Effect of cabin ventilation rate on ultrafine particle exposure inside automobiles’, *Environmental science & Technology,* vol. 44, no. 9, May 1. Pp. 3546-3551.
[27] ETC 2013, *Assessment of population exposure to air pollution during commuting in European cities, ETC/ACM Technical Paper 2013/2,* European Topic Centre on Air Pollution and Climate Change Mitigation.
[28] NSW Health, 2004, *Comparison of personal exposures to air pollutants by commuting mode in Sydney, BTEX & NO_2,* NSW Department of Health, Sydney.
[29] NSW Health, 2003, *M5 East Tunnels Air Quality Monitoring Project,* South Eastern Sydney Public Health Unit & NSW Department of Health.

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 10-16**.

Table 10-14 Volatile organic compounds speciation profile for vehicle emissions

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

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

Volatile organic compounds

VOCs have been modelled in **Appendix E** (Air quality technical report) 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)[30]. 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[31][32].

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[33], for the vehicle fleet assessed in **Appendix E** (Air quality technical report) (as summarised above). In relation to passenger vehicles it has been assumed that 60 per cent[34] 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 10-15 presents a summary of the weighted mass fraction for these VOCs considered for the project in 2026 and 2036.

Table 10-15 Weighted volatile organic compounds speciation profile for vehicle emissions

VOC	Weighted % of total VOC estimate	
	2026	2036
Benzene	3.9	3.4
Toluene	7.1	5.9
Xylenes	5.9	4.9
1,3-butadiene	1.1	0.9
Formaldehyde	3.4	4.6
Acetaldehyde	1.6	2.0

[30] NSW EPA 2012, *Air Emissions Inventory for the Greater Metropolitan Regional in New South Wales, 2008 Calendar Year, On-Road Mobile Emissions: Results,* NSW Environment Protection Authority Sydney,
[31] DEH 2003, *Technical Report No. 1: Toxic Emissions from Diesel Vehicles in Australia,* Environment Australia.
[32] NSW EPA 2012, *Air Emissions Inventory for the Greater Metropolitan Regional in New South Wales, 2008 Calendar Year, On-Road Mobile Emissions: Results,* NSW Environment Protection Authority Sydney,
[33] NSW EPA 2012, *Air Emissions Inventory for the Greater Metropolitan Regional in New South Wales, 2008 Calendar Year, On-Road Mobile Emissions: Results,* NSW Environment Protection Authority Sydney,
[34] 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.

Polycyclic aromatic hydrocarbons

PAHs have been considered in **Appendix E** (Air quality technical report) 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 2026 and 2036 total PAHs have been estimated to comprise 0.79 and 0.95 per cent respectively 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 (see **Appendix F** (Human health technical report).

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[35] 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 10-16 presents a summary of the PAH speciation profile considered in this assessment for the above traffic conditions.

Table 10-16 Polycyclic aromatic hydrocarbon speciation profile for diesel vehicle emissions

Individual PAH	Per cent of total PAH emissions (PAHs)
	Used to evaluate emissions in 2026 and 2036
Non-carcinogenic PAHs	
Naphthalene	70
Acenaphthylene	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

Assessment of health impacts

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.

[35] CCME 2010, *Canadian Soil Quality Guidelines, Carcinogenic and Other Polycyclic Aromatic Hydrocarbons* (*PAHs*) (*Environmental and Human Health Effects*), *Scientific Criteria Document (revised)*, Canadian Council of Ministers of the Environment, Quebec.

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[36] 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 10-18**.

For other VOCs and PAHs, where the health effects are associated with a threshold (i.e. a level below which there are no effects), the maximum predicted concentration from all sources (i.e. 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 10-17**.

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 10-18**.

Table 10-17 Adopted acute inhalation guidelines based on protection of public health

Compound assessed	Acute health based guideline (µg/m3)	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[37].
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[38].
Xylenes	7400	Acute 1 hour health based guideline, based on mild respiratory effects and subjective symptoms of neurotoxicity in human volunteers from TCEQ evaluation[39].
1,3-Butadiene	660	Acute 1 hour health based guideline, based on developmental effects derived by the California Office of Environmental Health Hazard Assessment[40]. The guideline developed is lower than developed by TCEQ[41] based on the same critical study.

[36] enHealth 2012b, *Environmental Health Risk Assessment, Guidelines for assessing human health risks from environmental hazards,* Commonwealth of Australia, Canberra.
[37] TCEQ 2013b, *Development Support Document, Xylenes,* Texas Commission on Environmental Quality
[38] TCEQ 2013c, *Development Support Document, Toluene,* Texas Commission on Environmental Quality
[39] TCEQ 2013e, *1,3-Butadiene*, *Development Support Document,* Commission on Environmental Quality
[40] OEHHA 2013, *Individual Acute, 8-hour, and Chronic Reference Exposure Level Summaries,* California Office of Environmental Health Hazard Assessment.
[41] TCEQ 2007, *1,3-Butadiene*, TEXAS COMMISSION ON ENVIRONMENTAL QUALITY.

Compound assessed	Acute health based guideline (µg/m3)	Basis
Formaldehyde	50	Acute 1 hour health based guideline, based on eye and nose irritation in human volunteers from TCEQ evaluation[42]). This guideline is noted to be lower than the acute guideline available from the WHO[43][44] 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[45].

[42] TCEQ 2014, *Formaldehyde, 24-hours Ambient Air Monitoring Comparison Value, Development Support Document,* Texas Commission on Environmental Quality.

[43] WHO, 2000a, *WHO air quality guidelines for Europe, 2nd edition, 2000 (CD ROM version),* World Health Organisation.

[44] WHO 2010, *WHO Guidelines for Indoor Air Quality, Selected Pollutants,* WHO Regional Office for Europe.

[45] OEHHA 2013, *Individual Acute, 8-hour, and Chronic Reference Exposure Level Summaries,* California Office of Environmental Health Hazard Assessment.

Table 10-18 Adopted chronic guidelines and carcinogenic unit risk values based on protection of public health

Compound assessed	Chronic health based guideline (µg/m3)	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[46] 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[47] health based guidelines.
Toluene	5000	Chronic guideline derived by the USEPA[48] 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[49] health based guidelines.
Xylenes	220	Chronic guideline derived by the Agency for Toxic Substances and Disease Register (ATSDR)[50] based on mild subjective respiratory and neurological symptoms in an occupational study (converted to public health value using safety factors).
Formaldehyde	3.3	Formaldehyde is classified by IARC as carcinogenic to humans. The guideline developed by TCEQ[51] 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[52].
Acetaldehyde	9	Chronic guideline derived by the USEPA[53] 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[54] 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[55] health based guidelines.
Acenaphthylene	200#	These are the non-carcinogenic PAHs. Guideline available from the USEPA[56]. 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
Acenaphthene	200	

[46] USEPA 2002b, *Health Assessment Document For Diesel Engine Exhaust*, United States Environmental Protection Agency.
[47] NEPC 1999 amended 2013b, *Schedule B1, Guideline on Investigation Levels For Soil and Groundwater, National Environment Protection (Assessment of Site Contamination) Measure*, National Environment Protection Council.
[48] USEPA 2005a, *Toxicological Review of Toluene (CAS No. 108-88-3), In Support of Summary Information on the Integrated Risk Information System (IRIS)*, U.S. Environmental Protection Agency, Washington.
[49] NEPC 1999 amended 2013b, *Schedule B1, Guideline on Investigation Levels For Soil and Groundwater, National Environment Protection (Assessment of Site Contamination) Measure*, National Environment Protection Council.
[50] ATSDR 2007, *Toxicological Profile for Xylene*, US Department of Health and Human Services, Agency for Toxic Substances and Disease Registry.
[51] TCEQ 2013a, *Development Support Document, Formaldehyde*, Texas Commission on Environmental Quality.
[52] WHO 2010, *WHO Guidelines for Indoor Air Quality, Selected Pollutants*, WHO Regional Office for Europe.
[53] USEPA database.
[54] USEPA 1998, *Toxicological Review of Naphthalene (CAS No. 91-20-3), In Support of Summary Information on the Integrated Risk Information System (IRIS)*, U.S. Environmental Protection Agency, Washington.
[55] NEPC 1999 amended 2013b, *Schedule B1, Guideline on Investigation Levels For Soil and Groundwater, National Environment Protection (Assessment of Site Contamination) Measure*, National Environment Protection Council.
[56] USEPA.

Compound assessed	Chronic health based guideline (µg/m3)	Basis
Fluorene	140	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[57]. # 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.
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[58] [59] 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[60]. This has considered the same studies as WHO and USEPA, but included more recent studies and more relevant dose-response modelling.
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[61] 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 5.9.5 and Annexure B).

Table 10-19 and **Table 10-20** present a summary of the maximum predicted one hour or annual average concentrations of VOCs and PAHs assessed on the basis of a threshold with comparison against acute and chronic health based guidelines. The table also presents a Hazard Index (HI) which is the ratio of the maximum predicted concentration to the guideline. Each individual HI is added up to obtain a total HI for all the threshold VOCs and PAHs considered. The total HI is a sum of the potential hazards associated with all the threshold VOCs and PAHs together assuming the health effects are additive, and is evaluated as follows[62]:

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

[57] USEPA 2009a, *Risk Assessment Guidance for Superfund, Volume I: Human Health Evaluation Manual, (Part F, Supplemental Guidance for Inhalation Risk Assessment)*, United States Environmental Protection Agency, Washington, D.C.
[58] WHO 2000a, *WHO air quality guidelines for Europe, 2nd edition, 2000 (CD ROM version)*, World Health Organisation.
[59] WHO 2010, *WHO Guidelines for Indoor Air Quality, Selected Pollutants*, WHO Regional Office for Europe.
[60] TCEQ 2013d, *Development Support Document, Benzene*, Texas Commission on Environmental Quality.

[61] WHO 2010, *WHO Guidelines for Indoor Air Quality, Selected Pollutants*, WHO Regional Office for Europe.
[62] enHealth 2012b, *Environmental Health Risk Assessment, Guidelines for assessing human health risks from environmental hazards*, Commonwealth of Australia, Canberra.

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 10-19** and **Table 10-20**, 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 10-21** and **Table 10-22**, 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 10-21** and **Table 10-22** also present 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 10-23 and **Table 10-24** 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[63]. 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 2026 and 2036 as modelled in **Appendix E** (Air quality technical report) . 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 (i.e. a benefit).

Table 10-19 Assessment of acute exposures to VOCs – maximum impacts in community associated with project: 2026

Key VOC	Maximum predicted 1 hour average concentration associated with project (background plus project) and calculated HI			
	2026: Without project		2026: With project	
	Maximum concentration (µg/m3)	HI	Maximum concentration (µg/m3)	HI
Benzene	9.7	0.017	7.7	0.013
Toluene	17.8	0.0012	14.0	0.00093
Xylenes	14.6	0.0020	11.5	0.0016
1,3-Butadiene	2.6	0.0039	2.0	0.0031
Formaldehyde	8.0	0.16	6.3	0.13
Acetaldehyde	3.8	0.0082	3.0	0.0064
Total HI		0.19	0.15	

63 enHealth 2012b, *Environmental Health Risk Assessment, Guidelines for assessing human health risks from environmental hazards*, Commonwealth of Australia, Canberra.

Table 10-20 Assessment of acute exposures to VOCs – maximum impacts in community associated with project: 2036

Key VOC	Maximum predicted 1 hour average concentration associated with project (background plus project) and calculated HI					
	2036: Without project		2036: With project		2036: Cumulative	
	Maximum concentration (µg/m3)	HI	Maximum concentration (µg/m3)	HI	Maximum concentration (µg/m3)	HI
Benzene	5.4	0.0093	5.2	0.0089	5.2	0.0090
Toluene	9.4	0.00062	9.0	0.00060	9.1	0.00061
Xylenes	7.7	0.0010	7.4	0.0010	7.5	0.0010
1,3-Butadiene	1.5	0.0022	1.4	0.0021	1.4	0.0022
Formaldehyde	7.0	0.14	6.7	0.13	6.8	0.14
Acetaldehyde	3.1	0.0066	3.0	0.0063	3.0	0.0064
Total HI		0.16	0.18		0.16	

Table 10-21 Assessment of chronic exposures to VOCs and PAHs – maximum impacts in community associated with project: 2026

Key VOCs and PAHs	Maximum predicted annual average concentration associated with project (background plus project) and calculated HI Residential exposures			
	2026: Without project		2026: With project	
	Max concentration (µg/m3)	HI	Max concentration (µg/m3)	HI
Benzene	0.51	0.017	0.52	0.017
Toluene	0.93	0.0002	0.96	0.0002
Xylenes	0.76	0.003	0.79	0.004
Formaldehyde	0.42	0.13	0.43	0.13
Acetaldehyde	0.20	0.022	0.21	0.023
Naphthalene	0.069	0.023	0.071	0.024
Acenaphthylene	0.0048	2.4 x10-5	0.0050	2.5 x10-5
Acenaphthene	0.0020	9.9 x10-6	0.0020	1.0 x10-5
Fluorene	0.0049	3.5 x10-5	0.0051	3.6 x10-5
Phenanthrene	0.0034	2.4 x10-5	0.0035	2.5 x10-5
Anthracene	0.00048	4.8 x10-7	0.00050	5.0 x10-7
Fluoranthene	0.00044	3.2 x10-6	0.00046	3.3 x10-6
Pyrene	0.00070	7.0 x10-6	0.00072	7.2 x10-6
Total HI – Residential		0.18		0.18
Max HI – Commercial/Industrial		0.039		0.040

Table 10-22 Assessment of chronic exposures to VOCs and PAHs – maximum impacts in community associated with project: 2036

Key VOCs and PAHs	Maximum predicted annual average concentration associated with project (background plus project) and calculated HI Residential exposures					
	2036: Do minimal		2036: With project		2036: Cumulative	
	Max concentration (µg/m3)	HI	Max concentration (µg/m3)	HI	Max concentration (µg/m3)	HI
Benzene	0.34	0.011	0.34	0.011	0.34	0.011
Toluene	0.60	0.0001	0.59	0.0001	0.59	0.0001
Xylenes	0.49	0.002	0.48	0.002	0.49	0.002
Formaldehyde	0.44	0.13	0.44	0.13	0.44	0.13
Acetaldehyde	0.20	0.022	0.19	0.022	0.19	0.022
Naphthalene	0.065	0.022	0.064	0.021	0.064	0.021
Acenaphthylene	0.0045	2.3 x10-5	0.0045	2.2 x10-5	0.0045	2.2 x10-5
Acenaphthene	0.0018	9.2 x10-6	0.0018	9.1 x10-6	0.0018	9.2 x10-6
Fluorene	0.0046	3.3 x10-5	0.0046	3.3 x10-5	0.0046	3.3 x10-5
Phenanthrene	0.0031	2.2 x10-5	0.0031	2.2 x10-5	0.0031	2.2 x10-5
Anthracene	0.00045	4.5 x10-7	0.00045	4.5 x10-7	0.00045	4.5 x10-7
Fluoranthene	0.00042	3.0 x10-6	0.00041	2.9 x10-6	0.00041	2.9 x10-6
Pyrene	0.00066	6.6 x10-6	0.00065	6.5 x10-6	0.00065	6.5 x10-6
Total HI – Residential		0.18		0.18		0.18
Max HI – Commercial/Industrial		0.039		0.039		0.039

Table 10-23 Assessment of incremental lifetime carcinogenic risk – maximum impacts in community associated with project: 2026

Key VOC	Maximum predicted change in annual average concentration associated with project and cancer risk Residential			
	2026: With project		2026: Cumulative	
	Maximum concentration (µg/m3)	ILCR	Maximum concentration (µg/m3)	ILCR
Benzene	0.061	2 x 10-7		
1,3-Butadiene	0.0162	3 x 10-9		
Benzo(a)pyrene TEQ	5.4E-04	2 x 10-5		1 x 10-5
Total carcinogenic risk – Residential		2 x 10-5	1 x 10-5	
Maximum carcinogenic risk – Commercial/Industrial		4 x 10-6	3 x 10-6	

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

Table 10-24 Assessment of incremental lifetime carcinogenic risk – maximum impacts in community associated with project: 2036

Key VOC	Maximum predicted change in annual average concentration associated with project and cancer risk Residential			
	2036: With project		2036: Cumulative	
	Maximum concentration (µg/m³)	ILCR	Maximum concentration (µg/m³)	ILCR
Benzene	0.044	1×10^{-7}	0.052	1×10^{-7}
1,3-Butadiene	0.012	2×10^{-9}	0.014	3×10^{-9}
Benzo(a)pyrene TEQ	5.5×10^{-4}	2×10^{-5}	6.5×10^{-4}	2×10^{-5}
Total carcinogenic risk – Residential		2×10^{-5}	2×10^{-5}	
Maximum carcinogenic risk – Commercial/Industrial		4×10^{-6}	5×10^{-6}	

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

For the assessment of acute exposures to VOCs (**Table 10-19** and **Table 10-20**) the calculated HI associated with exposure to the maximum concentrations predicted is less than one for 2026, 2036 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 10-21 and Table 10-22**), the calculated HI associated with exposure to the maximum concentrations predicted is less than or equal to one for the 2026, 2036 Do something and the cumulative scenarios. 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 **Table 10-21 and Table 10-22**). 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.

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[64].

Guidelines are available in Australia from NEPC[65] 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[66] 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)[67], 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.

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[64] NEPC 2010, *Review of the National Environment Protection (Ambient Air Quality) Measure, Discussion Paper, Air Quality Standards*, National Environmental Protection Council.
[65] NEPC 2003, *National Environment Protection (Ambient Air Quality) Measure*, National Environment Protection Council.
66 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.
67 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.

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[68] 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 10-25 presents a summary of the maximum predicted cumulative one-hour average and eight-hour average concentrations of carbon monoxide for the assessment years 2026 and 2036, without the project, with the project and for the cumulative scenario.

Table 10-25 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
2026						
Maximum	5.3	5.3		3.7	3.7	
2036						
Maximum	5.0	4.7	4.8	3.5	3.3	3.3
Relevant health based guideline	30			10		

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.

Assessment of nitrogen dioxide

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 (e.g. gas heating or cooking) combustion sources, are primary producers of nitrogen oxides.

In terms of health effects, nitrogen dioxide is the only oxide of nitrogen that may be of concern[69]. 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[70]. Asthmatics, the elderly and people with existing cardiovascular and respiratory disease are particularly susceptible to the effects of nitrogen dioxide[71]

[68] WHO 2000c, *Guidelines for Air Quality*, World Health Organisation, Geneva
[69] WHO 2000b, *Transport, environment and health*, WHO Regional Publications, European Series, No. 89.
[70] WHO 2013b, *Health Effects of Particulate Matter, Policy implications for countries in eastern Europe, Caucasus and central Asia*, WHO Regional Office for Europe.
[71] Morgan, G, Broom, R & Jalaludin, B 2013, *Summary for Policy Makers of the Health Risk Assessment on Air Pollution in Australia*, Prepared for National Environment Protection Council by the University Centre for Rural Health, North Coast, Education Research Workforce, A collaboration between The University of Sydney, Southern Cross University, The University of Western Sydney, The University of Wollongong, Canberra.

[72]. 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[73] 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[74] [75] [76]. 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[77] 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[78].
- 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[79] 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 were assessed 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).

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[72] NEPC 2010, *Review of the National Environment Protection (Ambient Air Quality) Measure*, Discussion Paper, Air Quality Standards, National Environmental Protection Council.
[73] NEPC 2003, *National Environment Protection (Ambient Air Quality) Measure*, National Environment Protection Council
[74] Golder 2013, Exposure Assessment and Risk Characterisation to Inform Recommendations for Updating Ambient Air Quality Standards for PM2.5, PMN10, O3, NO2, SO2, Golder Associates for National Environment Protection Council Service Corporation.
[75] NEPC 2010, *Review of the National Environment Protection (Ambient Air Quality) Measure*, Discussion Paper, Air Quality Standards, National Environmental Protection Council.
[76] NEPC 2014, *Draft Variation to the National Environment, protection (Ambient Air Quality) Measure*, Impact Statement, National Environment Protection Council.
[77] USEPA 2015, *Integrated Science Assessment for Oxides of Nitrogen–Health Criteria, Second External Review Draft*, National Center for Environmental Assessment-RTP Division, Office of Research and Development, U.S. Environmental Protection Agency.
[78] COMEAP 2015, *Statement on the Evidence for the Effects of Notrogen Dioxide on Health*, Committee on the Medical Effects of Air Pollutants.
[79] WHO 2013b, *Health Effects of Particulate Matter, Policy implications for countries in eastern Europe, Caucasus and central Asia*, WHO Regional Office for Europe.

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 (i.e. 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 10-26 presents a summary of the maximum predicted cumulative one-hour average concentration of nitrogen dioxide the modelled scenarios.

Table 10-26 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
2027			
Maximum	348.5	307.9	
2037			
Maximum	375.1	334.9	321.5
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 E** (Air quality technical report) 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.

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 lowest observed adverse effect level (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)[80]. On this basis, the NEPC (and OEH) chronic guideline is protective of adverse health effects in all individuals, including sensitive individuals.

Table 10-27 presents a summary of the maximum predicted cumulative annual average concentration of nitrogen dioxide for the modelled scenarios.

Table 10-27 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**
2026			
Maximum	42.5	40.7	N/A
2036			
Maximum	44.8	42.7	42.2
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.

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 2026 and 2036.

The approach adopted for the assessment of incremental exposures is consistent with that adopted for particulates as outlined in **section 5.9.5**. 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 10-28 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[81] and are considered to be robust.

[80] NEPC 1998, *National Environment Protection (Ambient Air Quality) Measure - Revised Impact Statement*, National Environment Protection Council.
[81] Golder 2013, *Exposure Assessment and Risk Characterisation to Inform Recommendations for Updating Ambient Air Quality Standards for PM2.5, PMN10, O3, NO2, SO2*, Golder Associates for National Environment Protection Council Service Corporation.

Table 10-28 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/m³ 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
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[82]
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[83] [84]

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 10-29 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 2026 and 2036, including the cumulative scenario (refer to Annexure A to **Appendix F** (Human health technical report) 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 10-5 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 to **Appendix F** (Human health technical report) 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 5-16**.

Calculations relevant to the characterisation of risks associated with changes in nitrogen dioxide concentrations in the community are presented in Annexure D of **Appendix F** (Human health technical report). **Table 10-30** 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 2026 and 2036. All calculations relevant to the LGAs, including calculation for each individual suburb considered in the LGAs, are presented in Annexure E of **Appendix F** (Human health technical report).

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[82] EPHC 2010, *Expansion of the multi-city mortality and morbidity study, Final Report*, Environment Protection and Heritage Council.
[83] Golder 2013, *Exposure Assessment and Risk Characterisation to Inform Recommendations for Updating Ambient Air Quality Standards for PM2.5, PMN10, O3, NO2, SO2*, Golder Associates for National Environment Protection Council Service Corporation.
[84] Jalaludin, B, Khalaj, B, Sheppeard, V & Morgan, G 2008, 'Air pollution and ED visits for asthma in Australian children: a case-crossover analysis', *Int Arch Occup Environ Health*, vol. 81, no. 8, Aug, pp. 967-974.

Table 10-29 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)
2026 – with project			
Maximum residential	2×10^{-5}	3×10^{-6}	2×10^{-5}
Maximum workplace	1×10^{-5}	2×10^{-6}	2×10^{-5}
Maximum childcare and schools	7×10^{-6}	1×10^{-6}	1×10^{-5}
Maximum aged care	4×10^{-6}	7×10^{-7}	5×10^{-6}
Maximum hospitals/medical	2×10^{-6}	4×10^{-7}	3×10^{-6}
Maximum open space	4×10^{-6}	7×10^{-7}	5×10^{-6}
Maximum from sensitive receptors	2×10^{-5}	3×10^{-6}	2×10^{-5}
2036 – with project			
Maximum residential	1×10^{-5}	2×10^{-6}	2×10^{-5}
Maximum workplace	1×10^{-5}	2×10^{-6}	2×10^{-5}
Maximum childcare and schools	6×10^{-6}	1×10^{-6}	9×10^{-6}
Maximum aged care	3×10^{-6}	5×10^{-7}	4×10^{-6}
Maximum hospitals/medical	4×10^{-6}	7×10^{-7}	6×10^{-6}
Maximum open space	5×10^{-6}	1×10^{-6}	8×10^{-6}
Maximum from sensitive receptors	1×10^{-5}	2×10^{-6}	2×10^{-5}
2036 – cumulative			
Maximum residential	9×10^{-6}	2×10^{-6}	1×10^{-5}
Maximum workplace	2×10^{-5}	3×10^{-6}	2×10^{-5}
Maximum childcare	7×10^{-6}	1×10^{-6}	1×10^{-5}
Maximum aged care	2×10^{-6}	4×10^{-7}	3×10^{-6}
Maximum hospitals/medical	9×10^{-7}	2×10^{-7}	1×10^{-6}
Maximum open space	6×10^{-6}	1×10^{-6}	9×10^{-6}
Maximum from sensitive receptors	2×10^{-5}	3×10^{-6}	2×10^{-5}
Negligible risks	$<1 \times 10^{-6}$		
Tolerable/acceptable risks	$\geq 1 \times 10^{-6}$ and $\leq 1 \times 10^{-4}$		
Unacceptable risks	$>1 \times 10^{-4}$		

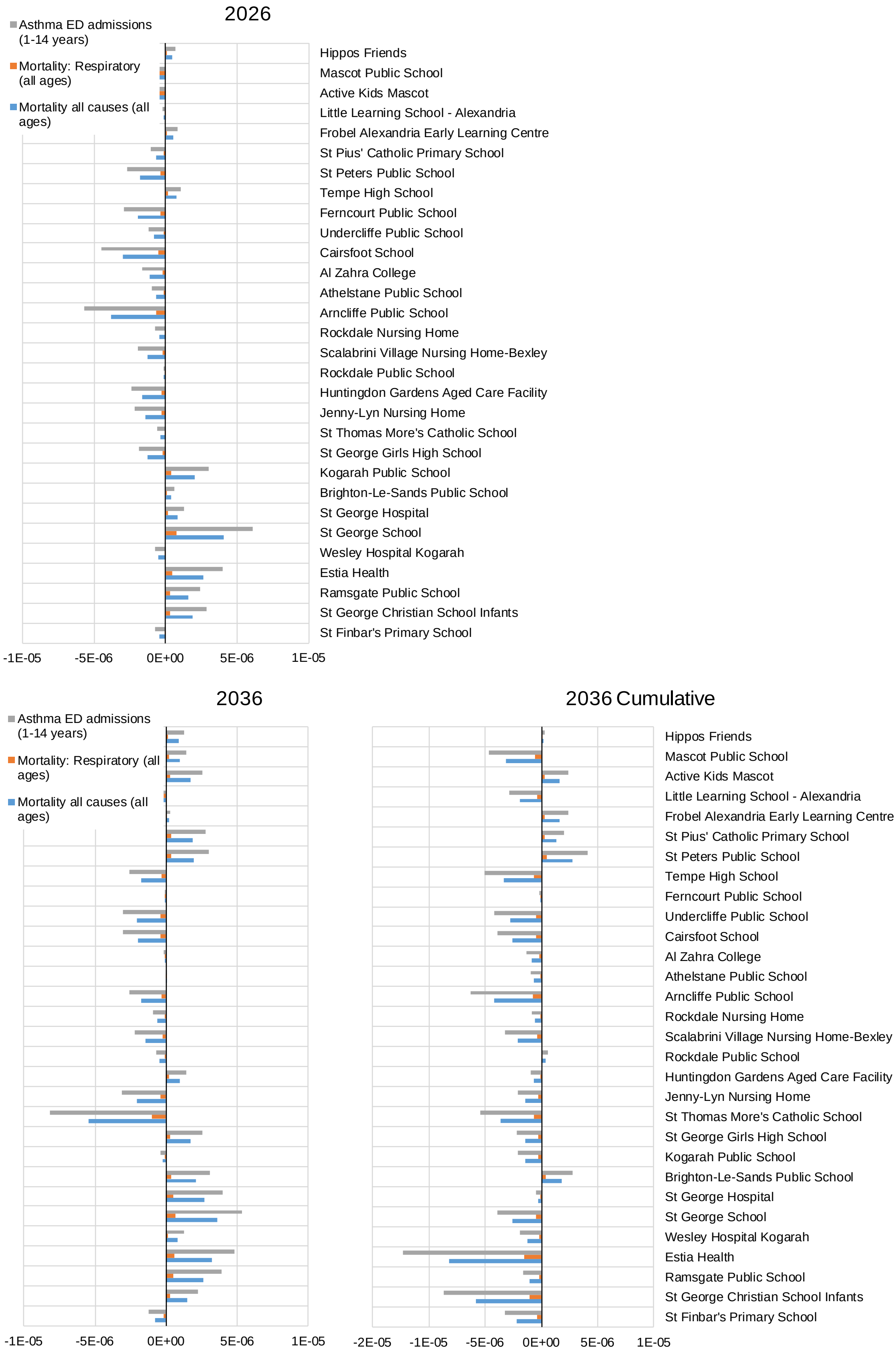

Figure 10-5 Change in calculated risk for key health endpoints associated with changes in nitrogen dioxide concentrations at community receptors (2026 and 2036)

Table 10-30 Calculated changes in incidence of health effects in population associated with changes in NO_2 concentrations

LGA	Change in population incidence number of cases					
	2026			2036		
	Mortality – All Causes	Mortality – Respiratory	Morbidity – Asthma ED Admissions	Mortality – All Causes	Mortality – Respiratory	Morbidity – Asthma ED Admissions
	All ages	All ages	1-14 years	All ages	All ages	1–14 years
With project						
Strathfield - Burwood - Ashfield LGA	-0.00026	-0.000050	-0.000078	-0.00011	-0.000022	-0.000034
Sydney Inner City LGA	-0.000057	-0.000010	-0.0000049	-0.00078	-0.00014	-0.000067
Marrickville - Sydenham - Petersham LGA	-0.00093	-0.00016	-0.00018	-0.0013	-0.00023	-0.00026
Canterbury LGA	-0.0000089	-0.0000016	-0.0000026	-0.00018	-0.000034	-0.000053
Botany LGA	-0.0024	-0.00041	-0.00053	-0.0041	-0.00071	-0.00091
Kogarah - Rockdale LGA	0.0011	0.00018	0.00021	0.00030	0.000051	0.000060
Hurstville LGA	0.000024	0.0000041	0.0000049	0.000031	0.0000053	0.0000063
Total for all LGAs	-0.0026	-0.00045	-0.00058	-0.0062	-0.0011	-0.0013
Cumulative						
Strathfield - Burwood - Ashfield LGA				-0.000061	-0.000012	-0.000018
Sydney Inner City LGA				-0.00063	-0.00011	-0.000054
Marrickville - Sydenham - Petersham LGA				-0.00018	-0.000031	-0.000035
Canterbury LGA				-0.000043	-0.0000080	-0.000013
Botany LGA				-0.0033	-0.00057	-0.00073
Kogarah - Rockdale LGA				-0.0056	-0.00094	-0.0011
Hurstville LGA				-0.0000052	-0.00000088	-0.0000011
Total for all LGAs				-0.0098	-0.0017	-0.0020

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

Assessment of particulate matter

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).

The health effects of particulate matter is provided in **Appendix F** (Human health technical report).

Review of the calculated changes in risk indicates the following in relation to impacts associated with the expected operation of the project in 2026 and 2036, including the cumulative scenario:

- A number of the calculated individual risks as shown in **Figure 10-5** 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 less than $1x10^{-4}$ and considered to be 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 0.001 to 0.11 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 2026 and 2036 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 two LGAs (Kogarah - Rockdale and Hurstville) 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 10-30** 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 of **Appendix F** (Human health technical report). Review of the incidence calculated for the individual suburbs indicates that these predominantly relate to small decreases in health incidence with some suburbs showing an increase. The largest increase in health incidence for any individual suburb is less than 0.1 cases. Hence there are no individual suburbs within the LGAs where there is a change incidence that is of significance or would be measurable.

Elevated receptors

Appendix E (Air quality technical report) 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 10 metres, 20 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, 20 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, 20 metres and 30 metres height has focused on the cumulative scenario in the year 2036 where impacts from the F6 Extension, Western Harbour Tunnel and Warringah Freeway Upgrade, Beaches Link and Gore Hill Connection, Sydney Gateway and WestConnex projects are included. The maximum change in $PM_{2.5}$ relevant to this scenario has been evaluated. As the approach adopted in **Appendix E** (Air quality technical report) is a screening level assessment no other pollutants have been evaluated.

Table 10-31 presents the calculated risks associated with the maximum predicted change (based on unconstrained and worst case traffic conditions) in $PM_{2.5}$ concentrations at a height of 10 metres, 20 metres and 30 metres above ground level throughout the study area. It should be noted that it was not necessarily the case that there are existing buildings at these heights at the RWR receptor locations, however this analysis has been included to evaluate potential future development.

Table 10-31 Calculated individual risk associated with changes in $PM_{2.5}$ concentrations – cumulative scenario in 2036 for elevated receptors

Health endpoint	Maximum calculated		
	10 m height	**20 m height**	**30 m height**
Annual average concentration			
$PM_{2.5}$ ($\mu g/m^3$)	1.4	0.23	0.30
Primary health indicators: $PM_{2.5}$			
Mortality all causes (long term effects, ages 30+)	8×10^{-5}	1×10^{-5}	2×10^{-5}
Cardiovascular hospitalisations (short term effects, ages 65+)	1×10^{-4}	2×10^{-5}	2×10^{-5}
Respiratory hospitalisations (short term effects, ages 65+)	2×10^{-5}	4×10^{-6}	5×10^{-6}
Secondary health indicators: $PM_{2.5}$			
Mortality all causes (short term effects, all ages)	6×10^{-6}	1×10^{-6}	1×10^{-6}
Mortality, cardiopulmonary (long term effects, ages 30+)	7×10^{-5}	1×10^{-5}	2×10^{-5}
Mortality, cardiovascular (short term effects, all ages)	2×10^{-6}	3×10^{-7}	4×10^{-7}
Mortality, respiratory (short term effects, all ages)	1×10^{-6}	2×10^{-7}	2×10^{-7}
Asthma emergency department hospitalisations (1–14 years)	3×10^{-5}	4×10^{-6}	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	$>1 \times 10^{-4}$		

The calculations presented in **Table 10-31** indicate the following:

- The maximum change in PM2.5 decreases by around 5 fold with increasing height from 10 to 30 metres.
- All calculated risks at elevated receptors, at 10 metres, 20 metres and 30 metres height are considered to be in the range of tolerable/acceptable risk.

Assessment of regulatory worst-case scenario

Table 10-32 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 10-32 Maximum calculated risks associated with short-term residential exposure changes in $PM_{2.5}$ concentrations: regulatory worst case 2036 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	3×10^{-5}	6×10^{-6}	1×10^{-6}	5×10^{-7}	3×10^{-7}	7×10^{-6}
Increase in risk for 1 day of worst-case emissions (24 hours which is highly conservative)	4×10^{-7}	8×10^{-8}	2×10^{-8}	7×10^{-9}	5×10^{-9}	9×10^{-8}
Increase in risk assuming worst-case event occurs 1 day each week (52 days per year)*	2×10^{-5}	4×10^{-6}	1×10^{-6}	3×10^{-7}	2×10^{-7}	5×10^{-6}
Maximum annual risk – expected conditions plus worst-case event**	5×10^{-5}	1×10^{-5}	2×10^{-6}	8×10^{-7}	5×10^{-7}	1×10^{-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) 1 day per week

Review of the maximum calculated changes in risk associated with short-term changes in $PM_{2.5}$ (**Table 10-32**) 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 $1x10^{-4}$ and hence there are no unacceptable risks identified in the community surrounding the project
- The calculated maximum individual risks are in the range $1x10^{-6}$ to $1x10^{-4}$ 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.

Sensitivity analysis

A sensitivity analysis was undertaken to determine the impact from emissions where the emission limit for the ventilation outlets were reached for at least 1 hour every day. **Figure 10-6** shows the different contributions to $PM_{2.5}$ concentrations for the expected traffic conditions (for background plus traffic), the sensitivity test (1 hour per day $PM_{2.5}$ concentrations reach the emission limit) and regulatory worse case (24 hours per day of $PM_{2.5}$ concentrations reaching the emission limit) for the 2036 do something cumulative scenario. This figure essentially shows that all assumptions for ventilation outlets result in relatively small contributions compared with the total.

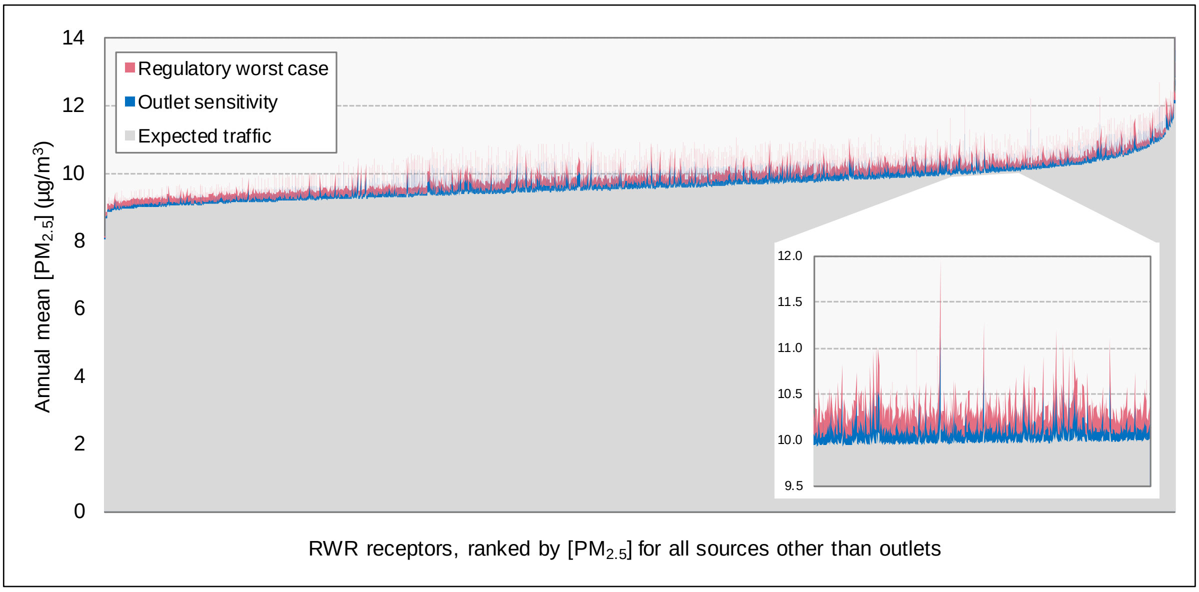

Figure 10-6 Results of sensitivity tests for ventilation outlets – total annual mean PM2.5 concentration at RWR receptors (2036-DSC scenario)

In relation to potential impacts on health, risk calculations have been undertaken for the change in $PM_{2.5}$ (for the primary health endpoints) and NO_2. These risk calculations have been undertaken for the 2036 cumulative scenario, consistent with the scenario evaluated in **Appendix E** (Air quality technical report).

Table 10-33 presents the maximum calculated risk, from all receptors, associated with the change in $PM_{2.5}$ and NO_2, for the expected traffic conditions and the sensitivity test.

Table 10-33 Calculated individual risk associated with maximum changes in $PM_{2.5}$ and NO_2 concentrations: sensitivity test – 2036 cumulative scenario

Health endpoint	Maximum calculated	
	Expected traffic	Sensitivity test
Primary health indicators: $PM_{2.5}$		
Mortality all causes (long term effects, ages 30+)	2×10^{-5}	6×10^{-5}
Cardiovascular hospitalisations (short term effects, ages 65+)	3×10^{-5}	7×10^{-5}
Respiratory hospitalisations (short term effects, ages 65+)	6×10^{-6}	2×10^{-5}
Health indicators: NO_2		
Mortality all causes (short term effects, all ages)	1×10^{-5}	2×10^{-5}
Mortality, respiratory (short term effects, all ages)	3×10^{-6}	4×10^{-6}
Asthma emergency department hospitalisations (1–14 years)	2×10^{-5}	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	$>1 \times 10^{-4}$	

Review of the maximum calculated changes in risk associated with changes in $PM_{2.5}$ and NO_2 concentrations relevant to the sensitivity test scenario evaluated indicates the following:

- For NO_2, the sensitivity test shows a very small increase in the maximum calculated risks. The calculated risks however remain low and are considered tolerable/acceptable.
- For $PM_{2.5}$, the sensitivity test shows a small increase in the maximum calculated risks. The calculated risks however remain low and are considered tolerable/acceptable.

On the basis of the above, emissions from the ventilation outlets, where the sensitivity test scenario is considered, has the potential result in a small increase in NO_2 and $PM_{2.5}$ risks, however the maximum individual risks associated with $PM_{2.5}$ and NO_2 are considered to be tolerable/acceptable.

Odour impacts

The changes in the levels of three odorous pollutants as a result of the project, and the corresponding odour assessment criteria from the Approved Methods for the Modelling and Assessment of Air Pollutants in NSW[85] are presented in **Chapter 9** (Air quality). It was concluded that that maximum 1-hour concentration of each pollutant was an order of magnitude below the corresponding odour assessment criterion in the Approved Methods.

10.4.3 Noise and vibration impacts on community health

The worst case assessment predicts that noise criteria will be exceeded at a number of properties adjacent to the project without mitigation measures, with 107 properties considered appropriate for mitigation measures due to operational noise. These properties are listed in **Appendix G** (Noise and vibration technical report) and shown in **Figure 10-7**. The worst-case levels estimated are sufficiently high for some receptors that health impacts are likely to occur. The main health effects in relation to road traffic noise are annoyance, sleep disturbance, cardiovascular disease, stroke and memory/concentration (cognitive) effects. In addition, impacts on the use and enjoyment of outdoor areas due to increased road noise may result in increased levels of stress at individual properties.

The criteria for consideration of noise mitigation from operational noise was either if the noise criteria was exceeded by 2.0 dB(A) or if the cumulative noise exceeded the noise criteria by 5 dB(A) and the receptor is impacted by the project.

The use of at or near source noise treatments would be preferred for the 107 receptors considered appropriate for mitigation measures during operation. Receptors identified as requiring at-property construction or operational noise mitigation will be identified and offered treatment prior to commencement of construction works that affects them. In-property treatments are not preferred as they have the potential to result in the loss or reduced use of outdoor areas for receptors, which has been shown to reduce wellbeing and increase levels of stress.

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 health effects (as discussed above) which will also need to be managed/considered.

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[85] NSW EPA (2016). Approved Methods for the Modelling and Assessment of Air Pollutants in NSW. NSW Environment Protection Authority, Sydney. http://www.epa.nsw.gov.au/resources/epa/approved-methods-for-modelling-and-assessment-of-air-pollutants-in-NSW-160666.pdf

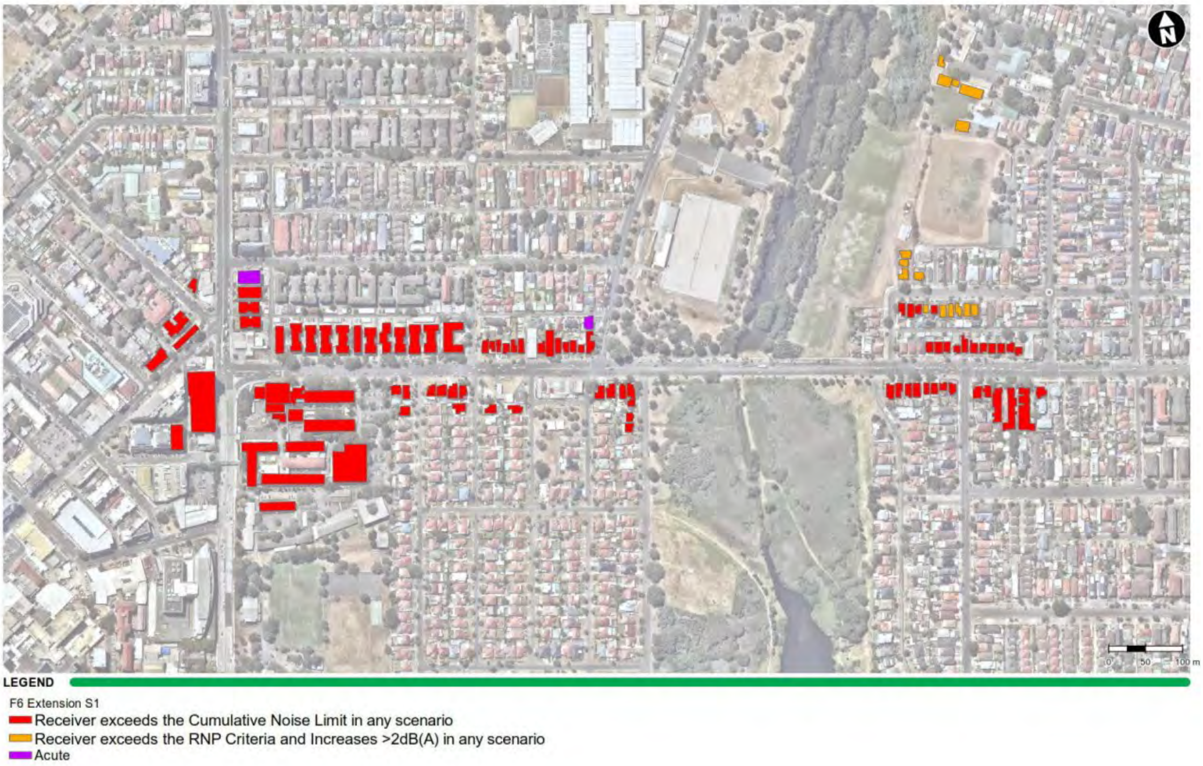

Figure 10-7 Receptors eligible for the consideration of noise mitigation

10.4.4 Dangerous goods and substances

Storage and handling

Dangerous goods and hazardous substances stored, used and transported for the project during operation would be limited and may include coagulants, polymers, acid and bases. Additional small quantities of other hazardous materials may occasionally be required on site to support maintenance activities.

The regulations and safe practices described for the construction phase of the project would also apply to the operational stage (refer to **section 10.3.3**).

Transport

Dangerous goods and hazardous substances are not allowed to be transported within prohibited areas, in accordance with Road Rules 2014 – Regulation 300-2: NSW rule: carriage of dangerous goods in prohibited areas (Regulation 300-2). Prohibited areas are listed under Regulation 300-2 and include Sydney's major tunnels.

The project tunnels would be listed as a prohibited area under Regulation 300-2 prior to the commencement of the operation of the project. Signage would be provided near tunnel entry portals advising of applicable restrictions to ensure compliance with Regulation 300-2.

10.4.5 Public safety risks to the community

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 the following sections.

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

Storage, handling and transport of dangerous goods

All materials will be stored and transported in accordance with the relevant legislation and codes (refer to **section 10.4.4**. Risks to public safety are therefore considered to be low.

Traffic incidents in the tunnels

Any road project carries an inherent risk of vehicle collision associated with its operation. The potential for incidents and crashes to occur is a function of:

- The design of the project
- The type and volumes of traffic using the project
- Driving conditions, including light conditions
- Human factors, including compliance with road rules, attention to driving conditions, driver behaviour and fatigue
- Vehicle failure and breakdown.

The project has been designed to provide for efficient, free-flowing traffic in the tunnels with physical capacity to accommodate predicted traffic volumes. The design has incorporated all feasible and reasonable design measures in relation to geometry, pavement, breakdown bays, lighting and signage. The design is consistent with current Australian Standards, road design guidelines and industry best practice, inherently minimising the likelihood of incidents and crashes.

Tunnel features designed to minimise the disruption caused by incidents and crashes include:

- Height detection system prior to the tunnel entry portals
- Tunnel barrier gates to prevent access in the event of tunnel closure
- Closed-circuit television (CCTV) throughout the tunnel and approaches
- Adjustable speed signs
- Appropriately spaced breakdown bays and emergency telephones.

The project has also been designed to meet appropriate fire and life safety requirements in the event of an incident or accident in the tunnel, as described in **Chapter 6** (Project description). Consultation has been undertaken and would be ongoing with Fire and Rescue NSW and other emergency services to ensure the fire and life safety requirements are achieved.

Each project tunnel would be one-directional, reducing the risk of crashes through head-on collisions and simplifying smoke management and egress requirements. The transport of dangerous goods and hazardous substances would be prohibited through the mainline tunnels and entry and exit ramps, reducing the risk of very large fires or the release of toxic materials in the tunnel.

Other fire and life safety aspects that would be incorporated into the project include:

- Public address systems to manage evacuation processes
- Multiple pedestrian cross-passages between the mainline tunnels and longitudinal egress passages along the entry and exit ramps, to allow pedestrians to exit the tunnel and ramps in the event of a major incident (refer to **Chapter 6** (Project description)). Cross-passages would cater for egress for people with disabilities; therefore, stairs or ramps with steep grades would be limited, or alternative safe holding zones would be provided where necessary
- Automatic fire and smoke detection within the tunnels
- Longitudinal ventilation to ‘push’ smoke in the direction of traffic flow away from the fire source towards a ventilation facility or tunnel portal
- A water deluge system that would be activated manually or automatically at the fire source
- Structures, linings and services that would be fire hardened to protect them from fire damage before the activation of the deluge system, or if the deluge system fails.

The likelihood of a fire during operation of the project cannot be entirely removed. Uncontrollable human factors inherently lead to a residual risk of incidents and crashes, although the likelihood of such events would be low.

In the event of an incident, approaching traffic would be prevented from entering the mainline tunnels. Vehicle occupants at the location of the fire and upstream of the fire source would be instructed to stop their vehicles, and exit in the opposite direction through the section of carriageway that would be protected by the smoke management system, or through an exit door to a cross-passage leading to the other (‘non-incident’) mainline tunnel.

Occupants downstream of the fire source would be encouraged to continue driving out of the tunnel. If this is not possible and they are forced to evacuate on foot, egress would be provided via an exit door to a cross-passage leading to the non-incident mainline tunnel. Emergency services would be able to reach the fire source via the non-incident tunnel (by vehicle or foot), or from the upstream direction in the affected tunnel (by foot).

Traffic incidents on surface roads

Traffic incidents on surface roads (including cyclist and pedestrian safety) are considered to pose a moderate risk to public safety, however the design of the project has been developed to inherently minimise the likelihood of incidents and crashes. Surface roads and infrastructure have been designed to provide an efficient and safe road network.

The project will involve a reduction in traffic on some roads. A detailed discussion of the impact of the project on traffic volumes is provided in **Chapter 8** (Traffic and transport).

The traffic reductions would result in the following traffic related benefits:

- Improved traffic flow and intersection performance
- Reduced crash rates
- Improved road safety for pedestrians, cyclists and motorists
- Improved travel times for bus services and motorists.

These traffic-related benefits are expected to result in an improved road safety environment. Section 8.2.5 of **Appendix D** (Traffic and transport technical report) provides further detail about the forecast changes in crash frequency and cost on road sections in the President Avenue intersection and surrounds. Impacts and improvements to air quality and noise are discussed in **Chapter 9** (Air quality), and **Chapter 11** (Noise and vibration).

Pedestrian safety during operation would improve with the provision of the shared cycle and pedestrian pathways. A safe connection over President Avenue would be provided by the shared cycle and pedestrian bridge.

Contamination

The potential for contamination risks to the community during operation is primarily related to contaminated tunnel groundwater ingress, and spills and leaks of dangerous goods or hazardous substances. An assessment of contamination risk within the study area is provided in **Appendix J** (Contamination technical report). Areas within the vicinity of the project that may contain contaminated soil and/or groundwater due to past or present land use practices have been investigated.

During operation, 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.

Groundwater along the tunnel alignment may be impacted by contamination. If contaminated groundwater occurs, it would enter the tunnels and would be treated at the Arncliffe Motorway Operations Complex (MOC1) to meet the appropriate discharge criteria (refer to **Chapter 18** (Surface water and flooding)) prior to discharge to the Cooks River.

Any contaminant spill of oils, lubricants, hydraulic fluids and chemicals from vehicle or plant or a vehicle crash within the project footprint has the potential to pollute downstream waterways, if conveyed to waterways via the stormwater network. The severity of the potential impact depends on the magnitude and/or location of the spill in relation to sensitive receptors, emergency response procedures and/or management controls implemented on site, and the nature of the receiving environment.

For the project, there would be spill containment facilities at the following locations:

- President Avenue water quality basin
- Mainline tunnel sump
- Ancillary facilities site at West Botany Street
- Water treatment plant site at Arncliffe

The proposed spill containment facilities would be designed to manage the potential risks to an acceptable level. Impacts to Scarborough Ponds and Cooks River are therefore likely to be minimal. Impacts and management measures for contaminated runoff and spills are discussed further in **Chapter 16** (Soils and contamination).

Electric and magnetic fields

The Draft Radiation Standard – Exposure Limits for Magnetic Fields[86] is based on a large body of scientific research since 1989. It proposes a series of exposure standards to replace the Interim Guidelines on Limits of Exposure to 50/60 Hz Electric and Magnetic Fields[87].

Although the Draft Radiation Standard has never been finalised and published, the exposure limits presented are typically applied when considering electric and magnetic fields from new development. The project would include the provision of three aboveground substations, one located at Arncliffe Motorway Operations Complex, and two located at Rockdale Motorway Operations Complex. As identified in **Chapter 14** (Property and land use), the project would also require the provision of new high voltage (132kV) utility infrastructure and the relocation, treatment and/or protection of existing high voltage utility infrastructure, within the vicinity of the project.

The detailed design of project substations and high voltage utility infrastructure would ensure that the exposure limits for the general public in the Draft Radiation Standard – Exposure Limits for Magnetic Fields[88] would not be exceeded at the boundary of the substation sites or for high voltage utility infrastructure. Electric and magnetic fields are therefore not expected to pose a significant risk to public safety.

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[86] Australian Radiation Protection and Nuclear Safety Agency (2006) Draft Radiation Standard – Exposure Limits for Magnetic Fields

[87] National Health and Medical Research Council (1989) Interim Guidelines on Limits of Exposure to 50/60 Hz Electric and Magnetic Fields

[88] Australian Radiation Protection and Nuclear Safety Agency December (2006) Draft Radiation Standard – Exposure Limits for Magnetic Fields

Bushfire risks

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 (road surface materials, retaining walls, road barriers) and a significant proportion of the infrastructure is in tunnels. Indirect bushfire risks to the project, including risks related to damage to communications networks or power supply are discussed in **Chapter 25** (Climate change risk and adaption).

Aviation risks

The operational design of the project has considered airspace protection and associated risks and hazards. As discussed in **Chapter 2** (Assessment process) and **section 10.3.4**, under the Airports Act, a 'controlled activity' in relation to a prescribed airspace must not be carried out or caused to be carried out, without the approval of the Secretary of DIRDC or otherwise exempt under the Airspace Regulations.

Australia's Civil Aviation Safety Authority (CASA) has determined that exhaust plumes with vertical velocities exceeding 4.3 metres per second may cause damage to aircraft airframes, or upset an aircraft flying at low levels. Light aircraft, including helicopters, are more likely to be affected by a plume than heavier aircraft cruising at the same altitude.

The exhaust plumes from the ventilation facilities have the potential to penetrate either or both the OLS or PANS-OPS levels. The project has been designed to satisfy requirements set by the DIRDC in relation to erected structures (such as ventilation outlets), equipment manoeuvring and lighting. To determine whether plume rise resulting from the operation of these ventilation facilities would be a controlled activity as defined in section 183 of the Airports Act, a plume rise assessment would be carried out in accordance with the CASA *Advisory Circular Plume Rise Assessments AC 139-5(1) November 2012* prior to the approval and operation of the project.

Aviation hazard lighting may be required on ventilation outlets at Arncliffe and Rockdale. Surface road lighting would include an 'aeroscreen' type lens to minimise upward light spill. Aviation hazard lighting and surface road lighting would be in accordance with the requirements of CASA and Sydney Airport.

Subsidence risks

Surface settlement due to drawdown of groundwater is expected to be negligible along the tunnel alignment other than at the palaeochannels in the vicinity of Spring Street, Bay Street and President Avenue. Preliminary estimates of the ground settlements at these locations are provided in **Chapter 17** (Groundwater and geology). As with construction, settlement monitoring would be undertaken during operation at buildings and infrastructure where exceedances of the settlement criteria are predicted. Settlement monitoring may include the installation of settlement markers or inclinometers. In the event that settlement criteria are exceeded for property and infrastructure during operation, measures would be taken to 'make good' the impact. These measures would be included as part of the OEMP. Any stress or anxiety experienced by property owners would be expected to be temporary.

10.4.6 Social impacts on community health

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. **Chapter 15** (Social and economic) of the environmental impact statement provides details 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 highlighted for the human health assessment.

Traffic and transport

Once the project is complete, it is expected to result in reductions in vehicle delays in a number of areas. There are some areas, however, where traffic volumes would increase, mainly around the President Ave corridor.

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[89]. 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[90]. Reducing travel times and road congestion has the potential to reduce these health impacts.

Public transport

From a public transport network perspective, the project, once complete, is expected to slightly increase bus travel times in 2026 AM peak periods around President Ave intersection, with minimal time changes over other periods. Minimal changes in bus travel times are predicted around the St. Peters interchange.

Shared cycle and pedestrian pathways

Once completed, the project would deliver new pedestrian and cyclist infrastructure project in the form of shared cycle and pedestrian pathways. The shared cycle and pedestrian pathways would be developed from Bestic Street, Brighton-le-Sands south to Civic Avenue, Kogarah through the reinstated Rockdale Bicentennial Park. A dedicated shared bridge would be built over President Avenue as part of the shared cycle and pedestrian pathways.

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.

Access and connectivity

Community severance effects often occur during both construction and operation of major transportation projects due to detours in the local road network, changes to active and public transport routes, and connector roads receiving an increase or decrease in traffic movements. Changes to the road networks may contribute to feelings of community severance and disconnection. The project is not introducing new major surface roadways that would change existing conditions in relation to severance.

Green space

An urban design strategy has been developed for the reinstatement of Rockdale Bicentennial Park (refer to **Appendix C** (Place making and urban design)) in accordance with the urban design objectives and principles for the project.

Upon project completion, the sporting facilities would be reinstated to maintain the same number of fields and level of amenity. Detailed plans for Rockdale Bicentennial Park would be developed in consultation with Bayside Council and Sydney Water.

During operation, the majority of Rockdale Bicentennial Park would be reinstated, including landscaping and reinstated facilities works. A concept design for urban design and landscaping works at Bicentennial Park has been prepared (refer to **Appendix C** (Place making and urban design)). The landscape plan for Rockdale Bicentennial Park would be further developed during detailed design, in consultation with Bayside Council.

Visual impacts

The operation of the 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. These impacts have the potential to increase stress and anxiety for some community members. However in order to mitigate such potential impacts, residual land would be subject to the Urban Design and Landscaping Plan (UDLP) for the project. The plan will detail built and landscape features to be implemented prior to operation of the project.

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[89] Hansson, E, Mattisson, K, Björk, J, Östergren, P-O & Jakobsson, K 2011, *'Relationship between commuting and health outcomes in a cross-sectional population survey in southern Sweden'*, BMC Public Health, vol. 11, no. 1, p. 834.
[90] Hansson, E, Mattisson, K, Björk, J, Östergren, P-O & Jakobsson, K 2011, *'Relationship between commuting and health outcomes in a cross-sectional population survey in southern Sweden'*, BMC Public Health, vol. 11, no. 1, p. 834.

Social equity

The health effects associated with impacts related to transport projects are not equally distributed across 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 along main roadways. The median house prices in the study area are variable, however in most areas, they are consistent with the Sydney average. Some public housing is located in the study area; however, these properties are mixed in with privately owned property such that there are no specific areas with higher populations of public housing tenants. Hence there are no social equity issues identified in relation to the change in air quality in the local community. However, there is an alignment of noise and air impacts along President Avenue and Princes Highway that coincide with increased traffic volumes.

Canterbury Bankstown is the only local government area in the study area identified as disadvantaged, based on the 2016 Census Data - Socio-Economic Index for Australia (SEIFA). However, it is noted that the major air and noise impacts are not located in this local government area. Therefore, the major impacts from the project are not impacting a low socioeconomic local government area.

In relation to broader equity aspects the project, along with approved WestConnex projects (M4-M5 Link, M4 East and New M5), is aimed at improving access to the area from outer lying areas in the south and west. The SEIFA for populations in the outer south and west 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 reduced levels of stress and anxiety.

Economic impacts

It is noted that some local businesses would be adversely impacted by both construction and operational activities, along with other businesses marked for acquisition. This can cause stress for the impacted individuals and lead to health impacts if not appropriately managed. To minimise these impacts the project will include development of a Business Management Plan. This plan will include ways to minimise stress to impacted individuals.

Road tolling

The implementation of road tolls can have direct impacts on the management of congestion, which has an impact on economic productivity, and social elements such as stress, time with family and friends, cost and environmental amenity such as reduced traffic emissions.

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.

An evaluation of road tolling undertaken in **Chapter 15** (Social and economic) found an overall positive impact from the toll road. However, this is undertaken on a regional scale and individual benefits would vary. Road tolling may increase the cost of living for individuals, and lower income households may travel long distances to avoid road tolls. These impacts have the potential to result in increased stress and anxiety for these households.

10.5 Management of impacts

The implementation of environmental management measures for the project would avoid, to the greatest extent possible, risk to public safety and achieve the desired performance outcomes in relation to the hazards identified in **Table 10-1**. Environmental management measures relating to hazards and risk are outlined in **Table 10-34**. Additional management measures relevant to human health are provided in the following chapters:

- Air quality management measures, including the management of air quality and odour during construction and operation – **Chapter 9** (Air quality)
- Noise and vibration management measures – **Chapter 11** (Noise and vibration)
- Social and economic management measures, including the management of construction fatigue – **Chapter 15** (Social and economic)
- Surface water and flooding management measures, including the management of contaminated material and migration off-site – **Chapter 16** (Surface water and flooding)
- Groundwater and geology management measures, including the management of groundwater quality and contamination during construction and operation – **Chapter 17** (Geology and groundwater)

In addition to these measures, a CEMP would be developed for the project and would be supplemented by site and activity specific Safe Work Method Statements.

Table 10-34 Environmental management measures

Impact	Reference	Environmental management measure	Timing
Construction			
Hazardous substances and dangerous goods spill	HS1	A Pollution Incident Response Management Plan (PIRMP) will be prepared for the project. The PIRMP will be prepared in accordance with legislative requirements and include measures to manage hazardous substances and dangerous goods including storage, handling and spill response.	Construction
Improper handling and transport of hazardous substances and dangerous goods	HS2	A Work Health and Safety Plan will be implemented during construction of the project, supplemented by site and activity specific Safe Work Method Statements.	Construction
	HS3	Transport of dangerous goods and hazardous substances will be conducted in accordance with relevant legislation and codes.	Construction Operation
	HS4	An Incident Response Protocol will be developed as part of the Emergency Response Plan for the project and implemented in the event of an accident or incident. The protocol is to detail operational management measures associated with the storage, handling and transport of hazardous substances and dangerous goods, including spill response.	Prior to operation
	HS5	The transport of dangerous goods and hazardous substances will be prohibited through the mainline tunnels and entry and exit ramps during operation.	Operation
Impact of lighting on airport operations	HS6	The project will be constructed and operated in accordance with the design requirements of CASA and the Sydney Airport Master Plan 2033, with respect to lighting.	Construction
	HS7	Should the exhaust plumes or structures at any of the F6 Extension Stage 1 ventilation outlets be assessed as a ‘controlled activity’ under the Airports Act and the Airspace Regulations, then the project will be operated in accordance with conditions of approval from the Secretary of DIRDC.	Operation
Impact of electric and magnetic fields	HS8	The project substations will be designed to ensure that the exposure limits for the general public detailed in by the Draft Radiation Standard (Australian Radiation Protection and Nuclear Safety Agency 2006) will not be exceeded at the boundary of the substation sites.	Detailed design

.

10.6 Environmental risk analysis

An environmental risk analysis was undertaken for health safety and hazards and is provided in **Table 10-35** below.

A level of assessment was undertaken commensurate with the potential degree of impact the project may have on that issue. This included an assessment of whether the identified impacts could be avoided or minimised (for example, through design amendments). Where impacts could not be avoided, environmental management measures have been recommended to manage impacts to acceptable levels.

The residual risk is the risk of the environmental impact after the proposed mitigation measures have been implemented. The methodology used for the environmental risk analysis is outlined in **Appendix O** (Methodologies).

Table 10-35 Environmental risk analysis – Health safety and hazards

Impact	Construction/ operation	Management and mitigation reference	Likelihood	Consequence	Residual risk
Spills and leaks from the storage and transport of dangerous goods and hazardous substances	Construction and operation	HR1, HR2, HR3, HR4, HR5, HR6 OpHR6, OpHR7, OpHR8, OpHR9	Unlikely	Moderate	Low
Potential impacts from fire and safety incidents	Operation	OpHR1, OpHR2, OpHR3, OpHR4, OpHR5	Unlikely	Major	Medium
Exposure to electric and magnetic fields	Operation	OpHR10	Unlikely	Minor	Low
Impacts on aviation safety	Operation	OpHR11, OpHR12	Unlikely	Moderate	Low

11 Noise and vibration

This chapter outlines the potential noise and vibration impacts associated with the project. This chapter is informed by **Appendix G** (Noise and vibration technical report). **Table 11-1** sets out the assessment requirements relevant to the noise and vibration and identifies where the requirements have been addressed in this EIS.

Table 11-1 SEARs - Noise and vibration

Assessment requirements	Where addressed in this EIS
1. The Proponent must assess construction and operational noise and vibration impacts in accordance with relevant NSW noise and vibration guidelines. The assessment must take into consideration and address the redistribution of traffic (including on local feeder roads) and operational plant and equipment, and must include consideration of impacts to sensitive receivers and include consideration of sleep disturbance and, as relevant, the characteristics of noise and vibration (for example, low frequency noise).	Section 11.1.1 Section 11.3 Section 11.4
2. An assessment of construction noise and vibration impacts must include: a) The nature of construction activities (including transport, tonal or impulsive noise generating works and the removal of operational noise barriers, as relevant);	Section 11.3
b) the intensity and duration of noise and vibration impacts (both air and ground borne). This must include consideration of extended impacts associated with ancillary facilities and activities (and the like) and construction fatigue;	Section 11.3 Section 11.3.6
c) the identification of receivers, existing and likely under approved developments, during the construction period;	Section 11.2.1
d) the nature, sensitivity and impact to receivers;	Section 11.3 Section 11.4
e) the need to balance timely conclusion of noise and vibration-generating works with periods of receiver respite, and other factors that may influence the timing and duration of construction activities (such as traffic management);	Section 11.5
f) the potential for works outside standard construction hours, including predicted levels, exceedances, number of potentially affected receivers, and justification for the activity in terms of the *Interim Construction Noise Guideline* (DECCW, 2009);	Section 11.3
g) a cumulative noise and vibration assessment inclusive of impacts from the project (including concurrent project construction activities);	Section 11.3.6
h) a cumulative noise and vibration assessment of the impacts from the project and the construction of other transport infrastructure and development in the vicinity of the project including taking into account the installation and removal of temporary noise walls;	Section 11.3.6
i) details and analysis of the predicted effectiveness of mitigation measures to adequately manage identified impacts, including cumulative impacts as identified in (g) and (h) and a clear identification of residual noise and vibration following application of mitigation measures; and	Section 11.3.5, Appendix G (Noise and vibration technical report)
j) description of how community preferences could be taken into account in the design of mitigation measures and consider tailored mitigation, management and communication strategies.	Appendix G (Noise and vibration technical report)
3. The Proponent must demonstrate that blast impacts are capable of complying with the current guidelines, if blasting is required.	Section 11.3.3
4. The Proponent must assess construction and operation noise and vibration impacts in accordance with relevant NSW noise and vibration guidelines. The assessment must include consideration of impacts to the structural integrity and heritage significance of items (including Aboriginal places and items of environmental heritage) and piped infrastructure, Muddy Creek constructed channel as well as property in	Section 11.3.4, Appendix G (Noise and vibration technical report)

Assessment requirements	Where addressed in this EIS
general.	

11.1 Assessment approach

The Noise and vibration technical report (**Appendix G**) details the approach taken for the noise and vibration assessment. A summary of the approach for the noise and vibration assessment is provided in the following sections.

11.1.1 Policy framework

The following documentation has been used to guide the development and implementation of the noise and vibration impact assessment:

- Construction noise:
  - *Construction Noise and Vibration Guideline* (Roads and Maritime 2016)
  - *Interim Construction Noise Guideline* (ICNG) (DECC 2009)
- Construction vibration:
  - *Assessing Vibration: a technical guideline* (NSW Department of Environment and Conservation (DEC) 2006)
  - *Technical Basis for Guidelines to Minimise Annoyance Due to Blasting Overpressure and Ground Vibration* (Australian and New Zealand Environment and Conservation Council (ANZECC) 1990)
  - DIN 4150:Part 2-1999 Structural vibration – Effects of vibration on structures (*Deutsches Institut für Normung* 1999)
  - DIN 4150:Part 3-1999 Structural vibration – Effects of vibration on structures (*Deutsches Institut für Normung* 1999)
  - Evaluation and Measurement for Vibration in Buildings Part 2, (British Standard (BS) 7385:Part 2-1993) (BS 7385)
  - Explosives − Storage and Use − Part 2: Use of Explosives (Australian Standard (AS) 2187:Part 2-2006) (AS 2187)
- Operational traffic noise:
  - *NSW Road Noise Policy* (RNP) (DECCW 2011)
  - *Noise Criteria Guideline* (NCG) (Roads and Maritime 2015)
  - *Noise Mitigation Guideline* (NMG) (Roads and Maritime 2015)
  - *Noise Model Validation Guideline* (Roads and Maritime 2016)
  - *Application Notes – Noise Criteria Guideline* (Roads and Maritime 2015)
  - *Environmental Noise Management Manual* (ENMM) (Roads and Maritime 2001)
  - *Procedure for Preparing an Operational Noise and Vibration Assessment* (Roads and Maritime 2011)
- Operational noise from fixed facilities:
  - *Noise Policy for Industry* (NPfI) (NSW Environment Protection Authority (NSW EPA) 2017)
- Construction and operation sleep disturbance guidance:
  - *NSW Road Noise Policy* (RNP) (DECCW 2011)
  - *Noise Policy for Industry* (NPfI) (NSW EPA 2017).

The above documents are discussed further in the following sections, including how they have been employed for the purposes of this assessment.

Two other guidelines were referenced by Department of Planning and Environment which are not relevant to the noise impact assessment for the project:

- *Development Near Rail Corridors and Busy Roads – Interim guidelines* (DoP 2008) is for new residential buildings being constructed near rail and road corridors, and do not include requirements or guidance for the assessment of noise impacts of road projects.
- *NSW Sustainable Design Guidelines Version 4.0* (TfNSW 2017) which include guidance for the sustainable design of projects, and do not include requirements or guidance for the assessment of noise impacts of road projects.

11.1.2 Study area

The study area for the noise and vibration assessment was developed according to the impacts likely to arise from project activities, including those related to the construction, operation and cumulative scenarios. The presence and locations of sensitive receptors also informed the boundary of the study area.

The project activities used to inform the study area included:

- Permanent operational infrastructure that would be built for the project
- Construction activities and construction ancillary facilities, including :
  - Arncliffe construction ancillary facility (C1)
  - Rockdale construction ancillary facility (C2)
  - President Avenue construction ancillary facility (C3) including the West Botany Street cut and cover works and the President Avenue intersection surface works
  - Shared cycle and pedestrian pathways east and west construction ancillary facilities (C4 and C5)
  - Princes Highway construction ancillary facility (C6) including Princes Highway/President Avenue intersection upgrade surface works
  - The mainline tunnel alignment
  - Power supply connection
- Construction vehicle routes as described in **section 7.5.4**

Once the potential extent of impacts had been identified based on project activities, the locations of sensitive receptors near construction ancillary facilities and/ or surface works were also considered. Noise sensitive receptors were identified using aerial photography and cadastral information, with discrete land uses determined by ground-truthing. This enabled buildings/ receptors to be classified as residential, commercial, industrial, educational, recreational and other uses (e.g. sheds and the like). Properties that would be acquired and demolished as part of the project were not included.

Groups of receptors potentially affected by the same activities were grouped into Noise Catchment Areas (NCAs). The NCAs have been developed according to the nature of the receptors and local conditions (such as topography and proximity to other major noise sources) and the anticipated extent of discernible noise impacts around each construction and operational activity/ site. A total of 17 NCAs were identified for the study area.

The 17 NCAs together form the noise study area for construction and operational elements of the project. Further detail on the NCAs is provided in **section 11.1.4**. A map of all NCAs is shown in **Figure 11-1** and **Figure 11-2**.

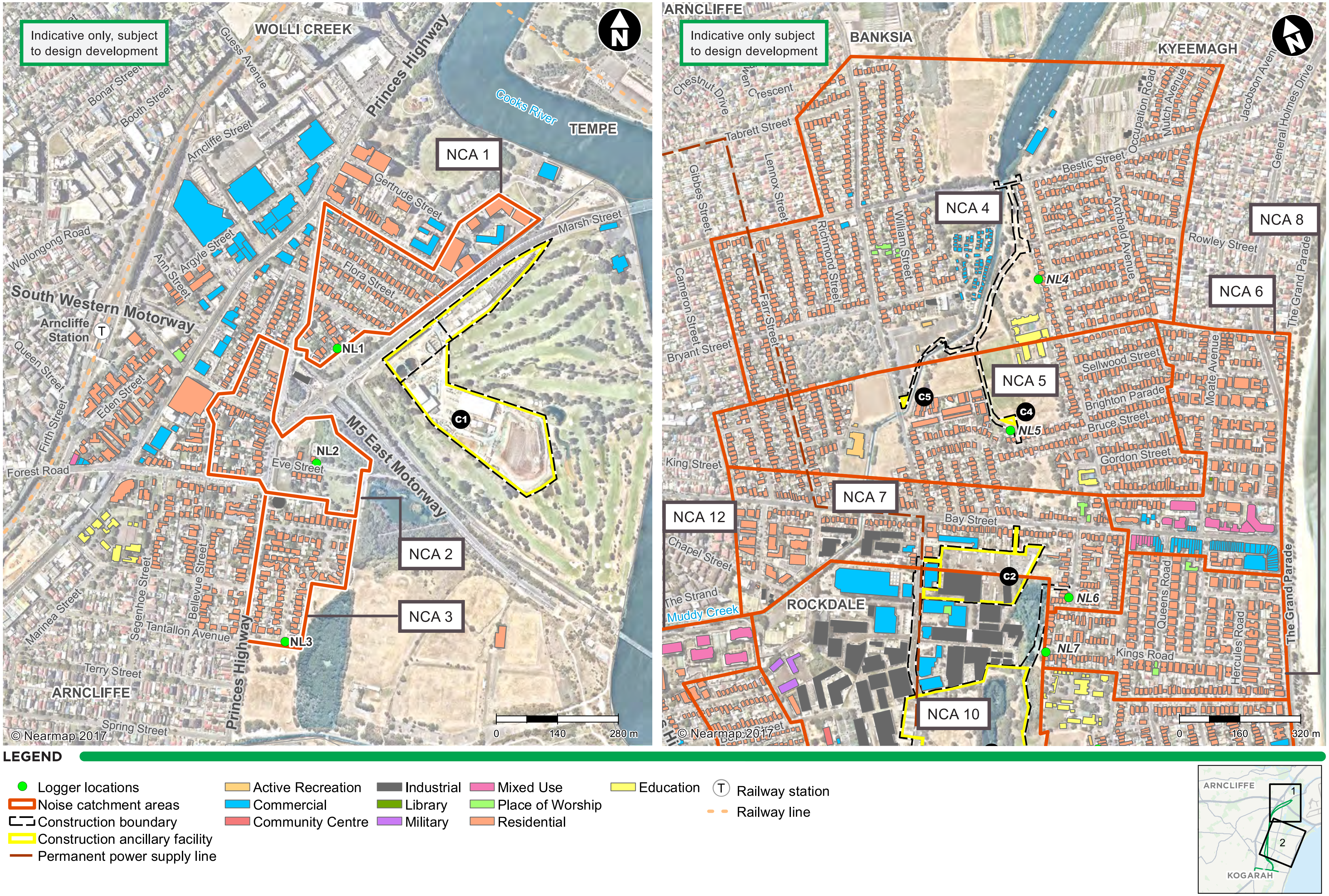

Figure 11-1 Project noise catchment areas and noise logging locations (1 of 2)

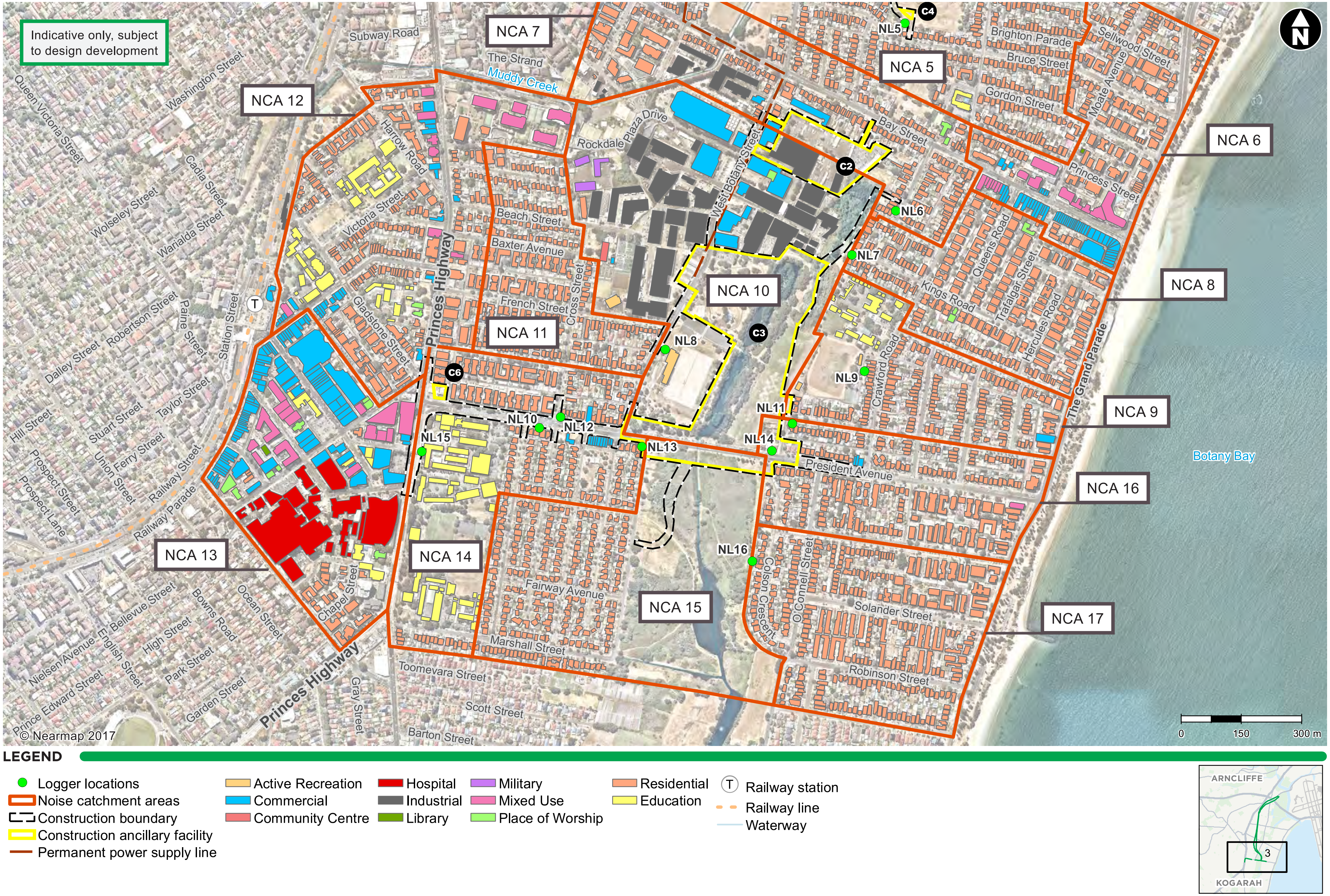

Figure 11-2 Project noise catchment areas and noise logging locations (2 of 2)

11.1.3 Background noise monitoring

Noise monitoring surveys were undertaken in July 2015 (as part of the New M5 Motorway project), November/December 2017 and February 2018 at 16 locations (shown in **Figure 11-1** and **Figure 11-2**). Locations, dates and purposes for each background monitoring event are outlined in Table 3-2 of **Appendix G** (Noise and vibration technical report).

The results of noise monitoring have been processed in accordance with the RNP and NPfI. Noise identified as extraneous and/or data affected by adverse weather conditions (such as strong wind or rain) have been excluded so as to establish representative noise levels in each NCA.

Two types of noise monitoring have been carried out:

- Noise monitoring at representative locations within each NCA. This monitoring data was used to:
  - Establish existing background noise levels for receptors in each NCA
  - Define the appropriate construction Noise Management Levels (NMLs), as per requirements of the ICNG
  - Define the applicable criteria for fixed facilities in accordance with the NPfI
- Traffic noise monitoring at locations that would be affected by road traffic noise during the construction and operation of the project. Monitoring locations NL10, NL12, NL13 and NL14 (shown in **Figure 11-1** and **Figure 11-2**) were used to validate the road traffic noise model by comparing the measured noise levels from these locations with the predicted noise levels provided by the noise model.

11.1.4 Construction noise and vibration assessment methodology

An outline of the construction noise and vibration prediction methodology is provided below. The full methodology is provided in **Appendix G** (Noise and vibration technical report).

Airborne noise assessment

Construction noise management levels

The risk of a community being subject to adverse impacts arising from construction noise is determined by the extent of its emergence above the existing background noise level, the duration of the event and the characteristics of the noise.

Residential receptors

Noise Management Levels for residential receptors are calculated relative to existing background noise levels, and take into account whether construction activities are proposed to be carried out during or outside standard construction hours. The ICNG also identifies the level at which a residential receptor is considered to be 'highly noise affected' (noise exceeding 75 dB(A)).

The method for calculating construction NMLs from existing noise levels (rating background levels (RBL)) for residential receptors is summarised in **Table 11-2**. Further details of this calculation are provided in the Noise and vibration technical report (**Appendix G**) and in the ICNG.

Commercial receptors

The ICNG specifies external NMLs for less sensitive receptor locations, such as businesses and industry. In line with the guidelines, an external NML of 70 dB(A) $LA_{eq(15\text{-minute})}$ has been adopted for commercial premises, while an external NML of 75 DB(A) $LA_{eq(15\text{-minute})}$ has been adopted for industrial premises.

Table 11-2 Calculating construction NMLs for residential receptors

Time of day	NML ($L_{Aeq(15\ minute)}$) (dB(A))	Application
Recommended standard hours: • Monday to Friday 7am to 6pm • Saturday 8am to 1pm • No work on Sunday or public holidays	Noise affected RBL + 10 dB(A)	The noise affected level represents the point above which there may be some community reaction to noise. • Where the predicted or measured $L_{Aeq\ (15\ min)}$ is greater than the noise affected level, the proponent should apply all feasible and reasonable work practices to meet the noise affected level. • The proponent should also inform all potentially impacted residents of the nature of works to be carried out, the expected noise levels and duration, as well as contact details.
Outside recommended standard hours	Noise affected RBL + 5 dB(A)	• A strong justification would typically be required for works outside the recommended standard hours • The proponent should apply all feasible and reasonable work practices to meet the noise affected level • Where all feasible and reasonable practices have been applied and noise is more than 5 dB(A) above the noise affected level, the proponent should negotiate with the community • For guidance on negotiating agreements see section 7.2.2 of the ICNG.
All day	Highly noise affected 75 dB(A)	The highly noise affected level represents the point above which there may be strong community reaction to noise. • Where noise is above this level, the relevant authority (consent, determining or regulatory) may require respite periods by restricting the hours that the very noisy activities can occur, taking into account: 1. times identified by the community when they are less sensitive to noise (such as before and after school for works near schools, or mid-morning or mid-afternoon for works near residences • if the community is prepared to accept a longer period of construction in exchange for restrictions on construction times.

Notes:
1 Noise levels apply at the property boundary that is most exposed to construction noise, and at a height of 1.5 metres above ground level. If the property boundary is more than 30 metres from the residence, the location for measuring or predicting noise levels is at the most noise-affected point within 30 metres of the residence. Noise levels may be higher at upper floors of the noise affected residence.

Other sensitive land uses

The ICNG also provides NMLs for other sensitive receptors, including schools, community centres and outside recreational areas, as summarised below. These have all been adopted as part of this project.

Other sensitive receiver type	Construction NML ($L_{Aeq(15\text{-}minute)}$) (dB(A))
Classrooms at schools and other education institutions	Internal noise level 45 dBA
Hospital wards and operating theatres	Internal noise level 45 dBA
Places of Worship	Internal noise level 45 dBA
Active recreation areas (characterised by sporting activities and activities which generate their own noise or focus for participants, making them less sensitive to external noise intrusion)	External noise level 65 dBA
Passive recreation areas (characterised by contemplative activities that generate little noise and where benefits are compromised by external noise intrusion, eg reading, meditation)	External noise level 60 dBA

Figure 11-3 Construction NMLs for other sensitive receptors

Construction road traffic noise goals

In relation to assessing feasible and reasonable noise mitigation measures, the RNP suggests that noise increases of up to 2 dB(A) are barely perceptible to the average person. Therefore to assess the noise impacts from construction traffic, an initial screening test has been undertaken by evaluating whether existing road traffic noise levels would increase by more than 2 dB(A). Where the predicted noise increase is 2 dB(A) or less, no further assessment is required. However, where the predicted noise increase is greater than 2 dB(A), and the predicted road traffic noise level exceeds the specific criterion for the relevant road category, then noise mitigation should be considered for those receptors affected. The RNP does not require assessment of construction traffic noise impacts to commercial or industrial receptors.

Construction noise sleep disturbance criteria

The ICNG requires a sleep disturbance assessment to be undertaken where construction works are planned to extend over more than two consecutive nights. The guidance provided in the RNP for assessing the potential for sleep disturbance recommends that to minimise the risk of sleep disturbance during the night-time period (10pm to 7am), the $L_{A1,1\ min}$ noise level outside a bedroom window should not exceed the $L_{A90,15\ min}$ background noise level by more than 15 dB(A). The NSW EPA considers it appropriate to use this metric as a screening criterion to assess the likelihood of sleep disturbance.

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

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

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

The sleep disturbance screening and sleep disturbance awakening criterion at each NCA is provided in **Appendix G** (Noise and vibration technical report).

Assessment of impacts

Construction noise prediction

Airborne noise arising from construction of the project have been assessed primarily through the use of noise modelling and takes account of the three-dimensional topography, buildings and structures in the local area.

For the purposes of the assessment, all sensitive receptors within each NCA are assigned the same background noise level and noise management level.

As per the requirements of the ICNG, the assessment provides a 'realistic worst case' based on proposed works within a 15-minute period. This is typically achieved by creating a hypothetical scenario whereby works are simultaneously located at the nearest location to a particular sensitive receptor.

The overall duration of construction noise impacts at any one location would vary depending on the nature of the construction. For example, areas near major construction compounds would experience a longer duration of noise impact compared to those adjacent to short term works, such as the construction of the shared cycle and pedestrian pathways. Actual impact durations may vary depending on site conditions and finalised methodology and would be considered in the Construction Noise and Vibration Management Plan (CNVMP) developed for the project.

Further, 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 levels, the time at which the construction works are undertaken, and the character of the noise or vibration emissions.

Construction road traffic noise

Construction road traffic noise would be generated by vehicles associated with the construction of the project, including heavy vehicles transporting spoil and light vehicle movements generated by construction workers.

For the purposes of the construction traffic impact assessment, the period of construction activity that generates the peak volume of heavy vehicles was assessed to represent the worst case scenario.

Mitigation measures included in the assessment

Detailed noise assessments have been undertaken to determine the construction and operational noise and vibration impacts.

A detailed construction staging plan has been developed to inform duration and timing of construction noise impacts. This information has been used to inform the apparent severity of noise and vibration impacts to the affected sensitive receptors. Construction noise mitigation measures incorporated in the construction plan include:

- Acoustic sheds at Arncliffe and Rockdale (north) to enable 24 hour spoil stockpiling
- Site hoarding at Arncliffe, and Rockdale (north)
- Consideration of site layout and equipment selection.

Specifications have been provided for each of the noise mitigation measures which identify the required noise mitigation effectiveness.

Construction noise mitigation measures would be undertaken through community consultation. Hoarding and construction of acoustic sheds would typically be undertaken early in the construction process, and generally not be subject to community consultation. However, once construction has commenced, a communication process between the affected community and a community liaison officer would be established. This communication chain would allow the community to provide feedback on the noise impacts generated by the project which in turn would allow the construction team to improve management measures and reduce the projects noise and vibration impacts.

Ground-borne noise assessment

Ground-borne noise is that generated by vibrations arising from a ground-based source, typically underground mechanical equipment. These vibrations travel through the ground to the surface where the vibrations can ‘break-out’ as audible noises for surface receptors. Ground-borne noise is typically low-frequency, and if audible is perceived as a ‘rumble’.

As detailed in the ICNG, ground-borne noise goals for residences, are:

- Evening (6.00pm to 10.00pm weekdays): 40 dB(A) $LA_{eq(15\text{-}minute)}$
- Night-time (10:00pm to 7am): 35 dB(A) $LA_{eq(15\text{-}minute)}$.

Vibration

Construction vibration criteria

Structural damage

At present, no Australian Standards exist for the assessment of building damage caused by vibration. As such the German standard, DIN 4150, is used. DIN 4150 provides recommended maximum levels of vibration that reduce the likelihood of building damage caused by vibration. It should be noted that DIN 4150 states that buildings exposed to higher levels of vibration than the recommended limits would not necessarily be damaged.

Human comfort

Humans are sensitive to vibration such that they can detect vibration levels well below those required to cause any risk of damage to a building or its contents. Criteria to avoid annoyance are therefore more stringent than those to prevent structural damage.

Minimum working distances

In order to comply with the structural damage and human comfort criteria discussed above, the minimum working distances presented in **Table 11-3** should not be encroached.

Where specified construction equipment is used at greater distances from receptor locations than the specified working distance, it is deemed that there would be negligible risk of structural damage or impacts to human comfort. Where minimum working distances are not met, more detailed consideration of potential vibration impacts is warranted.

Table 11-3 Recommended minimum working distances for vibration intensive plant

Plant	Rating/description	Minimum working distance (metres)	
		Cosmetic damage[1]	Human response[2]
Vibratory roller	< 50 kN (Typically 1-2 T)	5	15-20
	< 100 kN (Typically 2-4 T)	6	20
	< 200 kN (Typically 4-6 T)	12	40
	< 300 kN (Typically 7-13 T)	15	100
	> 300 kN (Typically 13-18 T)	20	100
	> 300 kN (> 18 T)	25	100
Small hydraulic hammer	(300 kg – 5-12 T excavator)	2	7
Medium hydraulic hammer	(900 kg – 12-18 T excavator)	7	23
Large hydraulic hammer	(1,600 kg – 18-34 T excavator)	22	73
Vibratory pile driver	Sheet piles	2-20	20
Pile boring	≤ 800 mm	2 nominal	N/A
Jack hammer	Handheld	Avoid contact with structure	Avoid contact with structure

Notes:
1 More stringent conditions may apply to heritage or other sensitive structures. Any heritage property would need to be considered on a case by case basis and assessed in accordance with DIN4150:3

Assessment of impacts

Vibration arising from construction it typically site and activity specific. Key determining factors are the vibration energy generated by the source, the predominant frequencies of vibration, the localised geotechnical conditions and the interaction of structures and features that may dampen vibration.

A conservative assessment to determine the likely ground-borne noise impact on a building has been undertaken based on previous measurements of tunnelling activities from road headers and tunnel-boring machines in Sydney, using methods in accordance with *ISO14837: Mechanical vibration - Ground-borne noise and vibration arising from rail systems* .

A qualitative vibration assessment has been undertaken for the project whereby potential vibration impacts for this project have been considered against the recommended minimum working distances for construction plant as summarised in **Table 11-3**. Where there is the potential that vibration-intensive works may be required within these minimum working distances, mitigation such as vibration monitoring at the most affected receptor, has been recommended. A detailed assessment would be required as part of detailed design and the CNVMP developed for the project.

Blasting

Construction blasting can result in two adverse environmental impacts – airblast and ground vibration. The airblast and ground vibration produced may cause human discomfort and may have the potential to cause damage to structures.

With regards to blasting the following guidelines have been considered as part of this assessment:

- ANZECC Guidelines – Technical Basis for Guidelines to Minimise Annoyance due to Blasting Overpressure and Ground Vibration
- AS 2187.2-2006 Explosives - Storage and Use Part 2: Use of Explosives – Appendix J.

The ANZECC guideline has been adopted by the NSW EPA as comfort criteria to minimise annoyance and discomfort to persons at noise sensitive sites (e.g. residences, hospitals, schools etc.) as a result of blasting. The blast vibration criteria identified in the ANZECC guideline are considered conservative and were originally developed to protect communities exposed to long term blasting operations such as mining sites. For projects such as this, with a shorter duration of blasting of two months or less, a higher vibration criterion may be reasonable.

Given the conservative criteria prescribed in the ANZECC guideline, AS 2187.2 was also considered for the assessment. AS 2187.2 recommends ground vibration limits which are consistent with the ANZECC guideline but provides more detail with respect to criteria for human comfort and structural damage. AS 2187.2-2006 notes that building damage (even of a cosmetic nature) has not been found to occur at airblast levels below 133 dB (linear peak).

Blasting criteria

In relation to airblast overpressure, the following criteria have been adopted:

- Less than or equal to 115 dB (linear) peak for 95 per cent of total blasts over 12 months
- Less than 120 dB (linear) peak for any blasts.

For the purposes of this project, the AS 2187.2 ground vibration criteria have been considered and are summarised in **Appendix G** (Noise and vibration technical report). Based on guidance in AS2187.2, a human comfort vibration limit of 10 millimetres per second (peak particle velocity) for blasting operations lasing less than 12 months has been adopted for this project.

Recommended hours and frequency of blasting activities

The ANZECC guideline recommends that:

- Blasting should generally only be permitted during the hours of 9am - 5pm Monday to Saturday. Blasting should not take place on Sundays or public holidays
- Blasting should generally take place no more than once per day.

The recommended restrictions on times and frequency of blasting do not apply to those premises where the effects of the blasting are not perceived by occupants. In addition it should be noted that the recommendation of blasting taking place no more than once per day is taken to mean that one sensitive receptor should not be affected by blasting more than once per day.

For this project, blasting would occur 9am – 5pm Monday to Friday and 9am – 1pm Saturday. No blasting would occur on Sundays or public holidays. Blasting may be undertaken in locations more than 30 metres underground and where the geology is suitable (i.e. not soft ground). Blasting methods can significantly reduce the duration of exposure to noise and vibration for residents and businesses above the tunnels. Blasting would also shorten excavation timeframes.

Permanent power supply

A permanent power supply would be installed from the Ausgrid Canterbury subtransmission substation to the Rockdale (south) motorway operations complex. This would be used to service the operation of the project.

The power supply cable would, for the most part, be constructed and installed during standard construction hours, due to the route mainly following non-arterial roads. However, the following small sections of road may require night works to avoid traffic impacts associated with road closures during the day:

- William Street from the Homer Street intersection to Cameron Avenue
- Wolli Creek Road between Forest Road and Wollongong Road
- Princes Highway, between Tabrett Street and Kimpton Street
- Intersection at Bestic Street and Farr Street
- Bay Street between West Botany St and Farr Street.

The likely construction noise impacts from works which may be undertaken during the night-time period at the above locations have been modelled using SoundPLAN. Impacts from daytime works have been assessed using the Roads and Maritime's Construction Noise Estimator tool, due to the short term impacts (relative to the works associated with the rest of the project).

The power supply route alignment and noise area categories are shown in **Figure 11-4**.

The alignment of the permanent power supply connection would be refined and developed further during detailed design and in consultation with Ausgrid and key stakeholders. The concept design for the permanent power supply connection has been assessed using the following assumptions:

- Works occur along the centre of the road pavement
- Works are setback minimum 10 metres from residents with the exception of within NCA10
- Where noise monitoring has not been carried out, noise area categories detailed in the Construction Noise Estimator have been adopted
- Construction scenarios and associated sound power levels within the Construction Noise Estimator tool have been used
- Construction ancillary facilities are currently not proposed to be used in conjunction with the power line construction works
- Noise impacts on only residential receptors have been assessed
- The works are assumed to occur without hoarding or noise barriers.

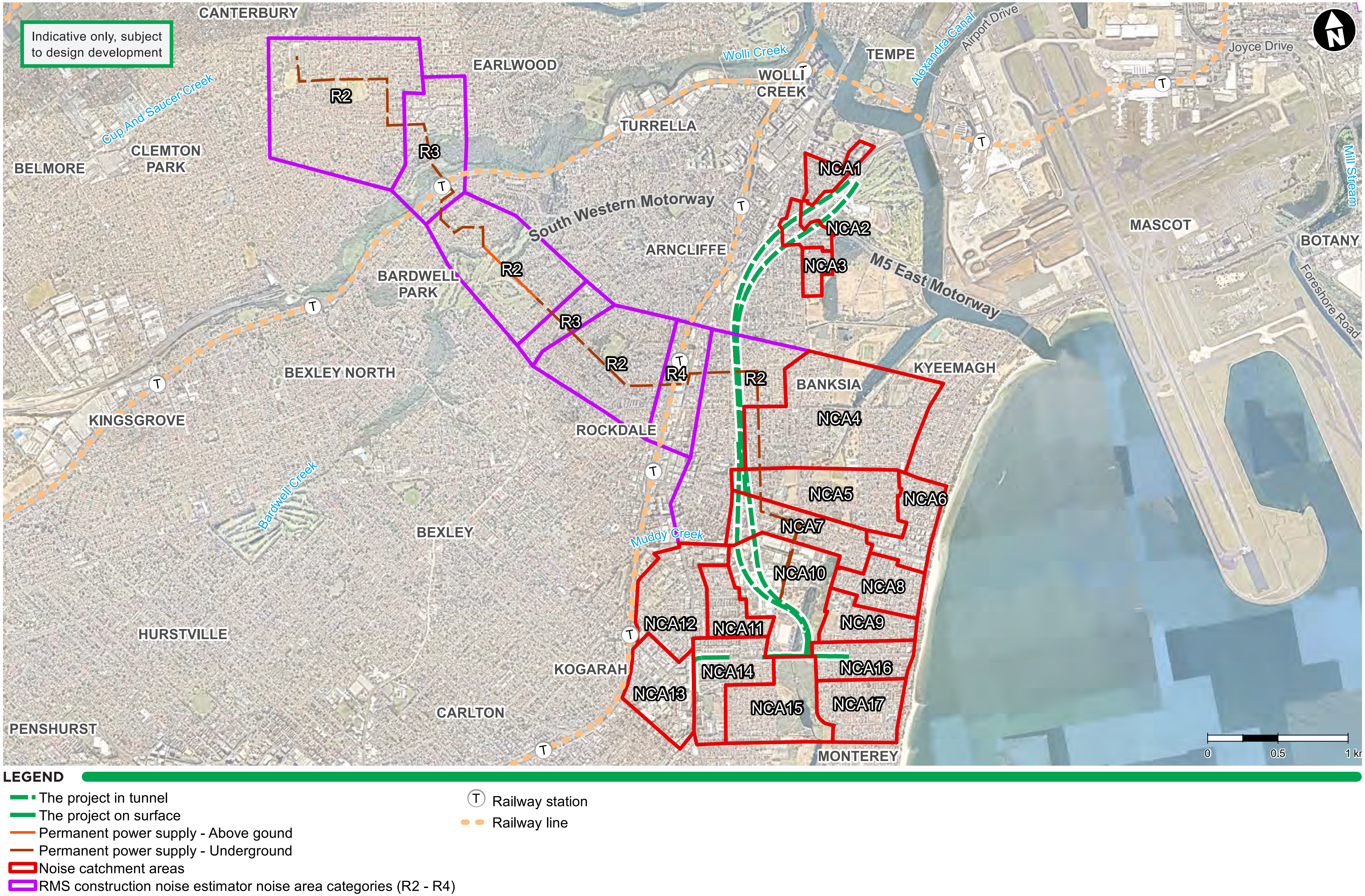

Figure 11-4 Power line alignment and associated noise area categories (R2 - R4)

Provided below in **Table 11-4** is a summary of the NMLs applicable to each noise category area presented in Figure 11-4**.**

Table 11-4 Powerline alignment noise criteria

Area category[2]	Time period	Rating background level	Noise management level
R2	Daytime	45	55
	Evening	40	45
	Night-time	35	40
R3	Daytime	50	60
	Evening	45	50
	Night-time	40	45
R4	Daytime	55	65
	Evening	50	55
	Night-time	45	50

Note 1: NMLs for NCA4, NCA5, NCA7 and NCA10 are defined in **section 11.1.4**.

Note 2: The area categories are defined in AS1055.2-1997 Acoustics – Description and measurement of environmental noise Part 1: General procedures.

11.1.5 Operational noise assessment methodology

An outline of the operational noise prediction methodology is provided below. A detailed description of the methodology is provided in **Appendix G** (Noise and vibration technical report).

Operation noise assessment criteria

Fixed facilities noise criteria

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

- In-tunnel jet fans along the tunnel alignment
- Ventilation facilities at the surface
- Motorway operations complexes
- Electrical substation within the Rockdale South Motorway Operations Complex (MOC3)
- Electrical substation and water treatment plant within the Arncliffe Motorway Operations Complex (MOC1).

The locations of these facilities are shown in **Figure 11-5** and **Figure 11-6**.

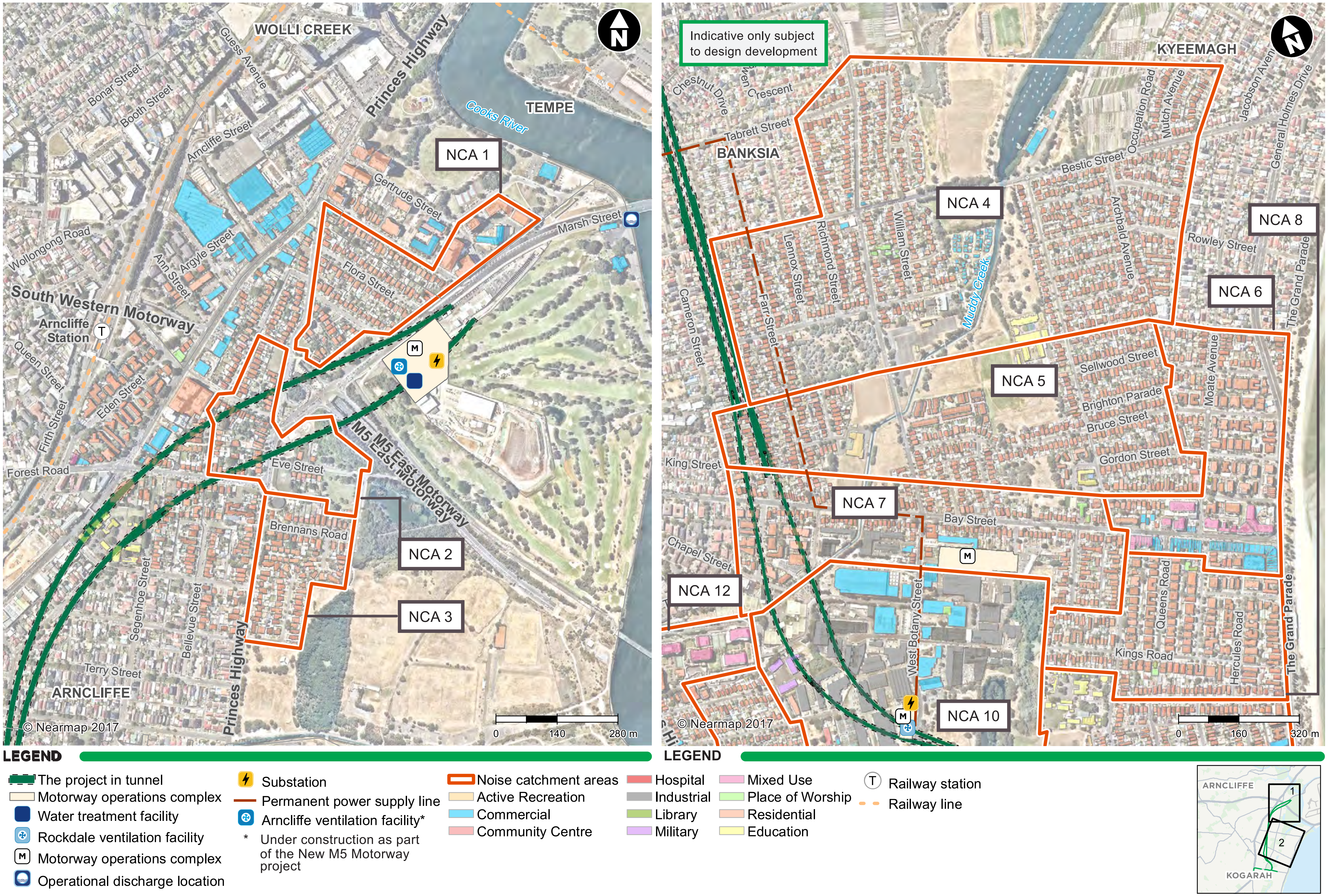

Figure 11-5 Location of fixed facilities (1 of 2)

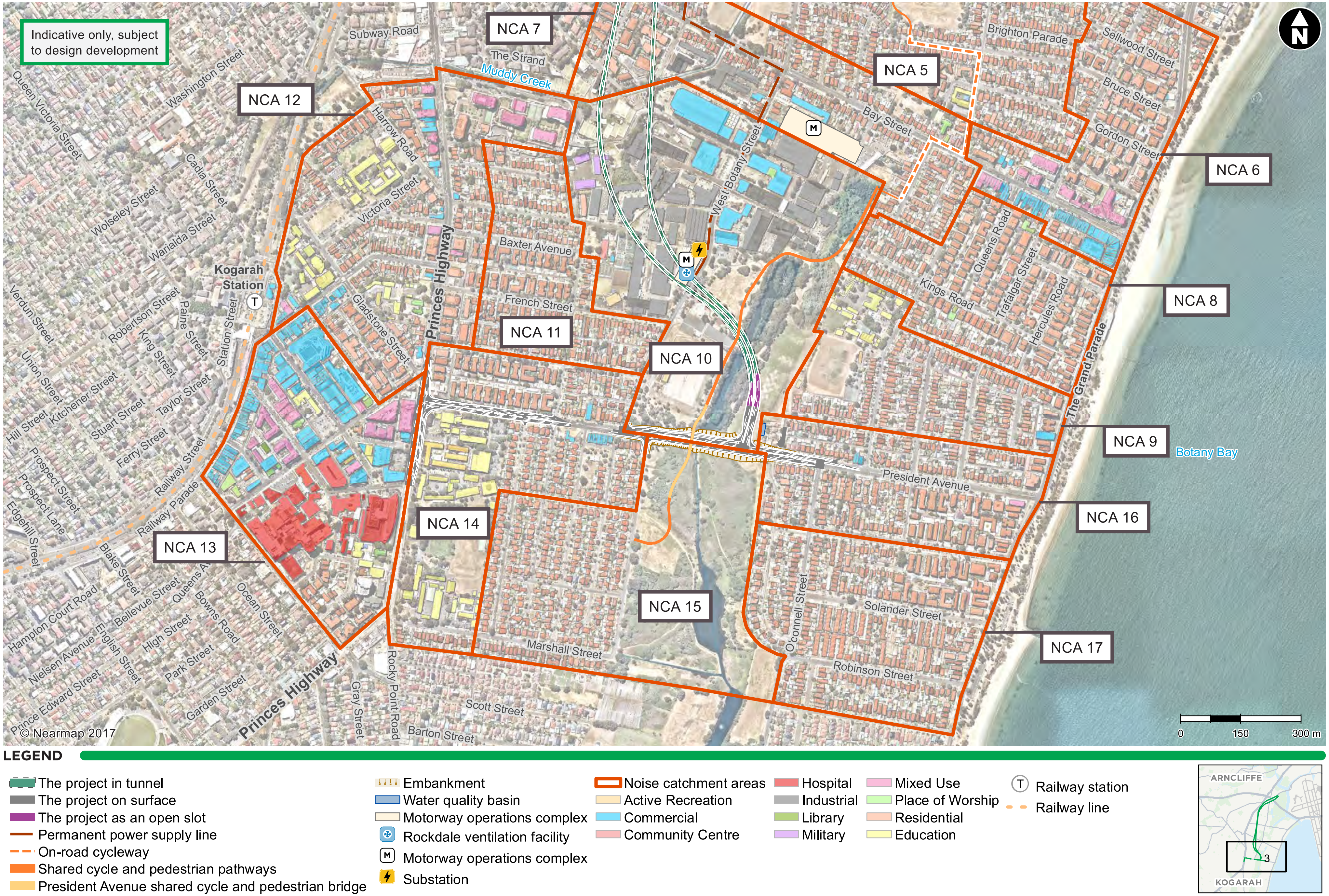

Figure 11-6 Location of fixed facilities (2 of 2)

The NPfI sets two separate noise criteria to meet the following environmental noise objectives:

- To control intrusive noise impacts in the short term for residences
- To maintain noise level amenity for residences and other land uses.

NPfI criteria for intrusive noise

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

The intrusiveness criteria are determined according to the RBLs for sensitive receptor locations nearest to the facilities.

NPfI criteria for amenity

To provide protection against impacts to amenity, the NPfI recommends suitable maximum L_{Aeq} noise levels for particular land uses and activities during the daytime, evening and night-time periods. These are summarised in **Table 11-5**.

The amenity level applicable to a project is equal to the recommended amenity level minus 5 dB(A). However, if cumulative industrial noise is not a necessary consideration at a certain receptor location (eg where no other industries are present or likely to be introduced), then the relevant noise amenity level from **Table 11-5** is assigned as the project amenity noise level. The project amenity level is then converted to a 15 minute period by adding 3 dB(A).

Tonality and NPfI modifying factors

As per the NPfI, penalties to the overall predicted noise levels apply if it is found that they possess annoying characteristics such as tonality, impulsiveness, intermittency, irregularity or dominant low frequency content. This typically takes the form of the addition of 5 dB(A) to the predicted sound power level of the equipment.

Sleep disturbance

In addition to intrusiveness and amenity, the NPfI requires the potential for sleep disturbance to be assessed by considering maximum noise level events during the night-time period. These are where the night-time noise levels at a residential location exceed the following screening levels:

- $L_{Aeq,15min}$ 40 dB(A) or the prevailing RBL plus 5 dB, whichever is the greater, or
- L_{AFmax} 52 dB(A) or the prevailing RBL plus 15 dB, whichever is the greater.

  a detailed maximum noise level assessment should be undertaken. The detailed assessment should cover the maximum noise level, the extent to which the maximum noise level exceeds the rating background noise level, and the number of times this happens during the night-time period.

Table 11-5 Amenity criteria for different receptor types

Receptor type	Indicative noise amenity area	Period	Recommended LAeq noise level (dB(A))	
			Acceptable	Recommended maximum
Residence	Suburban	Day	55	60
		Evening	45	50
		Night	40	45
	Urban	Day	60	65
		Evening	50	55
		Night	45	50
School classroom – internal	All	Noisiest 1-hour period	35	40
Hospital ward				
internal	All	Noisiest 1-hour period	35	40
external	All	Noisiest 1-hour period	50	55
Place of worship – internal		When in use	40	45
Area specifically reserved for passive recreation (e.g. National Park)	All	When in use	50	55
Active recreation area (e.g. school, playground, golf course)	All	When in use	55	60
Commercial	All	When in use	65	70
Industrial	All	When in use	70	75

Notes:
1 Day is defined as 7am to 6pm Monday to Saturday and 8am to 6pm Sundays and Public Holidays.
2 Evening is defined as 6pm to 10pm Monday to Sunday and Public Holidays.
3 Night is defined as 10pm to 7am Monday to Saturday and 10pm to 8am Sundays and Public Holidays.

Assessment of impacts

Noise modelling of the operational facilities used SoundPLAN v7.4, incorporating the CONCAWE noise propagation algorithm. CONCAWE has been used to model the adverse weather conditions which is required in the NPfI.

Adverse weather is considered to be the worst-case of the 3 m/s downwind and temperature inversion conditions. In all cases the 3 m/s downwind scenario has been found to be the worst-case. The operations of the facility and associated noise levels would not change dependent on the time period. The noise levels have been compared to the most stringent night-time criteria. Compliance with the night-time criteria would ensure compliance during all other periods.

The NCAs potentially affected by each fixed facility and their corresponding NMLs are presented in **Appendix G** (Noise and vibration technical report).

The characteristics of fixed facility operational noise has been assessed at noise sensitive receptor locations in accordance with the procedures set out in the NPfI. The assessment has been completed for the night-time period when background noise levels are lowest, and has considered worst case weather and operation conditions.

The proposed fixed facilities in the Rockdale area are relatively close together. To ensure the cumulative noise impacts of the project are appropriately considered, the facilities have been assessed as a single model.

Operational road traffic noise criteria

This assessment has been prepared under the guidance of the NCG which documents Roads and Maritime's interpretation of the RNP and provides a consistent approach to identifying road noise criteria for Roads and Maritime projects.

The RNP requires the consideration of two scenarios: the ‘No build’ option (without the project) and the ‘Build’ option (with the project). Each of these scenarios must be considered at the time of opening and the design year, typically ten years after opening. For this project, the year 2026 has been assessed as the year of opening and 2036 for the design year.

Criteria are based on the road development type which would affect the residential receptor. In some instances residential receptors may be exposed to noise from both ‘new’ and ‘redeveloped’ road development types. Where this occurs, the proportion of noise from each road is used to establish transition zone criteria.

A further check is made to identify large increases in noise levels using the relative increase criteria.

Other sensitive receptors are also subject to existing noise from major arterial roads, hence the eligibility of these receptors is considered in their highly urban context, in accordance with the NCG.

Road traffic noise assessment criteria for residential land uses are summarised in **Table 11-6**. Criteria for sensitive non-residential land uses are summarised in **Table 11-7**. For sensitive receptors such as schools, places of worship and childcare facilities, the NCG criteria presented in **Table 11-7** are based on internal noise levels.

Table 11-6 *Noise Criteria Guideline* (NCG) (Roads and Maritime 2015)criteria - residential

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

Notes:

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

2 The criteria at each facade are determined from the existing traffic noise level plus 12 dB(A).

Table 11-7 NCG criteria – other sensitive land uses

Existing sensitive land uses	Assessment criteria (dB(A))[1]		Additional considerations
	Daytime (7.00 am – 10.00 pm)	Night-time (10.00 pm – 7.00 am)	
School classrooms	$L_{Aeq(1\text{-}hour)}$ 40 (internal)	-	In the case of buildings used for education or health care, noise level criteria for spaces other than classrooms and wards may be obtained by interpolation from the 'maximum' levels shown in AS 2107.
Places of worship	$L_{Aeq(1\text{-}hour)}$ 40 (internal)	$L_{Aeq(1\text{-}hour)}$ 40 (internal)	The criteria are assessed inside of the place of worship. Areas outside the place of worship, such as a churchyard or cemetery, may also be deemed 'places of worship'. Therefore, in determining appropriate criteria for such external areas, the assessment should establish which activities in these areas may be affected by road traffic noise.
Open space (active use)	$L_{Aeq(15\text{-}hour)}$ 60 (external) when in use	-	Active recreation is characterised by sporting activities and activities which generate their own noise or focus for participants, making them less sensitive to external noise intrusion.
Open space (passive use)	$L_{Aeq(15\text{-}hour)}$ 55 (external) when in use	-	Passive recreation is characterised by contemplative activities that generate little noise and where benefits are compromised by external noise intrusion, e.g. playing chess, reading.
Childcare facilities	Sleeping rooms $L_{Aeq(1\text{-}hour)}$ 35 (internal) Indoor play areas $L_{Aeq(1\text{-}hour)}$ 40 (internal) Outdoor play areas $L_{Aeq(1\text{-}hour)}$ 55 (external)	-	Multi-purpose spaces, e.g. shared indoor play/sleeping rooms should meet the lower of the respective criteria. Measurements for sleeping rooms should be taken during designated sleeping times for the facility, or if these are not known, during the highest hourly traffic noise level during the opening hours of the facility.
Aged care facilities	-	-	Residential land use noise assessment criteria should be applied to these facilities, see Table 11-6.
Hospital wards	$L_{Aeq(1\text{-}hour)}$ 35 (internal)	$L_{Aeq(1\text{-}hour)}$ 35 (internal)	In the case of buildings used for education or health care, noise level criteria for spaces other than classrooms and wards may be obtained by interpolation from the 'maximum' levels shown in AS 2107.

Notes:
1 Internal NCG noise criteria has been converted to an external noise criteria for the purposes of assessment using external noise level predictions. Where detailed information relating to building construction is not available, the NSW EPA recommends a 10 dB(A) factor to convert internal to external noise levels on the basis that façades with windows open typically provide about 10 dB(A) attenuation from inside to outside (refer to guidance contained in the ICNG and INP).

Maximum noise levels

Maximum noise levels generated by road traffic noise have the potential to cause disturbance to sleep. Although noise goals are not provided in the RNP, this document does include a review of internal sleep arousal research. The RNP concludes that there appears to be insufficient evidence to set new indicators for potential sleep disturbance due to road traffic noise. Nevertheless, Roads and Maritime recognises the potential impact of sleep disturbance and requires an assessment of maximum noise levels to be made where such impacts may occur during the night.

Guidance for assessing maximum noise levels are provided in Practice Note iii of the ENMM. The maximum noise assessment should be used as a tool to help prioritise and rank mitigation strategies, but should not be used as a decisive criterion in itself and should not be used to aid in designing the degree of mitigation required.

The assessment considers the following:

- Calculation of maximum noise levels
- The extent to which the maximum noise levels for individual vehicle pass-bys exceed the L_{Aeq} noise level for each hour of the night (i.e. L_{Amax} noise levels greater than 65 dB(A) where L_{Amax} – $L_{Aeq(1hour)}$ ≥ 15 dB(A))
- The number of times the maximum noise levels for individual vehicle pass-bys exceed the L_{Aeq} noise level for each hour of the night.

Assessment of impacts

Operational road traffic noise generated by the project would only be discernible at locations surrounding the project where it is at the surface. This would include President Avenue and the Princes Highway. Therefore the assessment of operational road traffic noise, in accordance with the RNP, is limited to these areas. The project also has the potential to change traffic flows on the surrounding network.

The assessment method takes into consideration the impact of the new surface roads, as well as additional traffic generated by the project. Two separate years, in addition to three separate traffic scenarios have been assessed.

Road traffic noise levels were calculated using SoundPLAN v7.4 software, which implements the Calculation of Road Traffic Noise (CoRTN) algorithm. The UK Department of Transport devised the CoRTN algorithm and with suitable corrections, this method has been shown to give accurate predictions of road traffic noise under Australian conditions.

An existing road traffic noise model was developed incorporating the existing traffic flows and alignment for validation with road traffic noise measurements. The traffic flows used in the model were provided by tube counts that were deployed concurrently with noise logging for the project.

The noise model was validated and shown to be accurate within ±2 dB at all logger locations. Refer to **Appendix G** (Noise and vibration technical report) for further detail regarding the validation of the model.

11.1.6 Guidance for the evaluation of feasible and reasonable noise mitigation measures

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

The NMG provides two triggers where a receptor may qualify for consideration of noise mitigation (over and above the adoption of road design and traffic management measures). These are:

- The predicted 'Build' noise level exceeds the NCG controlling criterion and the noise level increase due to the project (i.e. the noise predictions for the' Build' minus the 'No Build') is greater than 2.0 dB(A), or
- The predicted 'Build' noise level is 5 dB(A) or more above the criteria (meets or exceeds the cumulative limit) and the receptor is significantly influenced by project road noise, regardless of the incremental impact of the project

In addition if the noise level contribution from the road project is acute (daytime $L_{Aeq(15\ hr)}$ 65 dB(A) or higher, or night time $L_{Aeq(9\ hr)}$ 60 dB(A) or higher) then it qualifies for consideration of noise mitigation even if noise levels are dominated by another road.

The eligibility of receptors for consideration of additional noise mitigation, such as at-property treatments, is determined before the benefit of noise mitigation such as quieter pavement and noise barriers is included. If the NCG criterion cannot be satisfied with quieter pavement and noise barriers, then the receptor is eligible for consideration of at-property treatment.

11.2 Existing environment

The project would traverse the suburbs of Wolli Creek, Arncliffe, Banksia Rockdale, Brighton-Le-Sands and Kogarah.

The study area, which covers parts of the above suburbs, includes a mixture of residential development (see **section 11.2.1**), commercial and industrial properties, and major roads and railway lines.

The study area for the permanent power supply route from the Ausgrid Canterbury subtransmission substation to the Rockdale (south) motorway operations complex would pass through Rockdale, Bardwell Park, and Earlwood.

An outline of the important characteristics of the existing noise environment is shown in **Figure 11-7**.

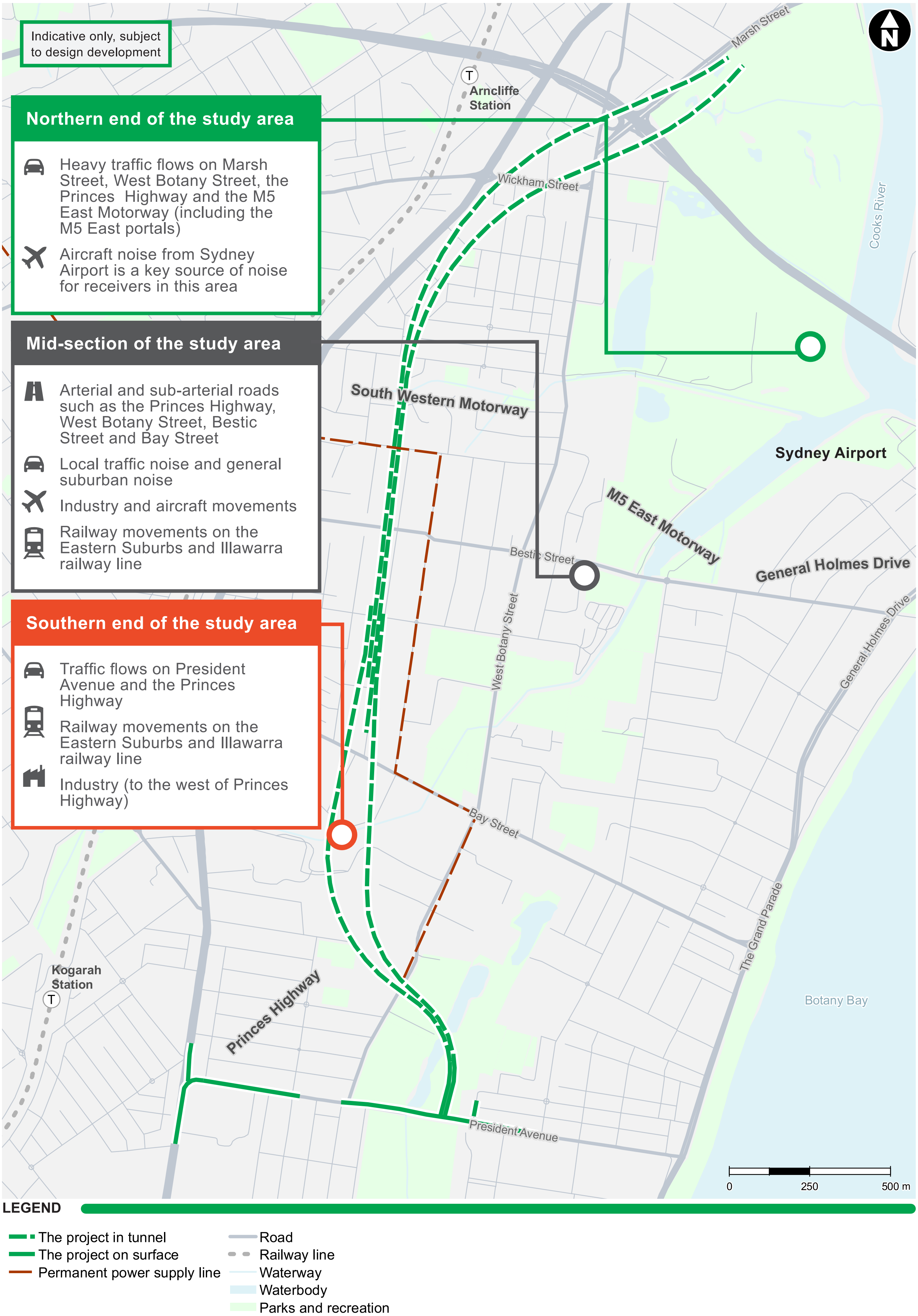

Figure 11-7 Existing noise environment

11.2.1 Noise sensitive receptors

Throughout the study area, receptors which are potentially sensitive to noise and vibration include people in the following locations:

- Residential dwellings
- Commercial and industrial properties
- Schools
- Community centres
- Active recreation areas
- Passive recreation areas
- Hospitals
- Libraries
- Places of worship.

A list of the noise sensitive receptors identified within the study area (excluding residential receptors) is provided in **Appendix G** (Noise and vibration technical report).

11.2.2 Existing noise levels

The results of the unattended ambient noise surveys undertaken in June 2015 (as part of the New M5 Motorway project) and November/December 2017 and February 2018 (specifically for this project) are provided in **Appendix G** (Noise and vibration technical report).

The background noise levels derived from monitoring indicate that the existing noise environment at the measurement locations is typical of major transport corridors in suburban/urban areas. In these locations daytime and evening background levels are generally high due to heavy and continuous traffic flows, with night time levels tending to decrease as a result of a reduction in these flows.

11.3 Potential impacts – construction

The construction noise and vibration assessment has considered impacts based on whether the construction activities would be conducted within or outside standard construction hours and the location of the construction activities in relation to receptors (refer **section 11.1.1**).

The Noise and vibration technical report (**Appendix G**) includes a detailed assessment of the construction noise impacts in these areas. A summary of the assessment is provided in the following sections. The results are based on background noise levels measured prior to the commencement of construction of the New M5 Motorway and therefore predicted noise levels do not represent an increase in noise on top of the noise levels associated with the New M5 Motorway project.

The assessment has considered the construction program for the project, as shown in **Figure 11-8** noting that it is a guide for timing and durations only and would be further refined by the construction contractor.

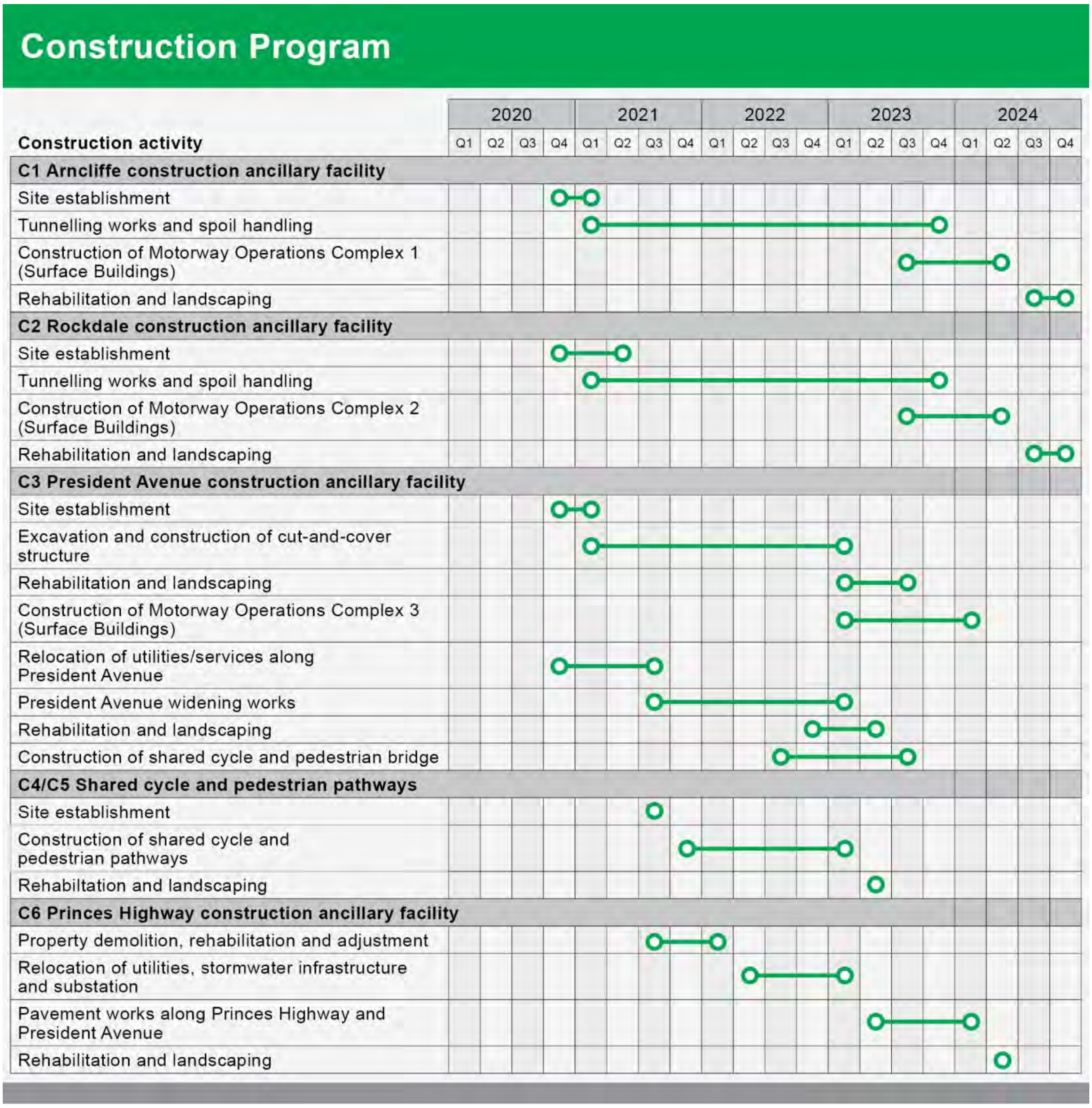

Figure 11-8 Indicative construction program

11.3.1 Airborne noise from construction activities

Activities within standard construction hours

The noise modelling results for activities proposed to be undertaken within standard construction hours are provided for each construction ancillary facility below. The tables present the number of receptors where the construction noise levels are predicted to exceed the NML for each NCA. The extent to which the construction noise levels exceed the NML is provided in **Appendix G** (Noise and vibration technical report).

The ICNG states that where a construction noise impact level of greater than 75 dB(A) is predicted, a receptor is considered to be 'highly noise affected' and should be afforded additional consideration for mitigation. The number of highly affected noise receptors at each NCA are provided in the tables below, and are shown in the noise contour maps in **Appendix G** (Noise and vibration technical report).

All results would be verified by the contractor during detailed design. The contractor would prepare a Construction Noise and Vibration Management Plan (CNVMP) to implement the environmental management measures provided in **Table 11-29** and commitments made in the EIS in relation to managing noise impacts.

Activities outside of standard construction hours

While the proponent would seek to limit construction activity to standard construction hours wherever practical it is inevitable that work on major infrastructure project requires some construction activities to be undertaken outside of these hours.

Activity to be undertaken outside of standard construction hours would include tunnelling and tunnelling support work (including spoil removal), which would need to be undertaken on a 24 hour basis. This is required to limit the overall duration of the project. Other work may be required outside standard construction hours for health and safety reasons, to prevent traffic congestion on major roads during peak periods, or for particular construction requirements. Such works would include:

- Relocation of utilities (where the location is in close proximity to traffic)
- Pavement and median works
- Asphalt works and line-marking
- Use of construction ancillary facilities
- Shared cycle and pedestrian pathway bridgeworks
- Diaphragm wall construction (proposed during the evening period only).

The results of construction noise modelling for out of hours work at each construction ancillary facility and for all surface works are provided for each construction ancillary facility below.

Sleep disturbance is assessed using an $L_{A1(1\ min)}$ parameter, which is considered to be the maximum noise level excluding extraneous noise events. A sleep disturbance assessment has been undertaken for the proposed night works based on the construction information available to date. The noise modelling results are provided with predicted noise levels compared with the sleep disturbance screening criteria and the awakening reaction criteria.

All feasible and reasonable mitigation measures, as provided in **section 11.5**, would be implemented to ensure that the potential for adverse impact on the local community is minimised. These mitigation measures would be further developed during detailed design by the construction contractor and would be further detailed in the CNVMP.

Arncliffe construction ancillary facility (C1)

The Arncliffe construction ancillary facility (C1) would be located above and below ground at Kogarah Golf Course at Marsh Street. The construction program for C1 is provided in **Figure 11-8**.

Standard construction hours

The noise modelling results for this site are provided in **Table 11-8**. The assessment has assumed that the indicative insertion loss of the non-acoustic spoil shed at this location would be 10 dB(A).

Generally construction noise associated with the Arncliffe construction ancillary facility (C1) would meet the NMLs. The exception to this would occur during the initial stage where a small number of exceedances would occur due to the installation of temporary noise attenuation measures (e.g. site hoarding), over a period of around four weeks. A small number of exceedances were also identified during rehabilitation and landscaping activities towards the end of the construction period.

The scale of construction activities proposed at the Arncliffe construction ancillary facility (C1) is expected to be substantial smaller than the New M5 Motorway works currently underway at this location.

Table 11-8 Arncliffe construction ancillary facility (C1) – standard hours works

NCA	L_{Aeq} NML dB(A)	Max L_{Aeq} noise level dB(A)	Number of NML exceedances	Number of highly noise affected receptors
Establishment of temporary noise attenuation measures				
NCA1	65	74	12	0
NCA2	59	53	0	0
NCA3	57	52	0	0
Construction of acoustic shed				
NCA1	65	54	0	0
NCA2	59	51	0	0
NCA3	57	50	0	0
Tunnelling works and spoil handling				
NCA1	65	54	0	0
NCA2	59	51	0	0
NCA3	57	51	0	0
Construction of the MOC				
NCA1	65	56	0	0
NCA2	59	53	0	0
NCA3	57	52	0	0
Fitout and testing of the MOC				
NCA1	65	45	0	0
NCA2	59	42	0	0
NCA3	57	41	0	0
Rehabilitation and landscaping				
NCA1	65	63	0	0
NCA2	59	47	0	0
NCA3	57	46	0	0

Works outside of standard construction hours

The results of noise modelling for out of hours work at the Arncliffe construction ancillary facility (C1) are provided in **Table 11-9.**

A large number of exceedances of the out of hours NMLs have been predicted for the tunnelling works associated with the Arncliffe construction ancillary facility (C1). Whilst the exceedances are generally in the range of 1 – 7dB(A), they would continue for a significant duration (Q1 2021 to Q1 2023). The predicted exceedances are attributed to the close proximity of the construction ancillary facility to residences, combined with the low existing background noise levels.

No exceedances of the sleep disturbance criteria or awakening reactions are predicted.

Table 11-9 Arncliffe construction ancillary facility (C1) – out of hours work (night)

NCA	L_{Aeq} NML dB(A)	Max L_{Aeq} noise level dB(A)	Number of NML exceedances	Sleep disturbance criteria $L_{A1(1min)}$ criteria, dB(A)	Number of Sleep disturbance exceedances	Awakening reaction
Tunnelling works and spoil handling						
NCA1	50	54	21	60	0	0
NCA2	47	51	43	57	0	0
NCA3	44	51	37	54	0	0

Rockdale construction ancillary facility (C2)

The Rockdale construction ancillary facility (C2) would be located above and below ground at Rockdale, with construction access via West Botany Street. The construction program for C2 is provided in **Figure 11-8**.

Standard construction hours

The noise modelling results for this site are provided in **Table 11-10**. The assessment has assumed that the indicative insertion loss of the acoustic spoil shed at this location would be 20 dB(A).

Noise levels from the construction works associated with this facility would exceed NMLs at nearby receptors during all construction scenarios. It should be noted though that the number and scale of exceedances varies substantially throughout the construction period, with the most affected noise catchment area being NCA7 (greatest number and degree of exceedance). Noise levels would decrease through the respective NCAs with distance from construction works and the noise modelling results provided in **Table 11-10** therefore represent a worst case scenario for receptors closest to the construction works.

Three construction scenarios would result in noise levels that would exceed the ‘highly noise affected’ threshold of 75 dB(A). These are establishment of the temporary noise attenuation measures (97 dB(A)), construction of the decline tunnel (100 dB(A)) and reconfiguration of the site (91 dB(A)). All of these highly noise affected receptors are within NCA7.

It should be noted that the establishment of temporary noise attenuation measures would be over a relatively short duration (expected to be less than four weeks). It should also be noted that:

- the modelling of the construction of the decline tunnel is considered to be conservative and does not include natural noise shielding that would be provided by the tunnel edges as the tunnel progresses underground. This scenario is expected to last for around six months.
- that this assessment is representative of the worst case 15 minute period of construction activity, while the construction equipment is at the nearest location to each sensitive receptor location. The assessed scenario does not represent the ongoing day to day noise impact at noise sensitive receptors for an extended period of time.

Particularly noisy activities, such as rock hammering and use of concrete saws, are likely to persist for a small component of the overall construction period. In addition the predictions use the shortest separation distance to each sensitive receptor. However, in reality separation distances would vary between plant and sensitive receptors. For linear works (works that move along the road alignment, rather than works located at a construction ancillary facility), noise exposure at each receptor would reduce due to increases in distance as the works progress along the alignment. Typical noise levels could be 5 to 10 dB(A) lower dependent on the site and nature of works.

Table 11-10 Rockdale construction ancillary facility (C2) – standard hours works

NCA	L_{Aeq} NML dB(A)	Max L_{Aeq} noise level dB(A)	Number of NML exceedances	Number of highly noise affected receptors
Establishment of temporary noise attenuation measures				
NCA5	49	60	126	0
NCA6	51	54	5	0
NCA7	51	97	158	21
NCA8	49	65	72	0
NCA9	48	50	10	0
Demolition and clearing of structures, including buildings				
NCA5	49	58	160	0
NCA6	51	55	9	0
NCA7	51	74	159	0
NCA8	49	63	79	0
NCA9	48	56	75	0
Construction of acoustic shed				
NCA5	49	56	68	0
NCA6	51	53	2	0
NCA7	51	75	126	0
NCA8	49	60	48	0
Construction of decline tunnel				
NCA5	49	59	141	0
NCA6	51	55	8	0
NCA7	51	91	155	5
NCA8	49	62	63	0
NCA9	48	51	25	0
Tunnelling works and spoil handling				
NCA7	51	56	13	0
Construction of the MOC/MCC				
NCA5	49	56	93	0
NCA6	51	53	2	0
NCA7	51	83	146	3
NCA8	49	61	51	3
Fitout of the MOC/MCC				
NCA7	51	72	37	0
NCA8	49	50	2	0
Rehabilitation and landscaping				
NCA5	49	54	24	0
NCA7	51	91	100	4
NCA8	49	59	26	0

Works outside of standard construction hours

The results of noise modelling for out of hours work at the Rockdale construction ancillary facility (C2) are provided in **Table 11-11** and **Table 11-12**.

A large number of exceedances of the out of hours NMLs have been predicted for construction works associated with C2. NCA7 would be subject to highly intrusive (greater than 20 dB(A)) exceedances of the NMLs, as well as exceedances of the sleep disturbance criteria. No sleep awakening events are expected.

The predicted exceedances are attributed to the close proximity of the construction ancillary facility to residences, combined with the low existing background noise levels.

As with the standard hours assessment, the modelling of the decline tunnel is considered to be conservative and does not include natural noise shielding that would be provided at the tunnel edges as the tunnel progresses underground. The scenario is likely to last for around six months.

Table 11-11 Rockdale construction ancillary facility (C2) – out of hours work (evening)

NCA	LAeq NML dB(A)	Max LAeq noise level dB(A)	Number of NML exceedances	Sleep disturbance criteria	Number of Sleep disturbance exceedances	Awakening reaction
Construction of decline tunnel						
NCA5	44	59	330	N/A[1]	N/A[1]	N/A[1]
NCA6	46	55	26	N/A[1]	N/A[1]	N/A[1]
NCA7	46	91	210	N/A[1]	N/A[1]	N/A[1]
NCA8	44	62	89	N/A[1]	N/A[1]	N/A[1]
NCA9	43	51	112	N/A[1]	N/A[1]	N/A[1]

Notes:
1 Construction of the decline tunnel would only occur in the evening up to 8pm.

Table 11-12 Rockdale construction ancillary facility (C2) – out of hours work (night)

NCA	LAeq NML dB(A)	Max LAeq noise level dB(A)	Number of NML exceedances	Sleep disturbance criteria	Number of Sleep disturbance exceedances	Awakening reaction
Tunnelling works and spoil handling (24 hours a day)						
NCA5	39	44	40	49	0	0
NCA6	38	41	5	48	0	0
NCA7	38	56	105	48	20	0
NCA8	41	45	4	51	0	0

President Avenue construction ancillary facility (C3)

The President Avenue construction ancillary facility (C3) would be located above ground at Rockdale Bicentennial Park and the western side of West Botany Street. The construction program for C3 is provided in **Figure 11-8**.

Standard construction hours

The noise modelling results for this site are provided in **Table 11-10**. The assessment has assumed that activities at this location would include:

- Temporary stockpiling of spoil and fill materials (refer **Table 11-13** for noise modelling results), which is predicted to create impacts that exceed the relevant criteria during construction
- Construction of MOC3 (refer **Table 11-14** for noise modelling results)

- Construction of the shared cycle and pedestrian pathways within C3, and bridge over President Avenue (refer **Table 11-15** for noise modelling results) which is predicted to create impacts that exceed the relevant criteria during construction
- Cut and cover surface works (refer **Table 11-16** for noise modelling results) which are predicted to create impacts that exceed the relevant criteria during construction
- President Avenue intersection surface works (refer **Table 11-17** for noise modelling results) which are predicted to create impacts that exceed the relevant criteria during construction

Activities which are predicted to create impacts that exceed the relevant criteria during construction are discussed further below.

Temporary stockpiling of spoil and fill materials would result in a few receptors experiencing noise levels which will result in major exceedances and a significant number of receptors experiencing noise levels resulting in minor and moderate exceedances.

Table 11-13 Temporary stockpiling of spoil and fill materials – standard hours works

NCA	L_{Aeq} NML dB(A)	Max L_{Aeq} noise level dB(A)	Number of NML exceedances	Number of highly noise affected receptors
NCA8	49	50	1	0
NCA9	48	72	32	0
NCA16	67	75	1	0

Table 11-14 Construction of MOC3 – standard hours works

NCA	L_{Aeq} NML dB(A)	Max L_{Aeq} noise level dB(A)	Number of NML exceedances	Number of highly noise affected receptors
Construction of MOC3				
NCA8	49	51	6	0
NCA9	48	52	18	0
Rehabilitation and landscaping				
NCA8	49	45	0	0
NCA9	48	46	0	0

Construction of the shared cycle and pedestrian pathways throughout Bicentennial Park and to the south of President Avenue would result in exceedances at numerous residential receptors. The exceedances are attributed to the close proximity of the construction site to residences and the length of the shared cycle and pedestrian pathways. Given the transient nature of the works for the shared cycle and pedestrian pathways, the noise modelling results provided in **Table 11-15** represent the worst case scenario for the time where construction works are closest to the receptors in the respective NCAs.

The noise levels in **Table 11-15** would therefore not be sustained across the duration of the construction program and worst case noise levels would not be experienced by all receptors at the same time. While some maximum impacts may be appreciable, the short duration associated with the construction of the shared cycle and pedestrian pathways (between two and three months depending on location) would minimise the associated overall impact to the affected community. While long term mitigation is not justified in this area, and noise mitigation such as hoarding may be difficult due to the transient nature of the works, effective noise management measures would be the key to the successful minimisation of impacts in this area.

Table 11-15 Construction of the shared cycle and pedestrian pathways within C3 – standard hours works

NCA	L_{Aeq} NML dB(A)	Max L_{Aeq} noise level dB(A)	Number of NML exceedances	Number of highly noise affected receptors
Construction of the shared cycle and pedestrian pathways within C3				
NCA7	51	91	157	5
NCA8	49	94	102	7
NCA9	48	62	135	0
NCA15	52	84	105	4
NCA17	52	60	70	0
Construction of the shared cycle and pedestrian bridge over President Avenue				
NCA9	48	55	10	0
NCA15	52	61	18	0
NCA17	52	55	5	0

A large number of minor exceedances of the NMLs have been predicted at receptors due to the cut and cover surface works (**Table 11-16**). These works are scheduled to occur for 27 months. Site establishment and landscaping are predicted to be the worst case construction scenarios for residential receptors within NCA9, NCA14 and NCA16. Some receptors are likely to be highly affected.

The exceedances are attributed to the close proximity of the construction site to residences. Both of these scenarios are not expected to have long term impacts and would only be carried out at the start and end of the project. For the majority of the construction period, exceedances would be minor.

Table 11-16 Cut and cover surface works - Standard hours work

NCA	L_{Aeq} NML dB(A)	Max L_{Aeq} noise level dB(A)	Number of NML exceedances	Number of highly noise affected receptors
Site establishment				
NCA7	51	59	16	0
NCA8	49	72	62	0
NCA9	48	94	104	4
NCA11	63	65	3	0
NCA14	76	97	9	9
NCA15	52	57	17	0
NCA16	67	99	27	18
NCA17	52	60	37	0
Relocation of utilities				
NCA8	49	55	29	0
NCA9	48	55	61	0
NCA11	63	67	5	0
Temporary stockpiling of spoil and fill materials				
NCA8	49	50	1	0
NCA9	48	72	27	0
NCA16	67	75	1	0

NCA	L_{Aeq} NML dB(A)	Max L_{Aeq} noise level dB(A)	Number of NML exceedances	Number of highly noise affected receptors
Establish and commission bentonite plant				
NCA7	51	52	1	0
NCA8	49	60	41	0
NCA9	48	56	56	0
Construct diaphragm wall guide-walls and panels				
NCA8	49	51	7	0
NCA9	48	65	60	0
NCA17	52	54	4	0
Install bored piles				
NCA8	49	50	1	0
NCA9	48	62	40	0
Excavate to soffit of roof slab				
NCA8	49	53	39	0
NCA9	48	69	89	0
NCA16	67	68	1	0
NCA17	52	54	4	0
Construction of the cut and cover structure				
NCA7	51	53	8	0
NCA8	49	56	73	0
NCA9	48	71	135	0
NCA11	63	64	4	0
NCA15	52	53	4	0
NCA16	67	70	2	0
NCA17	52	56	15	0
Excavate a temporary creek deviation and build working platform				
NCA9	48	56	18	0
Return creek to original alignment				
NCA8	49	54	35	0
NCA9	48	61	81	0
Install stormwater, pavement, mechanical / electrical services, stairs and architectural finishes throughout the motorway complex				
NCA7	51	54	23	0
NCA8	49	57	80	0
NCA9	48	71	152	0
NCA11	63	65	5	0
NCA15	52	57	20	0
NCA16	67	71	4	0
NCA17	52	60	58	0

NCA	L_{Aeq} NML dB(A)	Max L_{Aeq} noise level dB(A)	Number of NML exceedances	Number of highly noise affected receptors
Landscaping				
NCA7	51	53	1	0
NCA8	49	66	17	0
NCA9	48	88	37	3
NCA14	76	91	6	7
NCA16	67	93	18	9
NCA17	52	54	2	0

A large number of minor exceedances of the NMLs have been predicted due to the construction works associated with the President Avenue intersection works. A number of residences have also been predicted to be highly noise affected as a result of the demolition of houses and existing pavement, construction of the temporary widened pavement, relocation of services, installation of stormwater infrastructure, pavement works and final asphalting and line marking. This is attributed to the close proximity of the construction works to residences.

Residences NCA14 and NCA16 are the most impacted receptors with a small number of highly noise affected receptors being predicted across almost all construction scenarios related to the new President Avenue intersection. The works would be progressive so that not all receptors would be affected at any one time or for the duration of the works.

Table 11-17 President Avenue intersection surface works – Standard hours work

NCA	L_{Aeq} NML dB(A)	Max L_{Aeq} noise level dB(A)	Number of NML exceedances	Number of highly noise affected receptors
Demolition and clearing of structures, including buildings				
NCA8	49	52	21	0
NCA9	48	72	64	0
NCA15	52	54	6	0
NCA16	67	107	26	11
NCA17	52	59	50	0
Relocate services				
NCA8	49	51	7	0
NCA9	48	64	57	0
NCA14	76	99	6	6
NCA15	52	58	28	0
NCA16	67	97	21	9
NCA17	52	60	44	0

NCA	L_{Aeq} NML dB(A)	Max L_{Aeq} noise level dB(A)	Number of NML exceedances	Number of highly noise affected receptors
Install stormwater				
NCA8	49	55	78	0
NCA9	48	70	152	0
NCA11	63	64	1	0
NCA14	76	96	13	14
NCA15	52	60	70	0
NCA16	67	94	41	17
NCA17	52	63	82	0
Install culverts				
NCA9	48	55	8	0
NCA17	52	53	2	0
Pavement works				
NCA8	49	53	21	0
NCA9	48	67	96	0
NCA14	76	92	7	7
NCA15	52	59	42	0
NCA16	67	94	37	16
NCA17	52	61	67	0
Final asphalting and line marking				
NCA9	48	60	45	0
NCA14	76	89	7	9
NCA15	52	53	1	0
NCA16	67	89	44	39
NCA17	52	68	33	0

Works outside of standard construction hours

The President Avenue construction ancillary facility (C3) would be located above ground at Rockdale Bicentennial Park and the western side of West Botany Street. Out of hours activities at this location would include:

- Cut and cover surface works
- President Avenue intersection surface works

Wherever possible, cut and cover tunnel construction within Rockdale Bicentennial Park would be undertaken within standard construction hours. Due to the way in which the cut and cover structure is proposed to be constructed (diaphragm walls installed in sections down to bedrock), once a section is commenced, it must be completed without interruption. The assessment has therefore considered the potential that construction works could occasionally extend into the evening, and sometimes night time, on some days. As far as practicable, works would be scheduled such that they can be commenced and concluded that same day and within standard construction hours. However, this will not always be possible due to the nature of the works and the geological conditions on site. A process for notifying potentially affected residents would be included within the CNVMP and further measures to reduce the potential for noise and vibration disturbance would be included in the construction method statements (e.g. plant selection and positioning).

The results of noise modelling for out of hours work for the cut and cover construction within C3 are provided in **Table 11-19**.

A number of exceedances of the NMLs and sleep disturbance criteria have been predicted for construction works. The predicted exceedances are attributed to the close proximity of the construction works to residences, combined with the low existing background noise levels.

Exceedances of the out of hours NMLs were identified for both modelled scenarios and for all NCAs. These ranged from a single exceedance up to 202 properties. The magnitude of the NML exceedances varied between 1 dB(A) up to a maximum of 35 dB(A). NCA9, NCA15, NCA16 and NCA17 are considered to be the worst affected in this area. Noise barriers and/or hoarding were not included in the noise modelling of these scenarios and as such these measures would be considered in order to minimise noise impacts upon residences.

A number of exceedances of the sleep disturbance criteria have been predicted due to the night-time construction works associated with the cut and cover roadworks. Noise levels at up to four receptors may exceed the awakening reaction criterion during utility relocation works.

The cut and cover works are scheduled to occur for 27 months.

Table 11-18 Bicentennial Park cut and cover construction – out of hours work (evening)

NCA	LAeq NML dB(A)	Max LAeq noise level dB(A)	Number of NML exceedances	Sleep disturbance criteria	Number of Sleep disturbance exceedances	Awakening reaction
Construction of diaphragm wall guide walls and panels						
NCA7	46	48	13	NA[1]	NA[1]	NA[1]
NCA8	44	51	75	NA[1]	NA[1]	NA[1]
NCA9	43	65	145	NA[1]	NA[1]	NA[1]
NCA11	52	60	19	NA[1]	NA[1]	NA[1]
NCA15	45	51	35	NA[1]	NA[1]	NA[1]
NCA16	55	65	28	NA[1]	NA[1]	NA[1]
NCA17	45	54	93	NA[1]	NA[1]	NA[1]

Notes:
1 Construction works would only occur in the evening up to 8pm.

Table 11-19 Bicentennial Park cut and cover construction – out of hours work (night)

NCA	LAeq NML dB(A)	Max LAeq noise level dB(A)	Number of NML exceedances	Sleep disturbance criteria	Number of Sleep disturbance exceedances	Awakening reaction
Relocation of utilities/services						
NCA7	38	50	202	48	28	0
NCA8	41	55	122	51	12	0
NCA9	37	55	169	47	90	0
NCA10	43	53	1	53	0	0
NCA11	43	67	184	53	28	4
NCA15	37	50	208	47	7	0
NCA16	42	52	167	52	0	0
NCA17	37	49	276	47	9	0

The results of noise modelling for the President Avenue intersection out of hours works are provided in **Table 11-20**.

A large number of exceedances of the NMLs and sleep disturbance criteria have been predicted for President Avenue intersection works. A significant number of highly intrusive exceedances have been predicted in NCA16. Residential receptors in NCA9, NCA14, NCA16 and NCA17 are also predicted to be affected by sleep awakening events.

The scenarios associated with these works would last between Q4 2020 and Q4 2022.

The predicted exceedances are attributed to the close proximity of the construction works to residences, combined with the low existing background noise levels.

Table 11-20 President Avenue intersection – out of hours work

NCA	LAeq NML dB(A)	Max LAeq noise level dB(A)	Number of NML exceedances	Sleep disturbance criteria	Number of Sleep disturbance exceedances	Awakening reaction
Relocate services						
NCA7	38	46	2	48	0	0
NCA8	41	51	131	51	0	0
NCA9	37	64	169	47	83	0
NCA10	43	50	1	53	0	0
NCA11	43	62	162	53	22	0
NCA14	61	99	31	71	8	15
NCA15	37	58	219	47	159	0
NCA16	42	97	176	52	90	31
NCA17	37	60	290	47	164	0
Pavement works						
NCA7	38	48	2	48	0	0
NCA8	41	53	136	51	5	0
NCA9	37	67	169	47	122	4
NCA10	43	51	1	53	0	0

NCA	LAeq NML dB(A)	Max LAeq noise level dB(A)	Number of NML exceedances	Sleep disturbance criteria	Number of Sleep disturbance exceedances	Awakening reaction
NCA11	43	63	173	53	30	0
NCA14	61	92	49	71	12	23
NCA15	37	59	219	47	168	0
NCA16	42	94	184	52	107	42
NCA17	37	61	290	47	199	0
Final asphalting and line marking						
NCA7	38	40	1	48	0	0
NCA8	41	46	67	51	0	0
NCA9	37	60	167	47	52	0
NCA10	43	45	1	53	0	0
NCA11	43	58	70	53	5	0
NCA14	61	89	25	71	11	16
NCA15	37	53	211	47	20	0
NCA16	42	89	162	52	96	48
NCA17	37	68	278	47	99	3
Construction of shared cycle and pedestrian bridge						
NCA4	36	37	3	46	0	0
NCA5	39	41	11	49	0	0
NCA6	38	42	7	48	0	0
NCA7	38	44	131	48	0	0
NCA8	41	46	77	51	0	0
NCA9	37	55	167	47	23	0
NCA10	43	45	1	53	0	0
NCA11	43	56	103	53	3	0
NCA14	61	63	8	71	0	0
NCA15	37	61	215	47	69	0
NCA16	42	56	138	52	17	0
NCA17	37	55	284	47	52	0

Shared cycle and pedestrian pathways construction ancillary facilities (C4 & C5)

The noise modelling results for the shared cycle and pedestrian pathways east construction ancillary facility (C4) are provided in **Table 11-21**. The construction program for C4 and C5 is provided in **Figure 11-8**.

Standard construction hours

Although a large number of receptors would likely be affected by construction works associated with C4, the NML exceedances would be mostly in the range of 1 – 10dB(A). However receptors within NCA5 would experience noise levels resulting in moderate to major exceedances. The works at C4 are not expected to have long term impacts. The works are assumed to occur without hoarding or noise barriers. Noise levels would decrease through the respective NCAs with distance from construction works and the noise modelling results provided in **Table 11-21** therefore represent a worst case scenario for receptors closest to the construction works.

Table 11-21 Shared cycle and pedestrian pathways east construction ancillary facility (C4) – standard hours works

NCA	L_{Aeq} NML dB(A)	Max L_{Aeq} noise level dB(A)	Number of NML exceedances	Number of highly noise affected receptors
Pavement works				
NCA4	48	51	11	0
NCA5	49	84	114	3
NCA7	51	53	5	0

Works outside of standard construction hours

The noise modelling results for the shared cycle and pedestrian pathways west construction ancillary facility (C5) are provided in **Table 11-22**. The construction program for C5 is provided in **Figure 11-8**.

Although a large number of receptors would be likely to be affected by construction works associated with the shared cycle and pedestrian pathways west construction ancillary facility (C5), the NML exceedances for NCA4 and NCA7 would be mostly within the range of 1 – 10dB(A) . However some receptors within NCA5 would experience noise levels resulting in moderate to major exceedances. These receptors would not be the same as those affected by the shared cycle and pedestrian pathways east construction ancillary facility (C4) works. The works at C5 are not expected to have long term impacts. The works are assumed to occur without hoarding or noise barriers. Noise levels would decrease through the respective NCAs with distance from construction works and the noise modelling results provided in **Table 11-22** therefore represent a worst case scenario for receptors closest to the construction works.

Table 11-22 Shared cycle and pedestrian pathways west construction ancillary facility (C5) – standard hours works

NCA	L_{Aeq} NML dB(A)	Max L_{Aeq} noise level dB(A)	Number of NML exceedances	Number of highly noise affected receptors
Pavement works				
NCA4	48	54	53	0
NCA5	49	75	69	0
NCA7	51	55	1	0

Princes Highway construction ancillary facility (C6)

The noise modelling results for the Princes Highway/ intersection upgrade surface works are provided in **Table 11-23**. The construction program for these works is provided in **Figure 11-8**.

Standard construction hours

A large number of exceedances of the NMLs have been predicted due to the construction works associated with the Princes Highway/President Avenue intersection upgrade works. A number of residences have also been predicted to be highly noise affected as a result of all of the constructions scenarios.

The high number of highly noise affected receptors is attributed to the close proximity of the construction works to residences.

Residences in NCA14 are the most impacted receptors with highly noise affected receptors being predicted across almost all construction scenarios related to the Princes Highway/President Avenue intersection upgrade surface works.

Generally the works would be progressive so that not all receptors would be impacted at any one time or for the overall duration of the works.

Table 11-23 Princes Highway/President Avenue intersection upgrade surface works (C6) – Standard hours work

NCA	L_{Aeq} NML dB(A)	Max L_{Aeq} noise level dB(A)	Number of NML exceedances	Number of highly noise affected receptors
Property adjustments				
NCA14	76	95	23	23
NCA15	52	57	11	0
Demolition and clearing of structures, including buildings				
NCA14	76	103	3	4
C6 construction ancillary facility establishment				
NCA14	76	103	3	4
C6 construction ancillary facility operation				
NCA14	76	99	2	2
C6 construction ancillary facility rehabilitation				
NCA14	76	95	2	2
Relocation of utilities and traffic signals				
NCA14	76	95	5	5
Excavate to subgrade level				
NCA12	76	77	1	1
NCA14	76	91	28	31
NCA15	52	57	26	0
Modify stormwater				
NCA12	76	79	5	5
NCA14	76	96	31	31
NCA15	52	60	38	0
Pavement works				
NCA12	76	78	1	0
NCA14	76	95	31	31
NCA15	52	59	35	0

NCA	L_{Aeq} NML dB(A)	Max L_{Aeq} noise level dB(A)	Number of NML exceedances	Number of highly noise affected receptors
Line marking and finishing works				
NCA14	76	86	24	26
Rehabilitation and landscaping				
NCA14	76	89	32	33

Works outside of standard construction hours

The results of noise modelling for the Princes Highway/President Avenue intersection upgrade out of hours works are provided in **Table 11-24**.

A large number of moderate and major exceedances of the NMLs and sleep disturbance criteria have been predicted for this scenario. These range from 11 to 219 properties across the subject NCAs. The magnitude of the NML exceedances vary between 5 dB(A) up to a maximum of 34 dB(A). Residential receptors in NCA12 and NCA14 are predicted to likely be affected by sleep awakening events in all out of hours construction works associated with the intersection upgrade.

The predicted exceedances are attributed to the close proximity of the construction ancillary facility to residences.

It is essential that night time works are undertaken at this location due to the need to minimise the impact of the works upon traffic at the intersection of two major arterial roads.

Table 11-24 Princes Highway President Avenue intersection upgrade – out of hours work (night)

NCA	LAeq NML dB(A)	Max LAeq noise level dB(A)	Number of NML exceedances	Sleep disturbance criteria	Number of Sleep disturbance exceedances	Awakening reaction
Relocation of utilities and traffic signals						
NCA11	43	48	29	53	0	0
NCA12	61	74	21	71	6	13
NCA14	61	95	14	71	7	10
NCA15	37	44	145	47	0	0
Excavate to subgrade level						
NCA11	43	60	136	53	46	0
NCA12	61	77	22	71	6	14
NCA14	61	91	74	71	31	52
NCA15	37	57	219	47	118	0
Modify stormwater						
NCA11	43	63	163	53	75	0
NCA12	61	79	26	71	10	18
NCA14	61	96	94	71	37	68
NCA15	37	60	219	47	162	0
Pavement works						
NCA11	43	62	150	53	65	0
NCA12	61	78	26	71	7	17
NCA14	61	95	93	71	35	63
NCA15	37	59	219	47	135	0
Line marking and finishing works						
NCA11	43	55	112	53	5	0
NCA12	61	72	11	71	1	7
NCA14	61	86	45	71	28	34
NCA15	37	52	217	47	26	0

11.3.2 Construction road traffic noise

Construction road traffic noise would be generated by construction vehicles, including heavy vehicles transporting spoil, delivery of materials and light vehicle movements generated by construction workers.

For the purposes of the construction road traffic noise assessment, the period of construction activity that generates the peak volume of heavy vehicles was assessed to represent the worst case scenario.

The nominated construction vehicle routes to and from construction ancillary facilities are identified in **Appendix D** (Traffic and transport technical report). The locations of construction ancillary facilities have been selected to minimise the use of local roads and as such the majority of construction road traffic would occur on major roads only.

The construction road traffic noise assessment has been grouped around the five construction ancillary facilities. Further details of the assumptions for the construction road traffic noise assessment, as well as full results, are included in **Appendix G** (Noise and vibration technical report).

The following periods were considered within this assessment:

- Daytime peak period: 6:30am to 9.30am
- Daytime off peak period: the lowest non-peak traffic hour between 9.30am and 3.30pm
- Night-time peak period: 3.30pm to 7.00pm
- Night-time off peak period: the lowest non-peak traffic hour between 7.00pm and 6.30am.

In summary, the predicted increase in road traffic noise for daytime and night-time periods are generally expected to be less than the recommended construction traffic noise goal of 2 dB(A), as outlined in the RNP.

Increases in road traffic noise of 2.4 dB(A) (exceeding the 2 dB(A) goal) have been identified at Bruce Street during daytime off-peak periods when shared cycle and pedestrian pathways works are occurring. This assumes seven light vehicles and two heavy vehicles would access the C5 ancillary construction facility every hour. Considering the size of vehicles and nature of the site, these movements are considered to be conservative (overestimated). This impact is likely only to occur during times of peak construction periods. Work is expected to last for no longer than three months at this location and the impact when compared to the overall construction program is considered insignificant.

Due to potential night-time spoil haulage activities, appreciable increases in noise (up to 7 dB) are predicted to occur surrounding the Rockdale (north) facility. Other locations would generally not require heavy vehicle movements and would not exceed the applicable noise criteria. The most impacted time is the off-peak period where new spoil trucks would have a much more noticeable impact when compared to existing traffic flows. Night-time haulage would be avoided where practical and feasible during night-time off-peak traffic periods to minimise noise impacts.

Increases in road traffic noise of 2.5 dB(A) have been predicted at Wickham street during night-time off-peak periods.

Proposed management measures to address the above impacts are discussed in **section 11.5**.

11.3.3 Construction ground-borne noise

The ground-borne noise experienced in a building would be dependent on the generation and propagation of vibration associated with underground construction activities. For this project, vibration would be generated during tunnelling from the operation of road headers and rock breakers.

Ground-borne noise decreases over distance and is more likely to be experienced where surface receptors are close to the vibration source. The vibration of the walls and ceiling of a building results in the generation of low-frequency noise which can be audible if the vibration levels are great enough. The noise generated is often described as a low 'rumble'. These effects generally become diminished by interfaces between the subsurface and the foundations as well as up through subsequent floors of the building.

The results of the ground-borne noise assessment with respect to residential properties are provided in **Table 11-25**. These indicate that the maximum exceedance would be up to 1 dB(A) during the night-time period, which is minor, at one receptor location.

Table 11-25 Ground-borne noise assessment – tunnelling activities

L_{Aeq} criteria		Number of receptors where criteria are exceeded	
Evening	Night-time	Evening	Night-time
40 dB(A)	35 dB(A)	0	1

Tunnelling would typically progress around a maximum of seven metres per day. It is likely that ground-borne noise would be discernible for up to five days at each affected receptor with exceedances (of up to 1 dB(A)) occurring for up to two days. Tunnelling advance rates would reduce to two to five metres a day around the portals, which may increase the duration of exposure for receptors in these areas.

There is no daytime criterion for ground-borne noise. However, noise levels during the daytime would be consistent with predicted levels in the evening and night-time. Notwithstanding, background noise during the daytime is generally higher than background noise during the evening and night-time and therefore the assessment is considered to be conservative.

11.3.4 Construction vibration

The project may generate vibration during construction as a result of:

- Surface works within construction ancillary facilities or on subject roads
- Tunnelling activities, with vibration transmitted through the ground to surface receptors
- Blasting underground, if required during tunnelling.

Surface works

Potential impacts from vibration intensive works during construction include the risk of cosmetic/structural damage and human discomfort. This risk is based on conditions which may not be fully understood until work has commenced and therefore specific potential vibration levels are not assessed.

The risk of cosmetic/structural damage and human discomfort is reduced where vibration inducing plant is operated at a safe working distance away from structures and people. The minimum working distances that would be used for construction plant are presented in **Table 11-3**. Further mitigation of vibration would not be required where the minimum working distances are adhered to. More stringent conditions may apply to heritage or other sensitive structures. Any heritage property would need to be considered on a case by case basis and assessed in accordance with *DIN4150:3 (1999-02) Structural vibration - Effects of vibration on structures*.

Depending on the construction equipment that is used, it may be unavoidable that the minimum working distances are encroached. If vibration intensive works are planned within the minimum working distances identified, alternative equipment would be identified and vibration monitoring would be implemented.

In some circumstances, construction activity within the minimum working distance cannot be avoided due to the work required and the prevalent geological site conditions. These conditions may not be fully understood until work has commenced, resulting in a potential change in operating equipment. Approaches to manage such circumstances are discussed in **section 11.5**.

Tunnel works

Vibration associated with the use of road headers can potentially cause physical discomfort to people located above tunnelling works. Vibration associated with the use of road headers has been calculated for properties located above the main tunnel alignments. The results of the assessment are provided in **Appendix G** (Noise and vibration technical report).

The tunnelling activities are predicted to be compliant with both the preferred and maximum human comfort peak particle velocity criteria. Through proper management, such as informing affected receptors that they may feel vibration, the human comfort sensitivity to vibration could be reduced. Potential vibration contours have been mapped and are included in Annexure G of **Appendix G** (Noise and vibration technical report).

Blasting

One option available to the contractor to excavate the tunnel bench would be to use controlled blasting. Controlled blasting would be considered by the construction contractor along the length of the alignment during the excavation of the tunnel, at depths greater than 30 metres. Blasting methods can significantly reduce the duration of exposure to noise and vibration for residents and businesses above the tunnels. Blasting would also shorten excavation timeframes. Impacts created by blasting are largely dependent on the blast methodology. The size of the charge, spaces between charge and timing between charges results in a large variability in the vibration generated by a blast. This variability necessitates the use of a specialised blast consultant to design blasts to achieve compliance with the applicable vibration criteria.

The potential impacts from blasting are considered in Section 5.5.5 of **Appendix G** (Noise and vibration technical report). Using the formula provided in AS2187.2-2006, the assessment found that with a 7 kilogram maximum effective charge mass per delay, compliance with the applicable blasting vibration limits is likely to be achieved at tunnel depths greater than 30 metres.

However the standard notes "In practice due to variations in ground conditions and other factors, the resulting vibration levels can vary from two-fifths to four times that estimated". Hence this information should be used as an indicative guide only.

During construction of the project, a certified blast engineer would undertake test blasts when undertaking blasting in new areas across the project. The blast would be designed to ensure compliance with the blast criteria specified in **section 11.1.4**.

Heritage and other sensitive structures

Heritage and other sensitive structures (including any with Aboriginal significance) have the potential to be more sensitive to vibration than those identified. Some structures such as piped infrastructure and Muddy Creek constructed channel are unlikely to be more sensitive to vibration than the cosmetic damage criteria identified. Typically these structures have very high (>50 mm/s vibration velocity) tolerances to vibration. Considering the types of activities proposed in the vicinity of the Muddy Creek channel (construction of the shared cycle and pedestrian pathways), vibration generated by the project is very unlikely to exceed these vibration levels.

However due to the uncertain nature of the condition of each of these structures, and given their importance, a detailed investigation into each identified structures sensitivity to vibration would be undertaken during the detailed design phase of the project. Structure specific vibration criteria would be applied based on the integrity of the structure.

Where potential for sensitivity is identified, vibration monitoring would be undertaken during all vibration intensive works to ensure that appropriate thresholds are not exceeded.

11.3.5 Permanent power supply

It can be expected that there may be differences between predicted and measured noise levels due to variations in instantaneous operating conditions, plant in operation during the measurement and also the location of the plant equipment.

Construction of the power line would generally be carried out during standard daytime construction hours, however some activities may need to be undertaken outside of standard work hours. Works which may be completed during the night-time have been assessed against both the daytime and night-time criteria. Timing of activities would be refined during detailed design.

Provided below in **Table 11-26** and **Table 11-27** is a summary of the noise impacts from each scenario. The scenarios have been sourced from the Roads and Maritime construction noise estimator tool. Construction noise contours are presented in **Annexure D** to **Appendix G** (Noise and vibration technical report).

Table 11-26 Power line alignment construction noise assessment – Standard hours work

NCA	L_{Aeq} NML dB(A)	Maximum L_{Aeq} noise level dB(A)	NML exceedance 1 10 dB(A)	NML exceedance 11 20 dB(A)	NML exceedance > 20 dB(A)	Number of highly noise affected receptors
Mobilisation and site establishment						
NCA4	48	84	202	28	10	2
NCA5	49	66	183	20	0	0
NCA6	51	47	0	0	0	0
NCA7	51	90	71	49	42	31
NCA8	49	48	0	0	0	0
NCA9	48	47	0	0	0	0
NCA10	63	60	0	0	0	0
NCA11	63	52	0	0	0	0
NCA12	76	54	0	0	0	0
R2	55	88	255	52	28	24
R3	60	90	77	25	21	26
R4	65	87	14	5	1	6
Trenching						
NCA4	48	84	202	28	10	2
NCA5	49	66	183	20	0	0
NCA6	51	47	0	0	0	0
NCA7	51	90	71	49	42	31
NCA8	49	48	0	0	0	0
NCA9	48	47	0	0	0	0
NCA10	63	60	0	0	0	0
NCA11	63	52	0	0	0	0
NCA12	76	54	0	0	0	0
R2	55	88	255	52	28	24
R3	60	90	77	25	21	26
R4	65	87	14	5	1	6

NCA	L_{Aeq} NML dB(A)	Maximum L_{Aeq} noise level dB(A)	NML exceedance 1 10 dB(A)	NML exceedance 11 20 dB(A)	NML exceedance > 20 dB(A)	Number of highly noise affected receptors
Paving/asphalting						
NCA4	48	87	284	56	17	5
NCA5	49	69	197	57	3	0
NCA6	51	50	0	0	0	0
NCA7	51	93	90	49	60	32
NCA8	49	51	2	0	0	0
NCA9	48	50	1	0	0	0
NCA10	63	63	0	0	0	0
NCA11	63	55	0	0	0	0
NCA12	76	57	0	0	0	0
R2	55	91	445	89	36	31
R3	60	93	97	36	25	37
R4	65	90	28	4	5	7

Noise levels from the works associated with the power line alignment construction would exceed the NMLs at nearby receptors during a number of scenarios. The most affected catchment areas would be NCA4 and NCA5. A large number of noise sensitive receptors within Noise Area Category R2 would also be affected. Most of the NML exceedances would be up to 10 dB(A).

The scenario resulting in the highest construction noise levels would be paving/ asphalting. Sensitive receptors are likely to be highly affected when the works are directly adjacent. The severity of the exceedances is due to the small offset distance. As the works move further away from receptors, noise levels would reduce significantly. High noise impacts at any one receptor are unlikely to last for more than a few weeks for each sensitive receptor.

Table 11-27 Power line alignment construction noise assessment – Out-of-hours work (night)

NCA	L_{Aeq} NML dB(A)	Maximum L_{Aeq} noise level dB(A)	NML exceedance <5 dB(A)	NML exceedance 5 15 dB(A)	NML exceedance 16 25 dB(A)	NML exceedance > 25 dB(A)
Mobilisation and site establishment						
NCA4	36	84	11	301	149	22
NCA5	39	66	22	210	79	5
NCA6	38	47	3	14	0	0
NCA7	38	90	11	100	61	77
NCA8	41	48	37	3	0	0
NCA9	37	47	3	6	0	0
NCA10	43	60	9	18	1	0
NCA11	43	52	13	19	0	0
NCA12	61	54	0	0	0	0
R2	40	88	194	1161	255	76
R3	45	90	49	175	77	43
R4	50	87	44	49	14	6

NCA	L_{Aeq} NML dB(A)	Maximum L_{Aeq} noise level dB(A)	NML exceedance <5 dB(A)	NML exceedance 5 15 dB(A)	NML exceedance 16 25 dB(A)	NML exceedance > 25 dB(A)
Trenching						
NCA4	36	84	11	301	149	22
NCA5	39	66	22	210	79	5
NCA6	38	47	3	14	0	0
NCA7	38	90	11	100	61	77
NCA8	41	48	37	3	0	0
NCA9	37	47	3	6	0	0
NCA10	43	60	9	18	1	0
NCA11	43	52	13	19	0	0
NCA12	61	54	0	0	0	0
R2	40	88	194	1161	255	76
R3	45	90	49	175	77	43
R4	50	87	44	49	14	6
Paving / asphalting						
NCA4	36	87	0	244	202	37
NCA5	39	69	3	170	133	13
NCA6	38	50	0	17	0	0
NCA7	38	93	4	80	75	91
NCA8	41	51	12	35	0	0
NCA9	37	50	2	9	0	0
NCA10	43	63	10	23	2	0
NCA11	43	55	6	31	0	0
NCA12	61	57	0	0	0	0
R2	40	91	62	1084	445	120
R3	45	93	45	177	97	58
R4	50	90	52	65	28	7

Noise levels from the works associated with the power line alignment construction would exceed the NMLs at nearby receptors during a number of scenarios where works are required to be carried out during the night-time period. The most affected catchment areas would be NCA4, NCA5 and NCA7. Noise sensitive receptors within Noise Area Category R2 would also be affected when works are being undertaken in close proximity.

As with works to be undertaken during the daytime noise levels would reduce significantly as the works move further away from receptors and are unlikely to last for more than a few weeks for each sensitive receptor.

To minimise adverse impacts generated by these works, noise mitigation measures would be applied in accordance with standard noise mitigation measures identified in **section 11.5**. Noise mitigation would be detailed further in the contractors CNVMP.

11.3.6 Cumulative construction noise

Simultaneous noise from two or more project-related construction activities has the potential to cumulatively increase overall noise levels at nearby sensitive receptors. For locations subject to noise from more than one construction source, it has been assessed that overall noise levels could increase by as much as 3 dB(A) over the levels of the individual activities which is generally considered just discernible to most people.

It is understood that construction of the New M5 Motorway project is due for completion during 2019. Although construction of the project would not coincide with the main construction works of the New M5 Motorway project, construction of the two projects would occur sequentially, extending the impacts on receptors in Arncliffe.

Development is likely to occur in the vicinity of the project especially in the area around President Avenue and the Princes Highway into the future, however the extent and nature of potential future projects is unknown. Known proposed major development surrounding the project is outlined in **section 14.3.2**, however this development is currently under assessment.

Sydney Water is considering undertaking rehabilitation of Muddy Creek in the future, around the proposed shared cycle and pedestrian pathways in Brighton-Le-Sands. There are currently no publicly available plans or a timeline for this project so it is not possible to determine if it would coincide with the F6 Extension Stage 1 project. Considering the severity of the works, it is likely that noise associated with the Muddy Creek rehabilitation would be more substantial than the construction of the shared cycle and pedestrian pathways. If the works do coincide, both projects would be managed to ensure that impacts to the local community are minimised as far as practical.

Assuming that the noisiest stages of any other construction project were to coincide with this project construction, the greatest increase in noise levels from either project would be a maximum of 3 dB(A) on the levels presented in this assessment, where this project is the dominant source. Where receptors are affected to a greater extent by other construction projects, then overall construction noise levels at any receptor could be increased by as much as 3 dB(A) from those projects' noise levels. In the case of construction traffic, a maximum noise level increase of 3 dB(A) is also predicted should projects coincide (**Appendix G** (Noise and vibration technical report)).

The cumulative noise impacts of nearby major projects would be further considered by the contractor during detailed design. Consultation would be undertaken with other contractors to manage cumulative impacts on sensitive receptors within common areas. Feasible and reasonable mitigation measures would be detailed in the CNVMP.

Construction Fatigue

There is the potential for construction noise fatigue for sensitive receptors around the New M5 Motorway Arncliffe Motorway Operations Complex (MOC1). The Arncliffe ventilation facility is currently being built in this location as part of the New M5 Motorway project and would be utilised during the operation of the F6 Extension Stage 1 project. The ventilation facility works part of this project would be limited to just fitout within the constructed ventilation building.

While works for the New M5 Motorway project would be completed before this project commences, meaning cumulative noise impacts are not likely to be an issue, there is the potential for construction noise fatigue at nearby receptors due to the extended duration of the overall construction activity.

The project would also involve the construction of an electrical substation and water treatment plan within the New M5 Motorway Arncliffe Motorway Operations Complex (MOC1). This would also contribute to the potential for construction noise fatigue at nearby receptors.

Construction fatigue would predominantly be managed through discussions with the affected community and the careful planning of potential mitigation measures such as respite periods.

11.4 Potential impacts – operation

11.4.1 Operational road traffic noise

Noise sensitive receptors within the study area of the project are currently affected by appreciable levels of road traffic and other environmental noise. As per the requirements of the RNP, this project is only required to mitigate noise impacts resulting from and directly associated with this project.

The project would alter the volumes of operational road traffic throughout the study area. For several roads in the region, such as Princes Highway to the north of President Avenue, this would result in a reduction in the overall volume of traffic. As the L_{Aeq} road traffic noise levels are largely controlled by traffic volumes this project would result in an appreciable reduction in noise levels along Princes Highway to the north of President Avenue. These reductions are however not identified in this assessment as they occur outside the noise assessment study area.

Operational noise modelling scenarios

Operational road traffic noise levels for both the daytime and night-time periods have been assessed for the following scenarios:

- **Year 2026 No Build scenario –** a future network including NorthConnex, the WestConnex program of works, King Street Gateway, Sydney Gateway, and some upgrades to the broader road and public transport network over time to improve capacity and cater for traffic growth.
- **Year 2026 Build scenario –** with the 2026 No Build projects completed and the F6 Extension Stage 1 (New M5 Motorway, Arncliffe to President Avenue, Kogarah) complete and open to traffic.
- **Year 2036 No Build scenario –** a future network including NorthConnex, the WestConnex program of works, King Street Gateway, Sydney Gateway, and some upgrades to the broader road and public transport network over time to improve capacity and cater for traffic growth.
- **Year 2036 Build scenario –** with the 2036 No Build projects completed and the F6 Extension Stage 1 (New M5 Motorway, Arncliffe to President Avenue, Kogarah) complete and open to traffic.
- **Year 2036 Cumulative scenario -** With the 2036 Build projects completed and Western Harbour Tunnel and Beaches Link, and future stages of the F6 Extension between Kogarah and Loftus complete and open to traffic.

There is no Year 2026 Cumulative scenario as there are no additional projects which would be operational by 2026.

Operational noise modelling results

Operational road traffic noise levels have been predicted for each of the operational noise modelling scenarios outlined above. The results are summarised in **Table 11-28**. Detailed noise prediction results are provided in **Appendix G** (Noise and vibration technical report).

Table 11-28 Summary of operational road traffic noise impacts

Period	Summary of impacts
Daytime period	• Daytime road traffic noise levels are predicted to exceed the $L_{Aeq(15hour)}$ noise criterion at a total of 148 sensitive receptors • Noise levels that exceed the applicable daytime noise criterion are predicted to increase by more than 2 dB(A) at 19 sensitive receptors • Noise levels are predicted to exceed the cumulative limit at 90 sensitive receptors (i.e. ≥ $L_{Aeq(15\ hour)}$ noise criterion + 5 dB(A)) • 105 sensitive receptors are considered to be eligible for the consideration of feasible and reasonable noise mitigation measures.
Night-time period	• Night-time road traffic noise levels are predicted to exceed the $L_{Aeq(9hour)}$ noise criterion at a total of 135 sensitive receptors • Noise levels are predicted to exceed the applicable night-time noise criterion and increase by more than 2 dB(A) at 14 noise sensitive receptors • Noise levels are predicted to exceed the cumulative limit at 80 sensitive receptors (i.e. ≥ $L_{Aeq(9\ hour)}$ noise criterion + 5 dB(A) • 90 sensitive receptors are considered eligible for the consideration of feasible and reasonable noise mitigation measures.
Combined impacts during the daytime and night-time period	• Traffic noise levels are predicted to exceed either the daytime $L_{Aeq(15hour)}$ noise criterion, the night-time $L_{Aeq(9hour)}$ noise criterion, or both criterion at a total of 159 sensitive receptors • Noise levels are predicted to exceed the applicable daytime noise criterion and increase by more than 2 dB(A), exceed the night-time noise criterion and increase by more than 2 dB(A), or exceed both of these combined criteria at 19 noise sensitive receptors • Noise levels are predicted to exceed the cumulative limit at 92 sensitive receptors • 107 sensitive receptors are considered eligible for the consideration of feasible and reasonable noise mitigation measures.

For the Year 2026 and 2036 build scenarios, a total of 107 receptors (including residential and school receptors) are predicted to experience exceedances of the operational road traffic noise criteria for the project and are therefore eligible for consideration of additional noise mitigation. A list of these 107 receptors is provided in **Appendix G** (Noise and vibration technical report).

Additional noise mitigation to be considered would include architectural treatment. While this assessment has concluded that architectural treatment may be required, in accordance with the Roads and Maritime NMG, the actual noise mitigation that would be incorporated in the project design would be confirmed at the detailed design phase. Changes in the design may mitigate the design sufficiently at the source so that at-receptor noise mitigation is no longer required. These details would be confirmed in the Operational Noise and Vibration Review (ONVR) that would be developed at the detailed design phase of the project. Refer to **section 11.5** for further information regarding additional noise mitigation measures.

Parallel routes assessment

The project is expected to generate additional traffic throughout the local area, on roads which have not been considered as project roads (i.e. those roads not being created or upgraded as part of the project). This has the potential to lead to increases in road traffic noise levels during the operational period of the project.

The NCG considers any project to be a traffic generating development if it is predicted to increase noise levels by greater than 2.0 dB(A) on any other road. A screening assessment was undertaken and identified potential noise increases exceeding this limit along Civic Avenue, Kogarah and O'Connell Street, Monterey.

The project also has the potential to affect traffic flows on surface roads surrounding St Peters interchange, however road traffic noise levels in this location are not predicted to increase by more than 2 dB(A).

The full screening assessment for the parallel routes noise assessment is provided in **Appendix G** (Noise and vibration technical report) and is summarised below.

Civic Avenue

The use of local streets for non-local trips has been identified for westbound President Avenue traffic, turning left onto Civic Avenue, then right onto Marshall Street, and left onto Rocky Point Road. This route has been identified in preference to traffic travelling east on President Avenue, south on The Grand Parade and then accessing Rocky Point Road from Ramsgate Road or Sandringham Street.

The screening assessment identified that the most affected scenario would be the 'Year 2036 Build night-time' (10pm to 7am) scenario, where noise levels on Civic Avenue would increase by about 2.6 dB(A).

Traffic control measures would be investigated to encourage heavy vehicles to take major routes in preference to this route (such as President Avenue, Princes Highway, and The Grand Parade). These would be reviewed and examined further detail during detailed design phase of the project.

O'Connell Street

The existing dominant southbound heavy vehicle route in this area is south on The Grand Parade, westbound Ramsgate Road or Sandringham Street, then continuing southbound on Rocky Point Road. With the new F6 off ramps at President Avenue, the strategic traffic model predicts heavy vehicles would travel down O'Connell Street and Chuter Avenue until Ramsgate Road. This would result in a noise increase on O'Connell Street as a result of both heavy and light vehicles of about 2.8 dB(A).

An existing 4.5 tonne limit is in operation on Barton Street and O'Connell Street south of President Avenue. This means that many of the heavy vehicles that the strategic model is predicting to travel on O'Connell Street would not legally be allowed to do so. The strategic model is unable to differentiate in different heavy vehicle weight classes, hence the model conservatively predicts that all heavy vehicle traffic would use this route.

The existing weight classes on The Grand Parade have been analysed and results show approximately 45% of the heavy vehicle traffic is over 4.5 tonne. As such it is likely that at least 45% of heavy vehicles that are predicted to use O'Connell Street would be forced by this restriction to continue to use The Grand Parade, or head west to the Princes Highway, dependent on their ultimate destination, rather than use O'Connell Street.

As O'Connell Street is an unclassified regional road, a strategy would be developed by Roads and Maritime in consultation with Council to minimise the impacts of the project. This may involve Local Area Traffic Management (LATM) measures along O'Connell Street. Initial analysis suggests that reassigning this forecast traffic demand to the Princes Highway and The Grand Parade may require upgrades to The Grand Parade / President Avenue intersection.

It is expected that a proposed Road Network Performance Review Plan would confirm the operational traffic impacts of the project on surrounding arterial roads and major intersections. These reviews would be scheduled at 12 months and five years after the commencement of operation of the project and would examine potential management measures, following the collection of data that would facilitate a clearer understanding of actual project impacts.

Maximum noise level assessment

Maximum noise level events are generally related to truck engine braking events, however loud exhausts and horns may also contribute. Maximum noise level events have been considered at 750 Princes Highway, Kogarah, as described in **Appendix G** (Noise and vibration technical report). This location is considered to be generally representative of receptors along the future proposed alignment.

The maximum noise levels events at 750 Princes Highway, Kogarah indicate that the area is already exposed to maximum noise level events that have the potential for awakening reactions. Given the predicted increase in heavy vehicle patronage due to the project, there is the potential for additional maximum noise level events in the future. Maximum noise level assessments can be used to prioritise the application of other noise mitigation measures which may also provide a noise benefit for these events.

Roads and Maritime has long term strategies which are being employed to ensure noise levels from trucks are reduced across the entire NSW road network. These include:

- Advocating for tighter vehicle noise standards
- Regulation of heavy vehicle noise including periodic inspections of heavy vehicles at testing stations to ensure that silencers are fitted and maintained
- Engaging with the Commonwealth process coordinated by the National Transport Commission to look at ways of reducing engine compression brake noise.

11.4.2 Fixed facilities noise

Fixed facilities which would operate as part of the project include:

- Arncliffe MOC, including the ventilation facility, electrical substation, water treatment plant and car parking
- Rockdale North MOC, including the Motorway Control Centre office building, car parking, fire pump room and deluge water tanks, maintenance facility, motorway bulky equipment store and yard and car parking
- Rockdale South MOC, including the ventilation facility, distribution substation, car parking and disaster recovery system
- Portals for entry and exit ramps at President Avenue .

Key noise sources within these fixed facilities include:

- Axial ventilation fans housed within buildings, noise emissions arising primarily via the external outlets/inlets
- Noise break-out from in-tunnel jet fans at tunnel portals
- Switches within substations
- Transformers within substations
- Noise from accelerating cars, door/boot slamming and people talking within car parking areas
- Pumps and blowers within the water treatment facilities
- Noise from operation of fixed and mobile plant, truck movements, deliveries Within the maintenance facility

Noise emissions during operation of the project would be influenced by the volumes of traffic using the project tunnels. Ventilation fans within the project tunnels would be operated at different speeds to maintain acceptable in-tunnel air quality, with the speed of the ventilation fans therefore related to traffic conditions within the tunnels. To take different ventilation fan operational modes into account, the fixed facility noise assessment has considered operation of the project under the following conditions:

- normal traffic conditions, i.e. when traffic speeds are around the posted speed limit and fans are turned off
- low speed traffic conditions, i.e. when traffic speeds slow towards 40 kilometres per hour or less and select jet fans are required to be operated in direction of travel to generate more tunnel airflow
- emergency operating conditions, invoked in the incident of a fire and all jet fans are required to be operated in the direction of the nearest exhaust facility in order to get the smoke out of the tunnel.

The sound power levels under the conditions listed above are provided in detail in **Appendix G** (Noise and vibration technical report).

The fixed facility operational noise assessment has also taken into account different weather conditions including ‘neutral’ weather, wind speeds of up to three metres per second and temperature inversion conditions where the direction in which sound travels can be altered by weather conditions, which may result in varying noise levels at the same location at different times.

Assessment

In summary, the predicted noise levels presented in **Appendix G** (Noise and vibration technical report) demonstrate that during normal traffic conditions, low speed traffic conditions and emergency operating conditions, the operational noise criteria would not be exceeded during neutral or adverse weather conditions. The assessment also found that the noise would not contain any low-frequency or tonal characteristics.

The results also show that the $L_{A1(1min)}$ levels at all receptors would comply with the sleep disturbance noise screening criteria and therefore no further sleep disturbance assessment is required.

11.4.3 Predicted effectiveness of mitigation measures

The operational noise assessment has been undertaken, investigating the project generated noise impacts. The investigation found that 19 sensitive receptors would exceed the applicable noise criteria and increase by more than 2 dB(A) throughout the project area. A total of 92 sensitive receptors already exceed the applicable noise criteria and would continue to in the future (i.e. impacts are not as a result of an increase in noise). A quiet road surface was investigated to reduce noise levels, however due to low traffic speeds and congested traffic, it was found not to be effective. Noise barriers were also found to be unfeasible due to limited opportunities to build them (access needs to be maintained to properties). Mitigation in the form of architectural treatment would be considered in more detail at the detailed design phase of the project once a construction contract has been awarded. During detailed design, property investigations would take place, in consultation with property owners to determine their preferences for architectural treatments.

Cumulative construction and operational noise impacts have also been considered. Construction noise impacts would need to be managed when more detail about specific work packages and concurrent works are available. Generally speaking, due to the location of the site and receptors, concurrent works are unlikely to have an appreciable impact on sensitive receptors.

11.4.4 Cumulative operation noise

Other motorway projects

The cumulative noise impacts from other motorway projects have been assessed in **section 11.4.1**. The assessment has included a cumulative scenario in the design year (2036). The cumulative scenario takes into consideration other major road projects throughout the network.

Arncliffe Motorway Operations Complex (MOC1) assessment – combined New M5 Motorway and this project

This assessment has been undertaken to determine noise emissions from the Arncliffe Motorway Operations Complex (MOC1) with the plant and equipment from both the New M5 Motorway project and the F6 Extension Stage 1 (New M5 Motorway, Arncliffe to President Avenue, Kogarah).

The noise emissions from permanent combined operational fixed facilities at Arncliffe were assessed for neutral and adverse weather conditions and for normal traffic, low speed traffic and emergency conditions. The predicted noise levels, as presented in **Appendix G** (Noise and vibration technical report), demonstrate that during both normal traffic conditions and low speed traffic conditions, the operational noise criteria would not be exceeded during neutral or adverse weather conditions.

Operational noise levels at all non-residential sensitive receptors comply with the appropriate criteria.

11.4.5 Residual noise impacts

Adjacent to the project

The assessment has identified that predominantly due to the need to maintain access to dwellings and properties, in corridor noise mitigation by use of noise barriers is not feasible. Accordingly, where noise levels exceed the relevant trigger levels established in accordance with the procedures in the Roads and Maritime noise guidelines, dwellings would be eligible for consideration of at-property mitigation treatments.

In accordance with the Roads and Maritime NMG, the actual noise mitigation that would be incorporated in the project design would be confirmed at the detailed design phase, taking into consideration the existing level of property treatment. Controlling noise at the source is always the preferred approach, and changes in the design may mitigate the design sufficiently so that at-receptor noise mitigation is no longer required, or a lower level of treatment required instead. Specific details regarding noise mitigation for each eligible property would be confirmed in the Operational Noise and Vibration Review (ONVR) which would be developed at the detailed design phase of the project.

Where properties have been identified for architectural treatment and these properties would be impacted by noise from construction works, Roads and Maritime would consult with property owners about bringing forward the installation of treatments to provide noise mitigation during the construction of the project. Any treatment, once agreed to by the property owner, would be implemented within six months of the commencement of construction in the vicinity of the impacted receptor to minimise construction noise impacts. This approach would assist in managing noise through all phases of the project.

The installation of at-property treatments for this project would be separate to the Noise Abatement Program currently being rolled out by Roads and Maritime.

Parallel Routes

Heavy vehicles have been identified as the dominant source of the noise criteria exceedance along Civic Avenue. Installation of a 4.5 tonne limit on this road has the potential to reduce impacts to comply with the applicable criteria. A road traffic analysis throughout the area has identified that a 4.5 tonne limit would reduce heavy vehicle movements by 45% on Civic Avenue.

This option would need to be discussed, and agreed upon with Bayside Council and other stakeholders before it can be committed to. This process would be undertaken during the detailed design phase. In the event that a 4.5 tonne limit could not be installed, an alternative approach to controlling noise impacts would be considered and documented in the operational noise and vibration report (ONVR).

To manage noise impacts on O'Connell Street, the preference would be to limit traffic movements through Local Area Traffic Management (LATM) planning. This could involve providing a more attractive route via The Grand Parade by improving the timing of traffic signals for the right-turn from President Avenue onto The Grand Parade. However any proposed measures would need to be discussed with the Bayside Council and other stakeholders prior to being committed to. More detailed traffic and associated noise studies would also need to be undertaken to understand the likely improvements to noise impacts.

In the event that LATM measures cannot be committed to, or are not found to be successful, at-property treatment would be considered for receptors on O'Connell Street, 600 metres south of President Avenue. This distance represents the RNP required assessment offset. The extent of consideration would include all residential receptors on O'Connell Street between President Avenue and Bath Street.

Confirmation of noise management and mitigation measures would be provided in the ONVR at the detailed design phase of the project once discussions with the Bayside Council and other stakeholders has taken place.

11.5 Management of impacts

Mitigation and management measures for potential ambient noise and vibration impacts during construction and operation are shown in **Table 11-29**. Most of these measures are routinely employed as ‘standard practice; on projects of this scale.

Table 11-29 Environmental management measures – Noise and vibration

Impact	Reference	Environmental management measures	Timing
Construction noise and vibration	NV1	A Construction Noise and Vibration Management Plan (CNVMP) will be prepared. The CNVMP will include processes and responsibilities to assess, monitor, minimise and mitigate noise and vibration impacts during construction. The plan will: • Identify relevant performance criteria in relation to noise and vibration • Identify noise and vibration sensitive receptors and features in the vicinity of the project • Include standard and additional mitigation measures from the Construction Noise and Vibration Guideline (CNVG) (Roads and Maritime 2016) and details about when each will be applied • Describe the process(es) that will be adopted for carrying out location and activity specific noise and vibration impact assessments to assist with the selection of appropriate mitigation measures • Consider cumulative construction noise impacts and construction noise fatigue • Include protocols that will be adopted to manage works required outside standard construction hours, in accordance with relevant guidelines • Detail monitoring that will be carried out to confirm project performance in relation to noise and vibration performance criteria. The CNVMP will be implemented for the duration of the construction of the project.	Prior to construction
	NV2	Detailed noise assessments will be carried out for all ancillary facilities required for construction of the project. The requirement for temporary noise walls within ancillary facilities and adjacent to construction works, and the requirement for other appropriate noise management measures, is to be assessed and implemented prior to the commencement of activities which have the potential to cause noise or vibration impacts.	Prior to construction

	NV3	All residents affected by noise from the construction of the project which are expected to experience an exceedance of the construction NMLs will be consulted about the project prior to the commencement of the particular activity, with the highest consideration given to those that are predicted to be most affected as a result of the works. Roads and Maritime would consult with vulnerable members of the community who are likely to be more susceptible to adverse health effects of noise (especially those who are elderly, who do not speak English, are housebound, or who may be unwell) to accommodate their preferences for noise mitigation, as far as practicable. Consultation would also be undertaken with all schools likely to be affected, and in particular Cairnsfoot Special School, to determine suitable mitigation measures where necessary. The information provided to the residents will include: • General sequencing and locations of construction work • The hours of the project works • Construction noise and vibration impact predictions for the works • Construction noise and vibration mitigation measures likely to be implemented on site. Community consultation regarding construction noise and vibration will be detailed in the Community Involvement Plan for the construction of the project and will include a complaints handling process. The community will be able to provide feedback via a 24 hour, toll-free project information and complaints line, a dedicated email address and postal address for the project. For out of hours works, consultation with affected residents will take place with consideration to Practice note vii of the ENMM and Strategy 2 of the ICNG.	
	NV4	Noisy work (as defined in the EPL) and vibration intensive activities (those activities that exceed the vibration criteria) will be scheduled to be undertaken during standard construction hours as far as possible. Works or activities that cannot be undertaken during standard construction hours will be scheduled as early as possible during the evening and/or night-time periods. Respite measures are to be implemented for noisy work and vibration intensive activities in a manner consistent with EPL and Roads and Maritime guideline requirements.	Construction
	NV5	Receptors identified as requiring at-property operational noise mitigation will be identified and offered treatment prior to commencement of construction works that affects them.	Prior to construction
	NV6	Construction vehicle movements (on and off site) will be managed to avoid or minimise noise impacts. Where reasonable and feasible, spoil will only be removed from site during the day. Mitigation measures for vehicle movements outside of standard construction hours are to be included in the CNVMP.	Construction

Impact	Reference	Environmental management measures	Timing
	NV7	Vibration generating activities will be managed to minimise the potential for impacts on structures and sensitive receptor(s), including maximising minimum working distances where practicable, or use of alternate methods to minimise vibration where minimum working distances cannot be achieved. Where alternatives cannot be implemented, vibration monitoring is to be undertaken and receptors notified in advance of works. Vibration monitors are to provide real-time notification of exceedances of levels approaching cosmetic damage criteria.	Construction
Operational noise	NV8	Operational noise and vibration mitigation measures are to be identified in an Operational Noise and Vibration Review (ONVR). Requirements for at-property noise treatments in properties identified as 'eligible' in the EIS will be reviewed as part of the ONVR and progress of the detailed design. The implementation of treatments will be undertaken in accordance with Roads and Maritime Guidelines.	Detailed design
	NV9	Within 12 months of the commencement of the operation of the project, actual operational noise performance will be compared to predicted operational noise performance. The need for additional mitigation or management measures to address identified operational performance issues and meet relevant operational noise criteria will be assessed and implemented where reasonable and feasible.	Operation

11.6 Environmental risk assessment

An environmental risk analysis was undertaken for noise and vibration and is provided in **Table 11-30** below.

A level of assessment was undertaken commensurate with the potential degree of impact the project may have on that issue. This included an assessment of whether the identified impacts could be avoided or minimised (for example, through design amendments). Where impacts could not be avoided, environmental management measures have been recommended to manage impacts to acceptable levels.

The residual risk is the risk of the environmental impact after the proposed mitigation measures have been implemented. The methodology used for the environmental risk analysis is outlined in **Appendix O** (Methodologies).

Table 11-30 Environmental risk analysis – Noise and vibration

Summary of impact	Construction/ operation	Management and mitigation measures	Likelihood	Consequence	Residual risk
Noise and vibration impacts on sensitive receptors from construction activities, including the use of construction compounds	Construction	NV1, NV2	Likely	Moderate	Medium
Noise and vibration impacts outside of standard construction hours	Construction	NV1, NV3	Likely	Moderate	Medium
Road traffic noise impacts for receptors along some parts of the network as a result of the project	Operation	NV17	Likely	Moderate	Medium

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