Transport for NSW

Western Harbour Tunnel and Warringah Freeway Upgrade

Environmental Impact Statement

January 2020

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Chapter

12

Chapter 12

Air quality

January 2020

12 Air quality

This chapter outlines the potential air quality impacts associated with the project. A detailed air quality impact assessment has been carried out for the project and is included in Appendix H (Technical working paper: Air quality).

An assessment of potential human health impacts associated with air quality is provided in Chapter 13 (Human health).

The Secretary's environmental assessment requirements as they relate to air quality, and where in the environmental impact statement these have been addressed, are detailed in Table 12-1.

The proposed environmental management measures relevant to air quality are included in Section 12.7.

Table 12-1 Secretary's environmental assessment requirements – air quality

Secretary's requirements	Where addressed in EIS
Air quality	
1. The Proponent must undertake an air quality impact assessment (AQIA) for construction and operation of the project in accordance with the current guidelines.	**Section 12.5** and **Section 12.6** outlines the air quality impacts of the construction and operation of the project respectively.
2. The Proponent must ensure the AQIA also includes the following:	See below.
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 12.1** outlines information in respect to the *Protection of the Environment Operations Act 1997* and the Protection of the Environment Operations (Clean Air) Regulation 2010.
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;	The identification of all potential sources of air pollution during construction and operation are outlined in **Section 12.2**; the configuration and design of ventilation systems and tunnel portals are shown in **Chapter 5** (Project description).
c. A review of vehicle emission trends and an assessment that uses or sources best available information on vehicle emission factors;	Best available information on vehicle emission trends are presented in **Section 12.4**.
d. An assessment of impacts (including human health impacts) from potential emissions of PM_{10}, $PM_{2.5}$, CO, NO_2, and other nitrogen oxides and volatile organic compounds (eg BTEX) including consideration of short and long term exposure periods;	An assessment of impacts of air pollutants during short and long term exposure periods are outlined in **Section 12.6**. Impacts to human health due to the operation of the project is provided in **Section 13.5** (Human Health).

Secretary's requirements	Where addressed in EIS
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 network;	An assessment of impacts from the dispersal of air pollutants on ambient air quality along the project alignment is outlined in **Section 12.6**.
f. A qualitative assessment of the redistribution of ambient air quality impacts compared with existing conditions, due to the predicted changes in traffic volumes;	A qualitative assessment of the redistribution of ambient air quality impacts in comparison to existing conditions is presented in **Section 12.6.3**.
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 scenarios (variable speed) and the worst case breakdown scenario, and discussion of the likely occurrence of each;	**Section 12.6** outlines the assessment of in-tunnel air quality in addition to the assessment of issues related to ambient air quality.
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 (ie ventilation outlets and air inlets) including details of proposed air quality monitoring (including frequency and criteria);	Details of the proposed tunnel design and monitoring are presented in **Chapter 5** (Project description), while mitigation and management measures in relation to in-tunnel air quality and air quality in the vicinity of portals and mechanical ventilation systems are outlined in **Section 12.7**.
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 M4 East project, New M5 project and the In-Tunnel Air Quality (Nitrogen Dioxide) Policy;	Information relating to the design standard of the proposed ventilation system for the project is provided in **Chapter 5** (Project description). Criteria applied in this assessment are discussed in **Section 12.1** and **Section 12.3**. The project and ventilation system has been designed to meet in-tunnel criteria and ambient air quality goals and criteria as outlined in **Section 12.3**.
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;	Details of any emergency ventilation systems, such as air intake/ventilation outlets, including protocols for the operation of these systems in emergency situations, potential emission of air pollutants and their dispersal, and safety procedures are presented in **Chapter 5** (Project description).

Secretary's requirements	Where addressed in EIS
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;	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 are outlined in **Section 12.7** and expanded upon in **Chapter 5** (Project description). **Chapter 4** (Project development and alternatives), **Section 4.5** provides the ventilation system design alternatives.
l. A description and assessment of the impacts of potential emission 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 proposal, particularly in relation to ancillary facilities (such as concrete batching plants), dredge and tunnel spoil handling and storage at Glebe Island and White Bay, the use of mobile plant, stockpiles and the processing and movement of spoil; and	A description and assessment of impacts relating to potential emission sources relating to construction are outlined in **Section 12.5**, while mitigation measures to prevent the generation and emission of dust and other air pollutants (including odours) are presented in **Section 12.7** of this chapter.
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 motorway tunnels and surface roads.	The cumulative assessment of the in-tunnel, local and regional air quality impacts, as well as consideration of continuous travel through motorway tunnels, is outlined in **Section 12.6**.

12.1 Legislative and policy framework

The *Protection of the Environment Operations Act 1997* (NSW) (POEO Act) provides the legislative authority for the NSW Environment Protection Authority (EPA) to regulate air emissions in NSW. The Secretary's environmental assessment requirements for the project refer to the POEO Act and the Protection of the Environment Operations (Clean Air) Regulation 2010 (NSW). Although the Regulation specifies concentration limits for air emissions, these limits are designed primarily for industrial activities and the limit values are much higher than those imposed for road tunnels in Sydney. The monitoring and management of dust emissions during construction and the ventilation outlet emissions during operation would be regulated under an Environment Protection Licence prescribed under the POEO Act.

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 *Modelling and Assessment of Air Pollutants in NSW* (NSW EPA, 2016) (NSW EPA Approved Methods).

As part of the preparation of the air quality impact assessment for the project, the Technical working paper: Air quality (Appendix H) was issued to the Office of the Chief Scientist and Engineer and The Advisory Committee on Tunnel Air Quality (ACTAQ) to carry out a scientific review of the project's air emissions from ventilation outlets.

In February 2018, the NSW Government announced stronger measures on emissions from motorway tunnels and then established a new process for the assessment, determination, and compliance of significant road tunnels (and associated ventilation systems). The process, which applies to the project, is summarised below:

- Prior to public exhibition of the environmental impact statement:
  - The Office of the Chief Scientist and Engineer (OCSE) provides a scientific review of a project's air emissions from ventilation outlets for the Minister of Planning and Public Spaces' consideration
  - The NSW Chief Health Officer releases a statement on the potential health impacts of emissions from tunnel ventilation outlets informed by the review by the OCSE
- The EPA provides technical advice to the Department of Planning, Industry and Environment on operational air quality impacts during the assessment of the Environmental Impact Statement
- The Department of Planning, Industry and Environment seeks advice from an independent air quality expert during the assessment of the environmental impact statement, if required
- If the project is approved, the Department of Planning, Industry and Environment regulates the construction and operation of the project in accordance with the project approval
- The EPA licences emissions from ventilation outlets under the POEO Act.

For the operating years of the project, nitrogen dioxide (NO_2) would be the pollutant that determines the required airflow and drives the design of the tunnel ventilation system. In February 2016, the ACTAQ issued a policy entitled *In-tunnel air quality (nitrogen dioxide) policy* (ACTAQ, 2016). The policy consolidates the approach taken for similar projects (NorthConnex, M4 East and New M5), and requires tunnels to be 'designed and operated so that the tunnel average NO_2 concentration is less than 0.5 ppm as a rolling 15 minute average'. In 2018, ACTAQ released *Technical Paper TP07: Criteria for In-tunnel and Ambient Air Quality* (ACTAQ, 2018a), which concluded that the NO_2 criterion is the most stringent in Australia and compares favourably to the international in-tunnel NO_2 design guidelines which range from between 0.4 ppm to 1 ppm. The tunnel ventilation system would be designed to achieve this criterion.

With regards to regional air quality, the EPA has developed a *Tiered Procedure for Estimating Ground Level Ozone Impacts from Stationary Sources* (ENVIRON, 2011). This procedure was applied to the air quality impact assessment of the project to give an indication of the likely significance of the project's effect on ozone concentrations in the broader Sydney region.

The in-tunnel and ambient air quality assessment was carried out against criteria, or levels of pollutants, that have been adopted by the NSW Government. Schedule 4 of the Protection of the Environment Operations (Clean Air) Regulation 2010 (NSW) specifies standards of concentrations for general activities and plant. The project was assessed against the air quality criteria listed in the NSW EPA Approved Methods.

Odour emissions have been assessed and managed in accordance with the *Technical framework for the assessment and management of odour from stationary sources in NSW* (DEC, 2006). This framework introduces a system that protects the environment and the community from the impacts of odour emissions, while promoting fair and equitable outcomes for the operators of activities that emit odour.

12.2 Assessment methodology

12.2.1 Overview

The assessment methodology for air quality impacts has included the following key tasks:

- Qualitative assessment of potential dust impacts during construction of the project
- Dispersion modelling to assess the potential odour impacts on sensitive receivers resulting from dredging activities and the transport and treatment of dredge materials at White Bay during construction of the project
- Assessment to ensure the tunnel ventilation system can achieve acceptable in-tunnel air quality outcomes for carbon monoxide (CO), NO_2 and visibility during operation of the project
- Modelling of changes in the concentrations of key pollutants at community, residential, workplace and recreational receiver locations for expected traffic and operation of the project under a number of worst case operational scenarios
- Assessment of regional air quality impacts associated with the operation of the project
- Prediction of changes in the levels of three representative odorous pollutants (toluene, xylenes, and acetaldehyde) at receivers with the operation of the project.

The methodology for the assessment of both construction and operational air quality impacts, as well as the modelling inputs and assumptions used to carry out this assessment is provided in full at Appendix H (Technical working paper: Air quality) of this environmental impact statement.

12.2.2 Construction air quality assessment methodology

Air quality impacts as a result of construction of the project include those associated with exhaust emissions and from the generation of dust and odour.

Exhaust emissions during construction would occur as a result of the use of some plant and equipment. These impacts are considered to be minor and unlikely to have a noticeable impact on the surrounding environment. Any impacts associated with exhaust emissions would be managed through the environmental management measures described in Section 12.7.

Some construction activities could also result in the generation of dust and odours. The assessment methodology for the air quality impacts associated with the generation of dust and odour are described below.

Dust assessment

For the purpose of the construction dust assessment, construction activities have been categorised into four types to reflect their potential impacts:

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

It is difficult to quantify dust emissions from construction activities since it is not possible to predict the weather conditions that will prevail during specific construction activities. The effects of construction on airborne particulate matter would generally be temporary and of relatively short duration, and mitigation should be straightforward since dust suppression measures are routinely employed as ‘good practice’ at most construction sites. It is therefore common practice to provide a qualitative assessment of potential construction dust impacts. The qualitative assessment approach carried out for the project follows the UK Institute of Air Quality Management’s *Guidance on the assessment of dust from demolition and construction* (IAQM, 2014). The IAQM guidance has been adapted for use in NSW, taking into account factors such as the assessment criteria for ambient PM_{10} concentrations (being particulate matter less than or equal to 10 micrometre diameter). 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 considered the risk of dust deposition and elevated concentrations of dust (as PM_{10}) in the air from construction activities, and potential impacts on amenity, human health and the environment.

Key steps in the assessment included:

- An initial screening to identify whether there is a risk of construction dust impacts based on the proximity of human and ecological receivers to construction activities
- A risk assessment to determine which construction activities have the potential to generate a dust impact based on the scale and nature of the activities, and the sensitivity of nearby human and ecological receivers
- Identification of appropriate dust mitigation and management measures depending on the assessed risk of impact.

Further details of the construction dust assessment methodology are provided in Appendix H (Technical working paper: Air quality) of this environmental impact statement. The assessment of construction dust using the IAQM procedure is outlined in Figure 12-1. The construction dust assessment carried out for the project is summarised in Section 12.5.1.

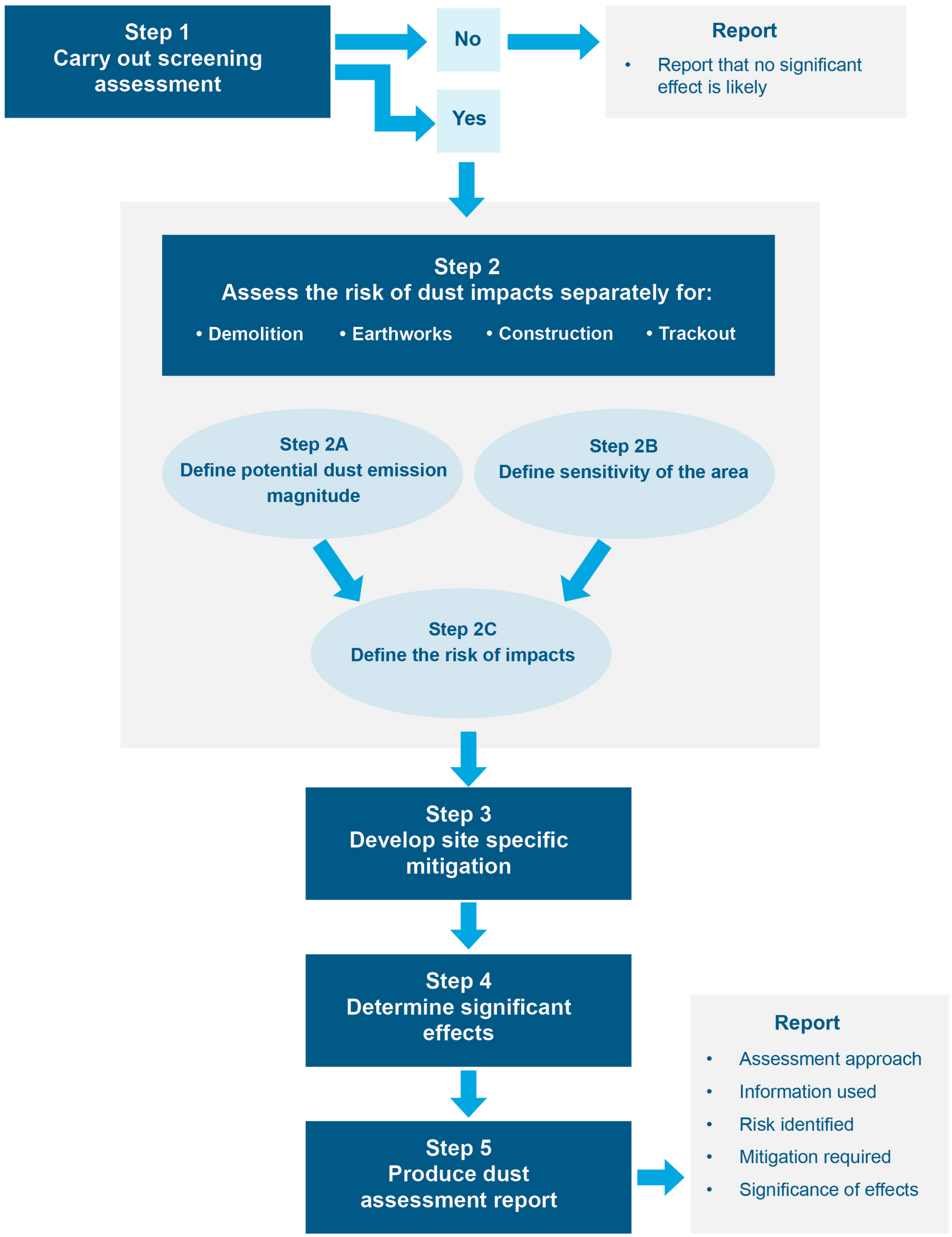

Figure 12-1 Construction dust assessment procedure

Odour assessment

Dispersion modelling has been carried out to assess the potential odour impacts at nearby sensitive receivers during construction of the project, specifically as a result of the dredging activities within Sydney Harbour, and the associated treatment and transport of dredged materials at the White Bay construction support site (WHT3).

Dispersion modelling requires consideration of environmental factors and construction methodologies, including local meteorological conditions and emission rates from potential sources of odour.

Estimates of odour emission rates were taken from measurements made for similar dredging operations. The dispersion model takes a conservative approach and assumes that the total treatment area would be exposed, with odorous material present for every day of the year. In reality, the exposure of odorous material would be much less in terms of both area and duration.

Meteorological data used in the model was obtained from weather stations at Manly, Fort Denison, Randwick and Sydney Airport.

12.2.3 Operational air quality assessment methodology

Air quality impacts from the operation of the project are associated with emissions from vehicles using the project. The impact of vehicle emissions was considered in terms of effects on in-tunnel air quality, local air quality, regional air quality and odour.

In-tunnel air quality

The tunnel ventilation system would be operated to achieve acceptable in-tunnel air quality outcomes for CO, NO_2 and visibility (as a measure of in-tunnel particulate matter concentrations) (refer to Section 12.3.2 for additional information relating to in-tunnel air quality criteria).

In-tunnel air quality modelling was carried out using IDA Tunnel software. The modelling considered traffic volumes, tunnel air flow, vehicle emission levels, and temperature. The modelling incorporated the Western Harbour Tunnel component of the project and all linked motorway tunnel projects (WestConnex and the proposed Beaches Link) and considered the following scenarios:

- Expected traffic – 24-hour operation of the project ventilation system under day-to-day conditions of expected traffic demand in 2027 and 2037
- Worst case traffic – the most onerous traffic conditions for the ventilation system (refer below)
- Travel route scenarios – a worst case trip scenario for in-tunnel exposure to NO_2.

Operational worst case scenarios

Operational worst case scenarios consider emissions from traffic within the tunnels and represent the theoretical maximum pollutant concentrations for all potential traffic operations in the tunnel as well as vehicle breakdown situations. The operational worst case scenarios are very conservative and would result in pollutant emission concentrations that are much higher than those that could occur under any foreseeable operational conditions in the tunnel.

The operational worst case scenarios for the assessment of in-tunnel air quality considered worst case (variable speed) traffic operations and worst case (breakdown or major incident) operations.

The worst case (variable speed) traffic operation scenario represents the upper limit of daily operations on the ventilation system of the mainline tunnels, regardless of the year of operation, and is based on the traffic flow splits of the predicted traffic peak periods with the mainline tunnels reaching a theoretical maximum lane capacity traffic flow rate. This scenario also includes the highest predicted number of buses using the mainline tunnels being introduced into the Beaches Link mainline tunnels, which connect to the Western Harbour Tunnel. The worst case (variable speed) traffic operation scenario was considered under four different average speeds for lane capacity; 20, 40, 60 and 80 kilometres per hour.

The worst case (breakdown or major incident) operation scenario assesses the most onerous traffic case, where congestion that occurs as a result of a breakdown affects the longest length within the mainline tunnel. This worst case operational scenario assumes a breakdown would result in a complete blockage on the specific ramp, causing traffic that would ordinarily use the mainline tunnel to take other routes.

In-tunnel air quality for extended journeys

The assessment for in-tunnel air quality for extended journeys considers the estimated average concentration of NO_2 for the longest potential journey that could be taken by motorists in the connected motorway network. This was identified as a journey that used the project, the proposed Beaches Link tunnel, the WestConnex network and the F6 Extension tunnel network.

Provided that each project satisfies the air quality criteria (which requires NO_2 concentrations to be below an average of 0.5 ppm over the length of each tunnel), the average through the entire network would remain at, or below, 0.5 ppm under all traffic conditions. For this assessment, the estimated journey assessment completed as part of the M4-M5 Link environmental impact statement has been combined with the in-tunnel modelling completed for the ‘Do something cumulative 2037’ scenario.

Ambient air quality

The potential impacts of the project on ambient air quality during operation were assessed in relation to CO, NO_2, PM_{10} and $PM_{2.5}$ (particulate matter less than or equal to 2.5 micrometre diameter), in accordance with the NSW EPA Approved Methods. The pollutants and criteria considered are outlined in Section 12.3.3.

The following terms have been used to describe the concentration of pollutants at a specific location or receiver:

- Background concentration describes all contributing sources of a pollutant concentration other than road traffic. It includes, 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 receiver, but also the net contribution of the rest of the modelled road network at the receiver
- Ventilation outlet concentration describes the contribution of pollutants from tunnel ventilation outlets
- Total concentration is the sum of the sources defined above: background, surface road and ventilation outlet concentrations. It may relate to conditions with or without the project under assessment
- The change in concentration due to the project is the difference between the total concentration with the project and the total concentration without the project (increase or decrease), depending on factors such as the redistribution of traffic on the network as a result of the project.

The modelling scenarios, modelling process, receivers considered and approach to the analysis of results are discussed below.

Modelling scenarios

Seven expected traffic scenarios were included in the operational air quality assessment and considered future changes in the composition and performance of the vehicle fleet, as well as predicted traffic speeds, traffic volumes and the distribution of traffic on the road network. The expected traffic scenarios that were modelled are summarised in Table 12-2.

Table 12-2 Operational air quality assessment modelling – expected traffic scenarios

Name	Existing network	Western Harbour Tunnel and Warringah Freeway Upgrade	Beaches Link and Gore Hill Freeway Connection	Full WestConnex	Sydney Gateway	F6 Extension – Stage 1	F6 Extension – Full
Scenario in the base year (2016)							
Base Year (existing conditions)	✓	-	-	-	-	-	-
Scenarios at project opening (2027)							
'Do minimum 2027' (without the project)	✓	-	-	✓	-	-	-
'Do something 2027' (with the project)	✓	✓	-	✓	-	-	-
'Do something cumulative 2027' (with the project and some other projects)	✓	✓	✓	✓	✓	✓	-
Scenarios at 10 years after project opening (2037)							
'Do minimum 2037' (without the project)	✓	-	-	✓	-	-	-
'Do something 2037' (with the project)	✓	✓	-	✓	-	-	-
'Do something cumulative 2037' (with the project and all other projects)	✓	✓	✓	✓	✓		✓

Modelling process

The modelling process involved an emissions model, a meteorological model (Graz Mesoscale Model – GRAMM) and a dispersion model (Graz Lagrangian Model – GRAL). The relationship between these models is illustrated in Figure 12-2.

For each expected traffic scenario, a spatial emissions inventory (emissions model) was developed for road traffic sources within the domain of the dispersion model. The following components were treated separately to take into account potential changes in traffic emissions across the road network:

- Emissions from existing and proposed ventilation outlets for tunnels where portal emissions would, or would not, occur
- Emissions from the portals of a small number of existing tunnels, where these currently occur
- Emissions from the traffic on the surface road network, including any new surface roads associated with the project.

The GRAMM meteorological model predicted wind fields (three-dimensional spatial pattern of winds). Predicted wind fields then became an input into the dispersion model following alignment with meteorological observations.

The GRAL dispersion model predicted potential ground-level pollutant concentrations by simulating the movement of individual 'particles' of a pollutant emitted from an emission source in a three-dimensional wind field.

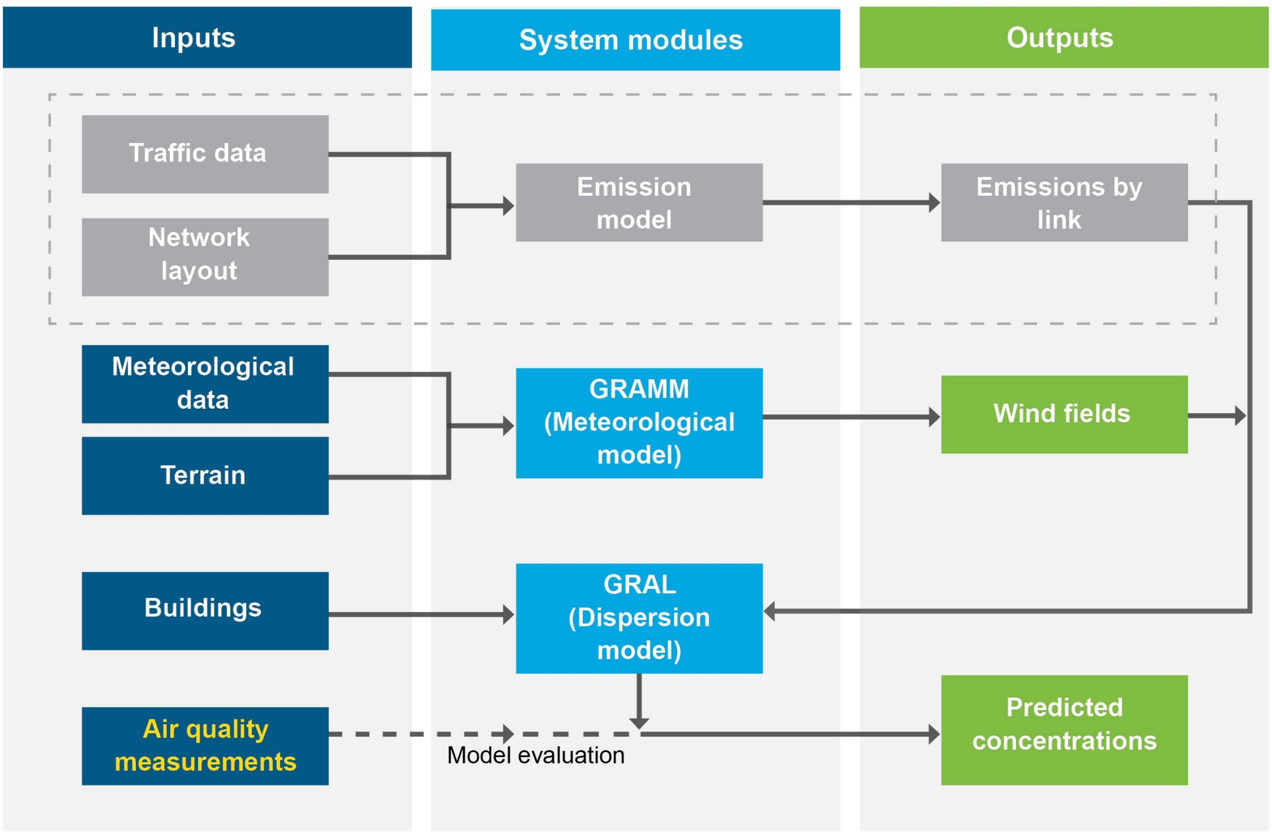

Figure 12-2 Overview of operational air quality modelling process

Receivers

Receivers are defined as anywhere someone works or resides, or may work or reside, including residential areas, hospitals, hotels, shopping centres, playgrounds and recreational centres. Due to its location in a highly built-up area, the dispersion modelling domain for the project contains many receivers.

Two types of receivers were considered in the air quality assessment:

- 'Community receivers'. These were taken to be representative of particularly sensitive locations such as schools, child care centres and hospitals within a zone of about 500 to 600 metres either side of the Western Harbour Tunnel and Beaches Link program of works corridor, and generally near significantly affected roadways. In total, 42 community receivers were included in the assessment (refer to Figure 12-3)
- 'Residential, workplace and recreational receivers'. These were all discrete receiver locations along the Western Harbour Tunnel and Beaches Link program of works corridor, and mainly covered residential and commercial land uses. In total, 35,490 residential, workplace and recreational receiver locations (including the 42 community receivers) were considered in the assessment of project air quality impacts.

The identified community and residential, workplace and recreational receiver locations were representative and not exhaustive. They have been selected using professional judgement to demonstrate potential impacts at a more detailed level.

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

Based on a review of available building height information, four elevated receiver heights were selected to cover both existing buildings and future developments at 10 metres, 20 metres, 30 metres and 45 metres.

The modelling domain extended well beyond the project to allow for the traffic interactions between Beaches Link and Gore Hill Freeway Connection project and the M4-M5 Link project, as well as changes along affected surface roads. A large model domain also increased the number of meteorological and air quality monitoring stations that could be included for model evaluation purposes.

Regional air quality

The potential impacts of the project on air quality more widely across the Sydney region were assessed through consideration of the changes in emissions across the road network. The regional air quality impacts of a project can also be considered in terms of its capacity to influence ozone production. As noted in Section 12.1, the 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.

Odour

The generation of odours from motor vehicle emissions tend to be very localised and short-lived, and there are unlikely to be any significant, predictable or detectable changes in odour due to the project. Odour was assessed based on the maximum change in 1-hour total hydrocarbon concentrations as a result of the project, which was converted into an equivalent change for three of the odorous pollutants identified in the NSW EPA Approved Methods (toluene, xylenes, and acetaldehyde). These pollutants were taken to be representative of other odorous pollutants from motor vehicles.

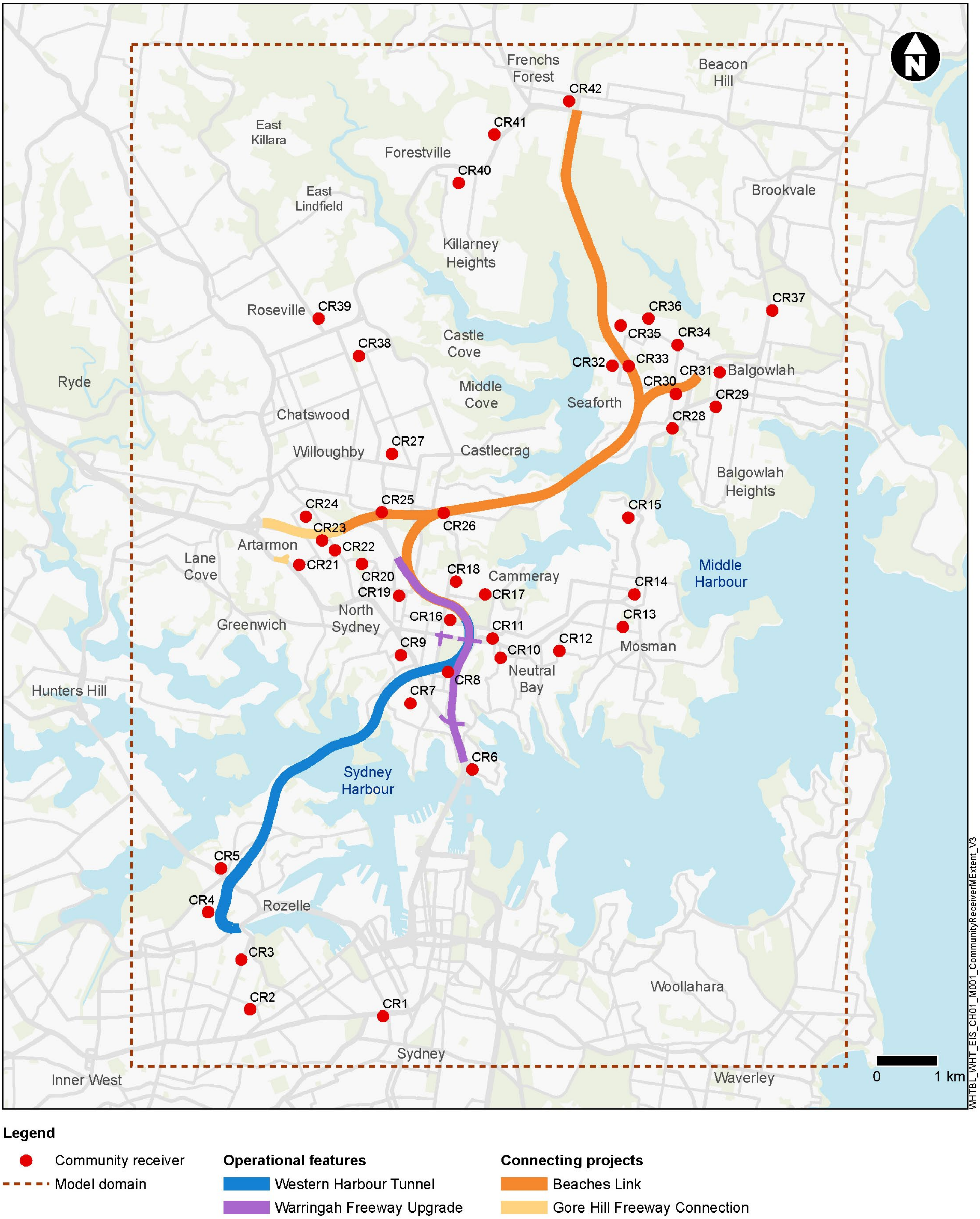

Figure 12-3 Location of community receivers and model domain

12.3 Criteria and standards

12.3.1 Overview

There are two types of criteria and standards that are relevant to the assessment of air quality impacts from construction and operation of the project:

- In-tunnel air quality criteria, which apply to the air quality inside the mainline tunnels
- Ambient air quality criteria and standards, which apply to outdoor air quality.

Air quality criteria and standards applied to the assessment of the project are outlined in the following sections, with further details provided in Appendix H (Technical working paper: Air quality).

12.3.2 In-tunnel air quality criteria

The project has been designed to achieve in-tunnel air quality that is protective of human health and amenity and provides a safe travel environment. Further details of the project's ventilation system design are provided in Chapter 5 (Project description).

The project's ventilation system would be operated to achieve the in-tunnel air quality criteria summarised in Table 12-3. The in-tunnel air quality limits for the project reflect those identified by the ACTAQ (ACTAQ, 2016 and ACTAQ, 2018a) and are consistent with the limits imposed on recent motorway projects in NSW.

Table 12-3 In-tunnel operational limits for CO, NO_2 and visibility

Parameter	Averaging period	Criteria
CO	3-minute (rolling), single point exposure limit	200 ppm
	15-minute (rolling), average along tunnel length	87 ppm
	30-minute (rolling), average along tunnel length	50 ppm
NO_2	15-minute (rolling), average along tunnel length	0.5 ppm
Visibility	15-minute (rolling), at any point in the tunnel	0.005 m^{-1}

12.3.3 Ambient air quality criteria

Air quality criteria and standards applied to the assessment of the project are outlined in the following sections, with further details provided in Appendix H (Technical working paper: Air quality), including Annexure B of that report.

Air pollutant criteria

The ambient air quality criteria applied to the assessment of the project are set in NSW EPA Approved Methods and summarised in Table 12-4. Some of these criteria are among the most stringent worldwide (see Annexure B of Appendix H (Technical working paper: Air quality)). For example, the annual average $PM_{2.5}$ criterion used, and on which the health metrics are based, is the lowest in world, including the World Health Organisation.

Table 12-4 Ambient air quality criteria applied to the assessment of the project

Pollutant	Criteria	Averaging period
CO	30 mg/m^3	1 hour
	10 mg/m^3	8 hours (rolling)
NO_2	246 µg/m^3	1 hour
	62 µg/m^3	1 year
PM_{10}	50 µg/m^3	24 hours
	25 µg/m^3	1 year
$PM_{2.5}$	25 µg/m^3	24 hours
	20 µg/m^3 (goal by 2025)	24 hours
	8 µg/m^3	1 year
	7 µg/m^3 (goal by 2025)	1 year
Benzene*	0.029 mg/m^3	1 hour
Polycyclic aromatic hydrocarbons (PAHs) (as benzo(a)pyrene)[1]	0.0004 mg/m^3	1 hour
Formaldehyde[1]	0.02 mg/m^3	1 hour
1,3-butadiene[1]	0.04 mg/m^3	1 hour
Ethylbenzene[1]	8 mg/m^3	1 hour

Note 1: These compounds were taken to be representative of the much wider range of air toxics associated with motor vehicles

Odour criteria

The NSW EPA Approved Methods provides assessment criteria for complex mixtures of odorous compounds, as summarised in Table 12-5. These criteria are 99th percentile values, meaning that they must not be exceeded more than one per cent of the time.

Table 12-5 Assessment criteria for odour

Population of affected community	Criteria for complex mixtures of odour (OU)
≤ ~2	7
~10	6
~30	5
~125	4
~500	3
Urban (>2000) and/or schools and hospitals	2

For the assessment of operational odour impacts, the change in the maximum 1-hour total hydrocarbon concentration as a result of the project was calculated at each of the residential, workplace and recreational receiver locations. The hydrocarbon pollutants were taken to be representative of other odorous pollutants from motor vehicles. The odorous pollutants assessed along with their relevant criteria include:

- Toluene (360 $\mu g/m^3$)
- Xylene (190 $\mu g/m^3$)
- Acetaldehyde (42 $\mu g/m^3$).

12.4 Existing environment

Air quality in a region is influenced by a number of factors including the terrain, meteorology (weather patterns), historical trends in road traffic emissions and the current (ambient) and historical air quality environment.

12.4.1 Meteorology

Analysis of meteorological data found that the Randwick station (operated by the Department of Planning, Industry and Environment (Environment, Energy and Science)) was the most representative of the project corridor. At Randwick, the wind speed and wind direction patterns over the five-year period between 2011 and 2016 were quite consistent. Average wind speeds ranged from 2.4 to 2.6 metres per second.

12.4.2 Vehicle emissions

The most comprehensive source of information on current and future air pollutant emissions in the Sydney area is the emissions inventory compiled periodically by the EPA.

For 2016, the emissions inventory identifies that road transport was the second largest contributor to emissions of CO (34 per cent) and the largest contributor to oxides of nitrogen (NO_X) (47 per cent) in Sydney. The sector was also responsible for substantial proportions of emissions of volatile organic compounds (13 per cent), PM_{10} (nine per cent) and $PM_{2.5}$ (10 per cent). Road transport contributed only two per cent of total sulfur dioxide (SO_2) emissions in Sydney, reflecting the reduced sulfur in road transport fuels in recent years.

Petrol passenger vehicles (mainly cars) accounted for a large proportion of the vehicle kilometres travelled (VKT) in Sydney and exhaust emissions from these vehicles were responsible for 65 per cent of CO from road transport in Sydney in 2016, 37 per cent of NO_X, and 71 per cent of SO_2. They were a minor source of PM_{10} (three per cent) and $PM_{2.5}$ (four per cent). Non-exhaust processes were the largest source of road transport PM_{10} (71 per cent) and $PM_{2.5}$ (57 per cent).

The road transport contribution to CO, volatile organic compounds and NO_X emissions 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.

12.4.3 Ambient air quality

Air quality in Sydney is monitored across a network of monitoring stations operated by the Department of Planning, Industry and Environment (Environment, Energy and Science), and at project-specific monitoring stations operated by Transport for NSW (formerly Roads and Maritime). A summary of ambient air quality in Sydney is provided in Table 12-6, based on data from these monitoring stations from 2004 to 2018.

Table 12-6 Ambient air quality in Sydney (2004 to 2018)

Air pollutant	Ambient air quality
CO (maximum 1-hour) CO (rolling 8-hour)	All monitoring data shows ambient concentrations well below the air quality criteria of 30 mg/m³ (1-hour) and 10 mg/m³ (8-hour). There is a general downward trend in maximum concentrations over time.
NO_2 (maximum 1-hour)	Although variable from year to year, maximum 1-hour NO_2 concentrations are relatively stable in the longer term. Data from all monitoring stations typically range from 80 µg/m³ to 120 µg/m³, and continue to be well below the criterion of 246 µg/m³.
NO_2 (annual mean)	Concentrations at all monitoring stations are well below the air quality criterion of 62 µg/m³. There is a general downward trend in annual mean concentrations over time.
PM_{10} (maximum 24-hour)	Maximum 24-hour PM_{10} concentrations show a large variation at most stations from year to year. There were multiple exceedances of the 24-hour criterion of 50 µg/m³, notably 2009, 2016 and 2018 due to events such as dust storms and hazard reduction burns.
PM_{10} (annual mean)	In recent years the annual mean concentration has been between 20 µg/m³ at most monitoring stations. The monitoring station at Lindfield shows substantially lower concentrations of about 15 µg/m³ -16 µg/m³. Monitoring data from stations operated by Transport for NSW (formerly Roads and Maritime) in 2018 increased slightly to around 16 µg/m³, which is below the air quality criterion of 25 µg/m³.
$PM_{2.5}$ (annual mean)	$PM_{2.5}$ has only been measured over several years at three of the Department of Planning, Industry and Environment stations reviewed. Concentrations at Chullora and Earlwood showed a similar pattern, with a steady reduction between 2004 and 2012 being followed by a substantial increase in 2013. The main reason for the increase was a change in the measurement method. The increases in measured concentrations meant that background $PM_{2.5}$ concentrations during 2016 to 2018 were already very close to or above the long-term goal of seven µg/m³.

12.5 Assessment of potential construction impacts

Potential sources of air quality impacts during construction of the project would include:

- Dust generated at construction sites and construction support sites
- Odour generated during handling and management of harbour sediments
- Emissions from plant and equipment used on construction sites and construction support sites
- Blast fumes, if blasting is required during construction of the project.

12.5.1 Dust

Screening assessment

The construction dust assessment considered potential dust impacts across five assessment zones. The construction zones, and their associated construction support sites and surface construction areas are summarised in Table 12-7. Receivers near the construction zones are shown in Figure 12-4.

Table 12-7 Construction assessment zones

Assessment zone	Construction support sites within assessment zone	Surface construction areas within assessment zone, beyond construction support sites
Zone 1	Rozelle Rail Yards (WHT1)	Fitout of operational infrastructure for the Western Harbour Tunnel, including the Rozelle ventilation outlet. Construction works associated with the Rozelle Interchange connection project.
Zone 2	Victoria Road (WHT2)	N/A
Zone 3	White Bay (WHT3)	N/A
Zone 4	Yurulbin Point (WHT4), Sydney Harbour south cofferdam (WHT5), Sydney Harbour north cofferdam (WHT6), Berrys Bay (WHT7)	Construction of the harbour crossing (including dredging and handling of dredged material).
Zone 5	Berry Street north (WHT8), Ridge Street north (WHT9), Cammeray Golf Course (WHT10 and WFU8), Waltham Street (WHT11), Blue Street (WFU1), High Street south (WFU2), High Street north (WFU3), Arthur Street east (WFU4), Berry Street east (WFU5), Ridge Street east (WFU6), Merlin Street (WFU7), Rosalind Street east (WFU9)	Warringah Freeway Upgrade and associated local road upgrade surface works. Construction works associated with Western Harbour Tunnel component. Construction works associated with the Motorway Control Centre.

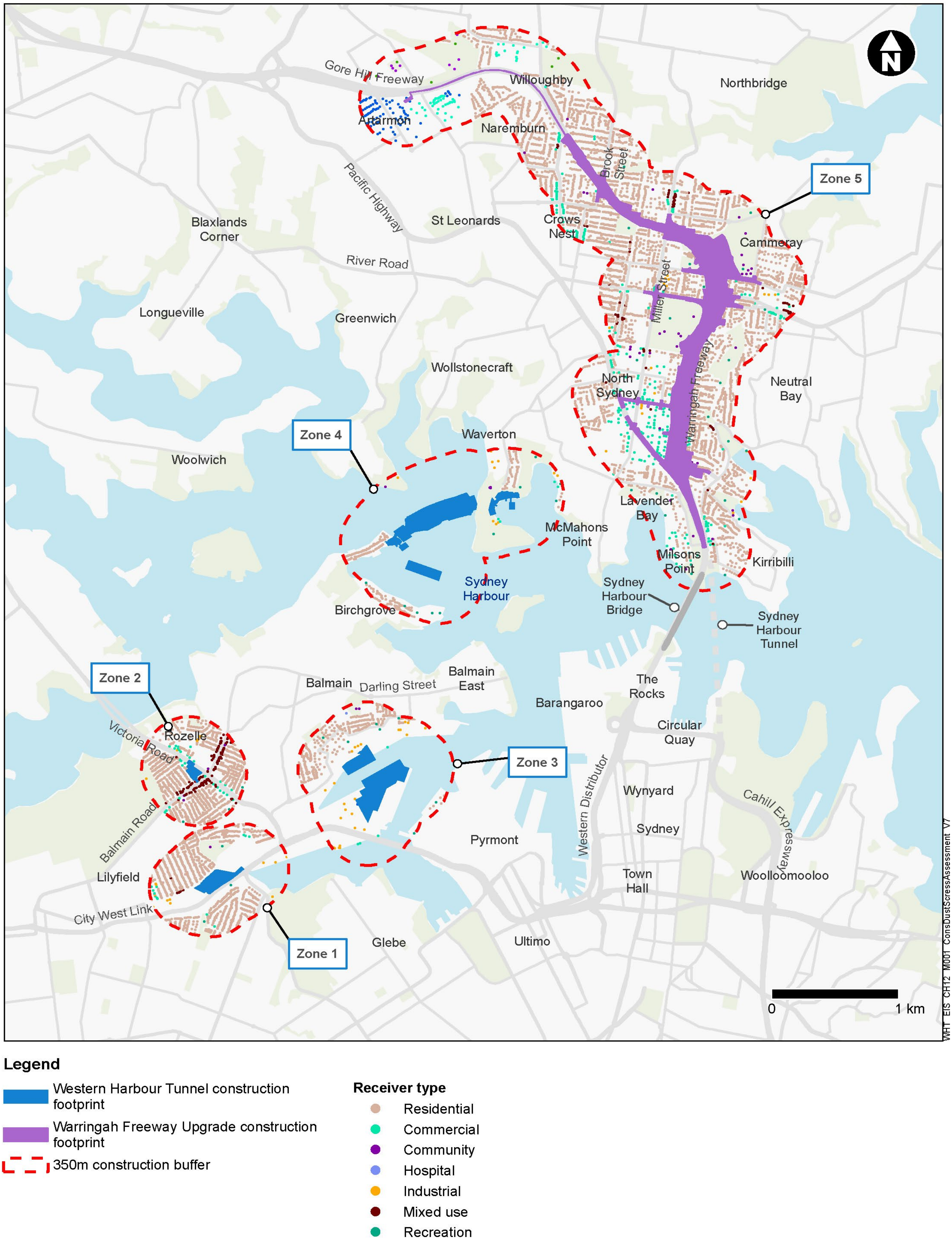

Figure 12-4 Construction dust screening assessment – receivers near the project footprint

Risk assessment

Potential for dust emissions from surface construction works

The potential magnitude of dust emissions from construction activities that would be carried out for demolition, earthworks, construction, and track-out (as defined in Section 12.2.2) is shown in Table 12-8.

Sensitivity of receivers during construction

The sensitivity of receivers to dust settlement effects, human health impacts, and ecological impacts during construction within the five surface construction zones assessed is provided in Table 12-8. The results in Table 12-8 show that:

- For construction dust settlement effects:
  - Zone 1, zone 2, zone 3 and zone 5 were considered to have a high sensitivity to dust settlement effects due to the high number of receivers, located in proximity to surface construction activities
  - Zone 4 was considered to have a medium sensitivity to dust settlement effect. This zone was nominated as having a medium sensitivity as while the receivers would be located near surface construction activities, there are fewer sensitive receivers at this location.
- For human health impacts:
  - The sensitivity of receivers in zone 1, zone 2, zone 3 and zone 5 would be considered high, except for demolition works in zone 1, which would be already complete as part of the WestConnex M4-M5 Link project
  - Zone 4 would have a medium sensitivity to human health risks.
- For ecological impacts, sensitive ecological receivers within zone 4 and zone 5 are located within 20 metres of the construction disturbance footprint. As a result, the sensitivity of these ecological receivers to construction dust would be considered high at these locations.

Risk of dust impacts

The risk of potential dust impacts, without mitigation, is determined by combining the following to provide an overall summary of potential risk:

- The magnitude of potential dust emissions (refer to Table 12-8)
- The sensitivity of the surrounding area to dust settlement effects, human health impacts and ecological impacts (refer to Table 12-8).

The summary of potential risk relating to construction dust is provided in Table 12-8.

Without mitigation, sites and activities that were determined to have a high and medium risk of dust impacts include:

- Rozelle Rail Yards construction support site (WHT1) and surrounds: Medium risk (if unmitigated) of dust settlement from earthworks, construction and track-out, and to human health from earthworks and construction
- Victoria Road construction support site (WHT2): Medium risk (if unmitigated) of dust settlement and to human health from demolition, earthworks and track-out
- White Bay construction support site (WHT3): Medium risk (if unmitigated) of dust settlement and to human health from earthworks and track-out
- Yurulbin Point (WHT4), Sydney Harbour south cofferdam (WHT5), Sydney Harbour north cofferdam (WHT6) and Berrys Bay (WHT7) construction support sites: Medium risk (if unmitigated) of dust settlement and to human health from earthworks. Medium risk to ecological receivers from demolition, earthworks and track-out

- Berry Street north (WHT8), Ridge Street north (WHT9), Cammeray Golf Course (WHT10), Waltham Street (WHT11) and all Warringah Freeway Upgrade component (WFU1-9) construction support sites (including surrounding surface works): High risk (if unmitigated) of dust settlement, to human health and ecological receivers from demolition, earthworks, construction and track-out.

The effects of airborne dust during construction would be temporary and of relatively short duration. As such, mitigation is considered straightforward because dust suppression measures are routinely employed as ‘good practice’ at most construction sites and areas of surface disturbance. The proposed environmental management measures are outlined in Section 12.7.

However, even with rigorous air quality management in place, it is not possible to guarantee that the mitigation measures implemented to manage any potential dust impacts during construction would be wholly effective all the time. There is still the residual risk that nearby residences, commercial buildings, hotel, cafés and schools in the vicinity of construction works might experience occasional dust 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 likely only arise during dry weather with the wind blowing towards a receiver at a time when dust is being generated and mitigation measures are not fully effective.

Table 12-8 Summary of construction dust risk assessment

Zone	Activity	Step 2A: Potential for dust emissions	Step 2B: Sensitivity of area - Dust settlement	Step 2B: Sensitivity of area - Human health	Step 2B: Sensitivity of area - Ecological	Step 2C: Risk of dust impacts - Dust settlement	Step 2C: Risk of dust impacts - Human health	Step 2C: Risk of dust impacts - Ecological
Zone 1 (WHT1)	Demolition	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Earthworks	Medium	High	Medium	N/A	Medium	Medium	N/A
	Construction	Medium	High	Medium	N/A	Medium	Medium	N/A
	Track-out	Medium	High	Medium	N/A	Medium	Low	N/A
Zone 2 (WHT2)	Demolition	Medium	High	High	N/A	Medium	Medium	N/A
	Earthworks	Medium	High	High	N/A	Medium	Medium	N/A
	Construction	Small	High	High	N/A	Low	Low	N/A
	Track-out	Medium	High	High	N/A	Medium	Medium	N/A
Zone 3 (WHT3)	Demolition	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Earthworks	Medium	High	High	N/A	Medium	Medium	N/A
	Construction	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Track-out	Medium	High	High	N/A	Medium	Medium	N/A

Zone	Activity	Step 2A: Potential for dust emissions	Step 2B: Sensitivity of area - Dust settlement	Step 2B: Sensitivity of area - Human health	Step 2B: Sensitivity of area - Ecological	Step 2C: Risk of dust impacts - Dust settlement	Step 2C: Risk of dust impacts - Human health	Step 2C: Risk of dust impacts - Ecological
Zone 4 (WHT4,5,6,7)	Demolition	Small	Medium	Medium	High	Low	Low	Medium
	Earthworks	Medium	Medium	Medium	High	Medium	Medium	Medium
	Construction	Small	Medium	Medium	High	Low	Low	Low
	Track-out	Medium	Medium	Medium	High	Low	Low	Medium
Zone 5 (WHT8-11 WFU1-9)	Demolition	Large	High	High	High	High	High	High
	Earthworks	Large	High	High	High	High	High	High
	Construction	Large	High	High	High	High	High	High
	Track-out	Large	High	High	High	High	High	High

Dust emissions containing contaminants

There is the potential for dust emissions to contain contaminants mobilised through the disturbance of contaminated soils, and other hazardous materials (such as asbestos fibres or organic matter) during demolition of buildings and other structures. These issues would be considered on a site-by-site basis, and would be adequately managed through standard air quality mitigation and management measures.

Areas identified as containing contaminated soils and other hazardous substances, which may be disturbed during construction include:

- Rozelle Rail Yards, Rozelle
- Birchgrove peninsula, Birchgrove
- Balls Head peninsula
- Warringah Freeway, North Sydney to Cammeray
- Waltham Street, Artarmon.

These areas are described in more detail in Chapter 16 (Geology, soils and groundwater).

12.5.2 Emissions from plant and equipment

The use of on-site diesel-powered vehicles, generators and construction equipment, and the handling and/or on-site storage of fuel and other chemicals, would result in localised increased concentrations of airborne particle matter, CO, NO_x, sulfur dioxide and volatile organic compounds. Minor emissions from these sources would be localised and would be adequately managed with standard environmental management measures.

12.5.3 Emissions during blasting

If blasting for the project is required, it would be carried out underground and there would be no direct emissions from blasting to the external air. Further analysis and assessment of potential blast impacts would be carried out during further design development, including the preparation of a Blast Management Plan. Emissions to ambient air from blasting would be managed to ensure safe working conditions for workers underground.

12.5.4 Odour

Odour assessment has been carried out for dredging activities, stockpiling and treatment works at White Bay.

As part of the harbour construction activities for the project, a large amount of material would be dredged from the harbour bed, bringing potentially odorous material to the surface. Dredged material on the barges would be wet, which would reduce any odour emissions. Any odour impacts from the dredged material would be low, given it would remain wet and located at some distance from any sensitive receiver.

At the White Bay construction support site (WHT3), an area covering about 1000 square metres would be used to stockpile and treat dredged material that is unsuitable for offshore disposal. Following treatment, material would be transferred to sealed trucks for delivery to landfill. Treatment would involve the addition of lime or a polymer to the material to make it spadable.

The results of odour modelling (refer to Figure 12-5) show that the predicted 99th percentile odour concentrations at all of the nearest receivers are below one OU, the theoretical level of detection. The highest concentration across the domain is 0.1 OU, which is well below the theoretical level of detection. Odour impacts would therefore be undetectable for all sensitive receivers near the site.

Legend

- Odour Contour
- Spoil treatment area
- Construction footprint
- Construction support site

Figure 12-5 Predicted 99th percentile odour concentration due to treatment of dredging material (OU)

12.6 Assessment of potential operational impacts

Key areas of consideration with regards to air quality impacts during operation of the project would include:

- In-tunnel air quality, including protection of motorist health and amenity when using the project tunnels and during longer trips through other parts of the motorway network
- Ambient air quality for receivers at ground level, as a result of changes in the distribution of surface traffic and operation of the project's ventilation outlets
- Ambient air quality for elevated receivers in existing and potential future high rise buildings, as a result of operation of the project's ventilation outlets
- Odour caused by odorous compounds in vehicle emissions.

12.6.1 In-tunnel air quality

The project's ventilation system has been designed to achieve the in-tunnel air quality criteria summarised in Section 12.3.2 under all traffic conditions, and to effectively manage smoke in the event of a fire in the project tunnels. The tunnel ventilation system would include:

- Jet fans installed in the ceiling of the project tunnels
- Ventilation tunnels and radial fans to extract air from the project tunnels and to transfer it to motorway facilities
- Ventilation tunnels and radial fans to push fresh air into the project tunnels
- Ventilation fans and other infrastructure within the motorway facilities to manage fresh and tunnel air and ventilation outlets to effectively disperse tunnel air into the atmosphere. Motorway facilities and ventilation outlets for the project are located at the Rozelle Interchange, Rozelle and the Warringah Freeway, Cammeray.

The design and operation of the tunnel ventilation system is shown in Figure 5-1 and described in Section 5.2.7 of Chapter 5 (Project description) and Appendix H (Technical working paper: Air quality).

Simulations have been carried out to demonstrate that in-tunnel air quality criteria would not be exceeded. The simulations consider in-tunnel air quality based on:

- Expected traffic volumes using the project tunnels
- Theoretical maximum traffic volumes using the project tunnels, based on the design capacity of the tunnels at different average traffic speeds
- A breakdown or incident in the project tunnels.

In-tunnel air quality under expected traffic volumes

The change in the peak in-tunnel NO_2 (rolling 15-minute average) emissions throughout the project tunnel and the adjoining tunnels confirm that the tunnel ventilation system would maintain in-tunnel air quality well within operational limits. The predicted in-tunnel NO_2 levels modelled for all 'Do something' and 'Do something cumulative' scenarios in 2027 and 2037 are provided in Section 7 of Annexure K of Appendix H (Technical working paper: Air quality). The in-tunnel operational air quality limits for CO and visibility would also be achieved under all expected traffic scenarios.

In-tunnel air quality under maximum traffic volumes

In-tunnel air quality was assessed with the mainline operating at theoretical maximum lane capacity over the full length of the tunnels (which is not expected to actually occur). Four variable speed scenarios were assessed along all northbound and southbound routes – 20 kilometres per hour, 40 kilometres per hour, 60 kilometres per hour and 80 kilometres per hour. Vehicles travelling at 20 kilometres per hour would result in the highest pollutant levels in the tunnel, due to less air moving through the tunnel, and is considered the worst case variable speed operation scenario.

The predicted in-tunnel NO_2 (rolling 15-minute average) emissions for the worst case northbound route through the tunnel confirms that the tunnel ventilation system would achieve the NO_2 emissions criteria during all variable speed operation scenarios. The in-tunnel operational air quality limits for CO and visibility would also be achieved during all variable speed operation scenarios (refer to Annexure K of Appendix H (Technical working paper: Air quality)).

In-tunnel air quality under worst case breakdown or major incident

The tunnel ventilation system would be designed to cater for various traffic scenarios, including a case where there is a breakdown or major incident at a point along the tunnel. The worst case traffic scenario would be where the resulting congestion due to a breakdown affects the longest length within the tunnel operating at capacity. The worst case scenario was determined to be where a breakdown occurs along the route for traffic travelling north from the M4-M5 Link and to the Warringah Freeway exit ramp (prior to the Beaches Link Tunnel connection).

The predicted in-tunnel NO_2 (rolling 15-minute average) emissions for the worst case vehicle breakdown or major incident in the tunnel confirms that the tunnel ventilation system would achieve the NO_2 emissions criteria during all breakdown scenarios. The highest NO_2 concentration of 0.49 ppm would occur during a breakdown or major incident along the tunnel route between the M4-M5 Link and the Warringah Freeway. The in-tunnel operational air quality limits for NO_2, CO and visibility would also be achieved during all breakdown or major incident scenarios (refer to Annexure K of Appendix H (Technical working paper: Air quality)).

In-tunnel air quality for extended journeys

The extended journey assessment, which considers a journey through the project, the proposed Beaches Link tunnel, WestConnex and the F6 Extension in 2037, has identified that the in-tunnel average NO_2 levels would be below 0.5 ppm. Further detail can found in Section 5.2.7 of the Annexure K of Appendix H (Technical working paper: Air quality).

12.6.2 Ambient air quality (receivers at ground level)

The predicted ambient air quality for the expected traffic scenarios are presented, by pollutant in this section. All results, including tabulated concentrations and contour plots are provided in Appendix H (Technical working paper: Air quality).

For the pollutants assessed, the following has been determined for the 35,490 residential, workplace and recreational receiver locations and 42 community receivers:

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

Due to the number of residential, workplace and recreational receiver locations, ranked plots for pollutant concentrations at each receiver location have been included. In each figure the background concentration, maximum contributions from each source (ventilation outlets and surface roads) and the maximum total concentration have been included for all of the 'Do something' and 'Do something cumulative' scenarios.

For community receivers, a figure showing the pollutant concentrations (background plus the project scenario contribution) at each receiver relative to the air quality criterion has been provided. A second figure showing the change in pollutant concentration as a result of the different project scenario contributions at each receiver has also been provided.

Nitrogen dioxide (NO_2) (maximum 1-hour mean)

Residential, workplace and recreational receiver locations

There are some predicted exceedances of the NSW 1-hour NO_2 criterion (246 µg/m^3), both with and without the project at residential, workplace and recreational receiver locations. In the 'Do minimum 2027' scenario (ie without the project), the maximum concentration of NO_2 exceeds the NSW criterion at 201 receivers (0.6 per cent of all receivers). With the introduction of the project in the 'Do something 2027' scenario, the number of receivers experiencing exceedances of the maximum concentration of NO_2 decreases to 183 receivers (0.5 per cent of all receivers). In the 'Do something cumulative 2027' scenario, the number of receivers experiencing exceedances of the maximum concentration of NO_2 further decreases to 88 receivers (0.2 per cent of all receivers).

In the 'Do minimum 2037' scenario (ie without the project), there are predicted to be exceedances at 234 receivers (0.7 per cent of all receivers), decreasing to 170 receivers (0.5 per cent of all receivers) in the 'Do something 2037' scenario. In the 'Do something cumulative 2037' scenario, the number further decreases to 86 receivers (0.2 per cent of all receivers).

Figure 12-6 shows the predicted contributions of the with-project and cumulative scenarios to the maximum 1-hour mean NO_2 concentration at all of the residential, workplace and recreational receiver locations.

The contribution from ventilation outlets to the maximum 1-hour mean NO_2 concentration at residential, workplace and recreational receiver locations cannot be calculated directly (refer to Section 8.4.11 of Appendix H (Technical working paper: Air quality)). However, given the maximum NO_X contribution by tunnel ventilation outlets at any receiver in any scenario was 60 µg/m^3 and that this did not coincide with maximum contributions from surface roads, the contribution from ventilation outlets would not lead to an exceedance of the 1-hour NO_2 criterion.

Community receivers

Figure 12-7 shows the maximum 1-hour NO_2 concentrations at community receivers in the with-project and cumulative scenarios. At all of these receiver locations in all scenarios assessed, the maximum concentration is predicted to be below the impact assessment criterion of 246 µg/m^3.

Figure 12-8 shows the predicted change in maximum 1-hour mean NO_2 concentration as a result of the project and cumulatively with other projects (the difference between the 'Do something' scenarios and the 'Do minimum' scenarios) in 2027 and 2037. There was a mixture of small (relative to the NSW criterion) increases and decreases across the scenarios assessed and some notable increases in the maximum concentration at a small number of receivers under a number of scenarios assessed, but as noted above, these did not result in any exceedances of the criterion.

In the hour in which the maximum 1-hour NO_2 concentration occurred, the background concentration was the most important source of NO_2, with generally a small contribution from surface roads but with some exceptions where surface roads contributions were greater (up to 50 per cent in some scenarios at a receiver in Seaforth (CR28)). The tunnel ventilation outlet contribution to the maximum NO_2 concentration was either zero or negligible.

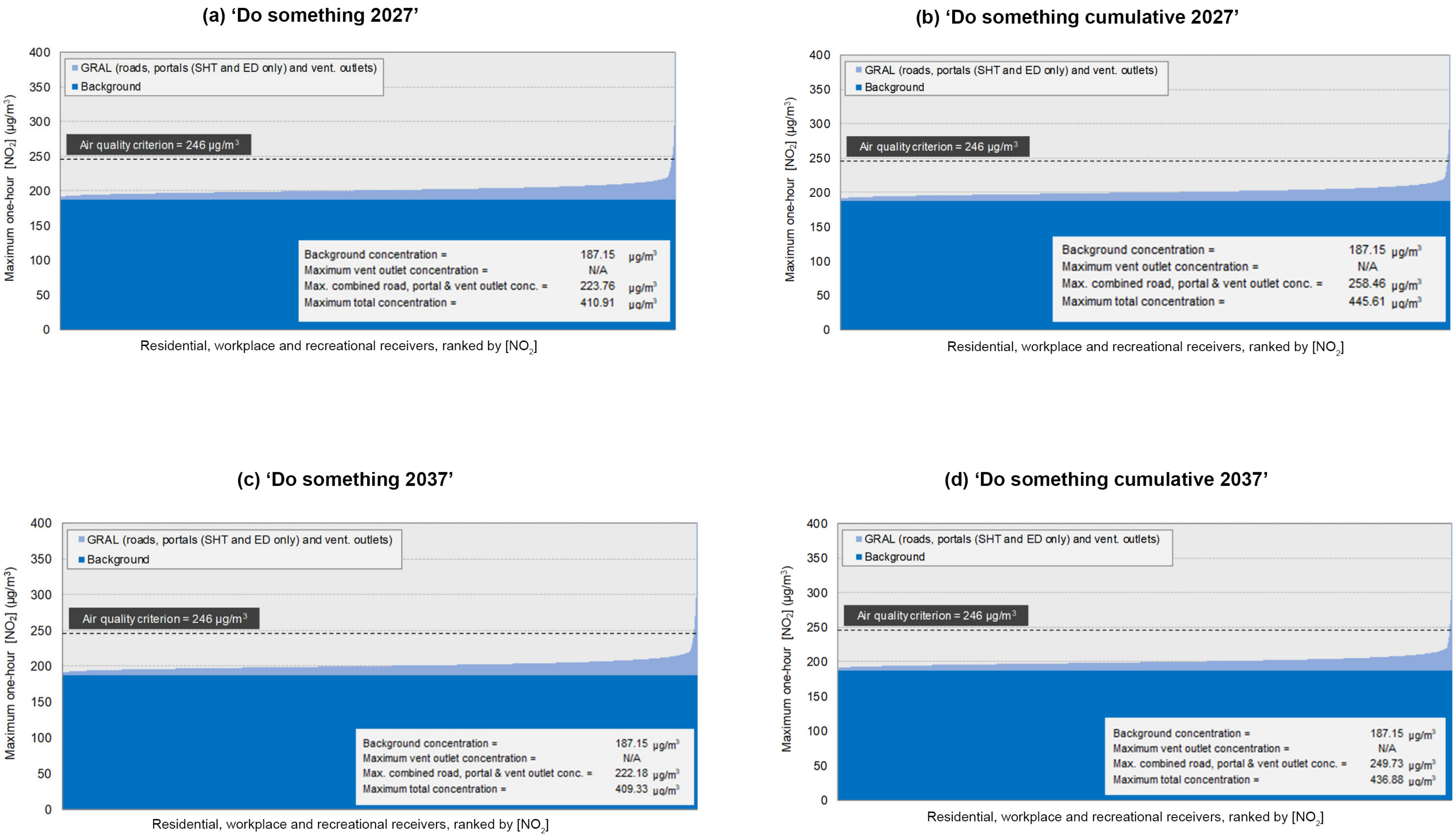

Figure 12-6 Contributions to maximum 1-hour mean NO_2 concentration at residential, workplace and recreational receiver locations

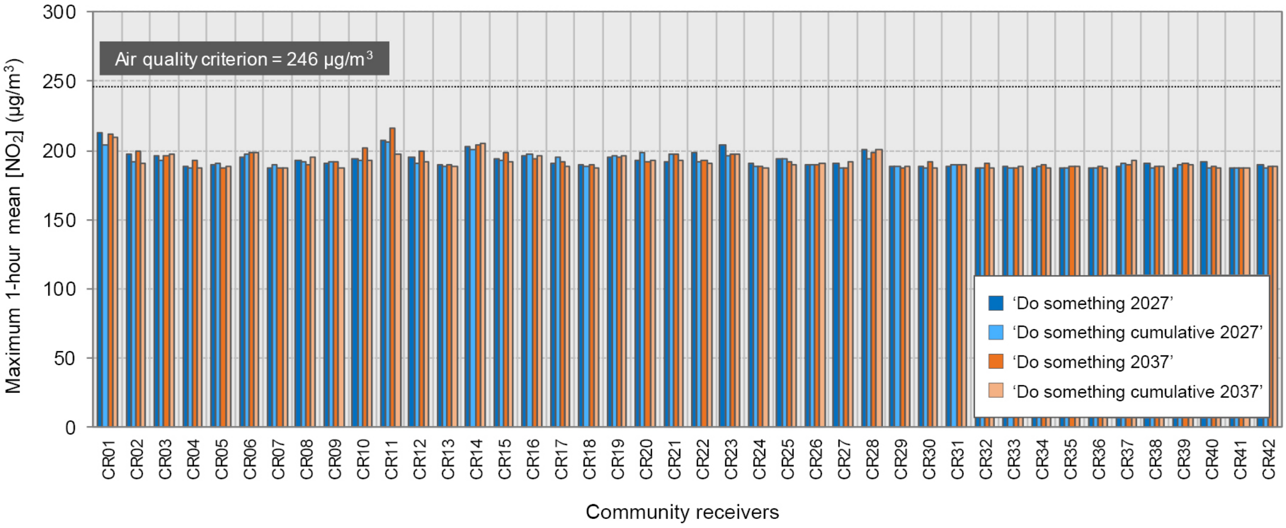

Figure 12-7 Maximum 1-hour mean NO_2 concentration at community receivers

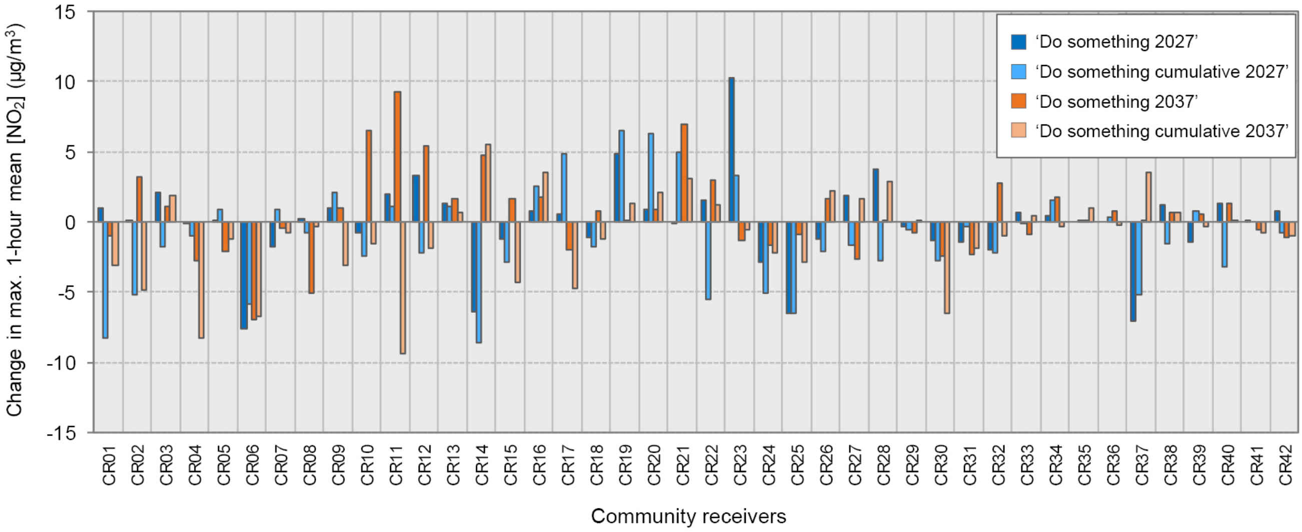

Figure 12-8 Change in maximum 1-hour mean NO_2 concentration at community receivers

Nitrogen dioxide (annual mean)

Residential, workplace and recreational receiver locations

Figure 12-9 shows the predicted contribution of the with-project and cumulative scenarios to annual mean NO_2 concentration at residential, workplace and recreational receiver locations. The predicted annual mean NO_2 concentrations at most (more than 97 per cent) of the receiver locations are between about 13 µg/m^3 and 25 µg/m^3. The annual mean NO_2 criterion of 62 µg/m^3 would not be exceeded at any receiver locations under all scenarios assessed.

The maximum predicted NO_2 contribution from the ventilation outlets would be 0.6 µg/m^3, and the maximum predicted surface road contribution would be 22 µg/m^3. Given that annual mean NO_2 concentrations at most receiver locations would be well below the criterion, the contribution of the ventilation outlets is small.

Community receivers

Figure 12-10 shows the predicted annual mean NO_2 concentrations for the project and cumulative scenarios at community receivers. At all of these locations, except one, the concentration is predicted to be below 30 µg/m^3, and well below the criterion of 62 µg/m^3 for all scenarios assessed.

The single exception is a receiver at Seaforth (CR28) which is located close to the heavily trafficked Manly Road (65,000 vehicles per day), and would have a high NO_2 concentration in the 'Do minimum' scenarios (32.3 µg/m^3 in 2027 and 33.1 µg/m^3 in 2037). The concentration at this receiver would remain above 30 µg/m^3 in the 'Do something' scenarios for 2027 and 2037, as well as in the 'Do something cumulative' scenario for 2037.

Figure 12-11 shows the predicted change in annual mean NO_2 concentration at community receivers as a result of the project and cumulatively with other projects (the difference between the 'Do something' scenarios and the 'Do minimum' scenarios) in 2027 and 2037. The largest predicted increase as a result of the project under the scenarios assessed would be about 2.5 µg/m^3 in the 'Do something 2027 scenario, and four per cent of the criterion. There would also be some notable decreases in concentration in the 'Do something' and 'Do something cumulative' scenarios at some receivers in 2027 and 2037.

For the scenarios assessed, the background component at the community receivers is likely to be responsible for, on average, about 80 to 90 per cent of the predicted total annual mean NO_2, with most of the remainder being due to surface roads. At most community receivers, surface roads would contribute between 10 per cent and 30 per cent of the total annual mean NO_2, but at some receivers close to busy roads there is a more substantial surface road contribution. The contributions of the project's ventilation outlets to the annual mean NO_2 concentrations would be less than three per cent in all scenarios.

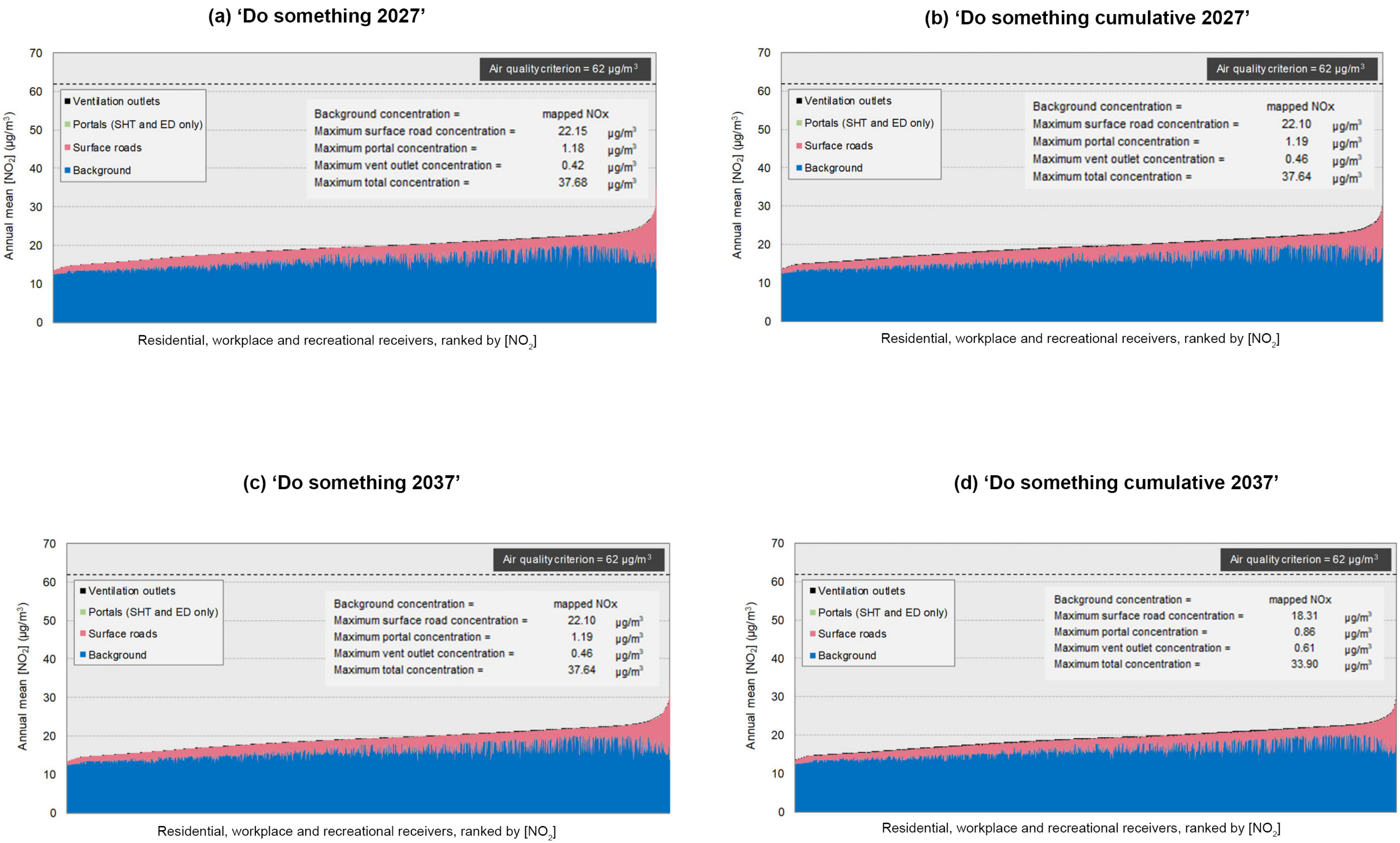

Figure 12-9 Contribution to annual mean NO_2 concentration at residential, workplace and recreational receiver locations

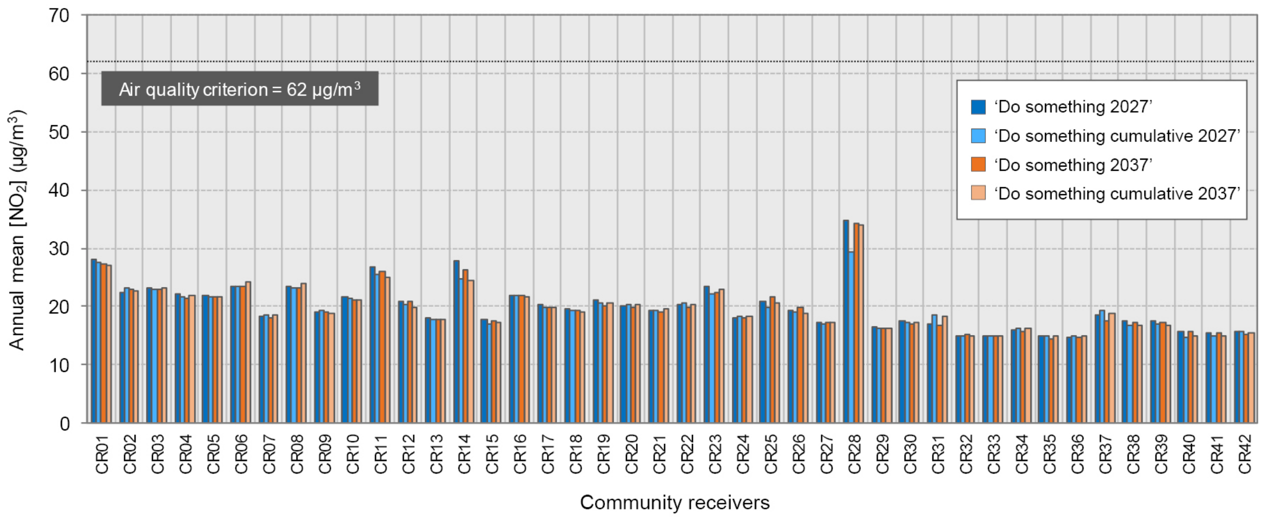

Figure 12-10 Annual mean NO_2 concentration at community receivers

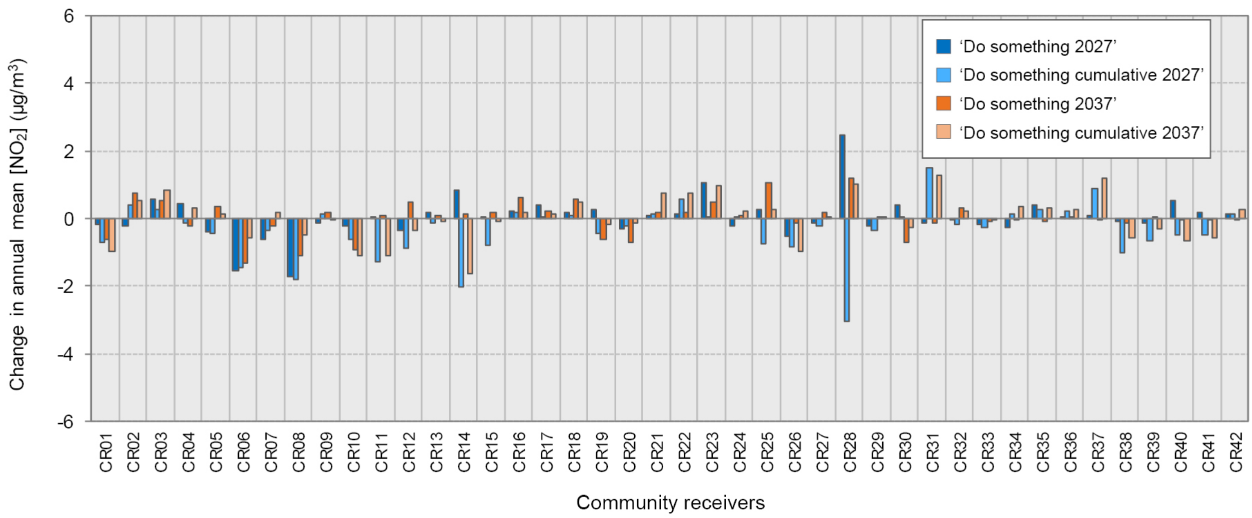

Figure 12-11 Change in annual mean NO_2 concentration at community receivers

PM_{10} (maximum 24-hour mean)

Residential, workplace and recreational receiver locations

Figure 12-12 shows predicted contributions of the with-project and cumulative scenarios to maximum 24-hour mean PM_{10} concentrations at residential, workplace and recreational receiver locations. It demonstrates that (with background concentrations of 48.04 μg/m^3) many of the receivers in the 'Do something' and 'Do something cumulative' scenarios (60 to 67 per cent respectively) would be above the criterion of 50 μg/m^3.

The number of receivers with a concentration above the criterion is predicted to decrease slightly as a result of the project, as follows:

- From 23,065 in the 'Do minimum 2027' scenario to 22,509 in the 'Do something 2027' scenario, decreasing further to 21,239 in the 'Do something cumulative 2027' scenario
- From 24,341 in the 'Do minimum 2037' scenario to 23,841 in the 'Do something 2037' scenario, decreasing further to 22,501 in the 'Do something cumulative 2037' scenario.

For the 'Do something' and 'Do something cumulative' scenarios, the maximum predicted contribution of the project's ventilation outlets at any receiver location would be between 1.3 μg/m^3 and 1.6 μg/m^3.

Community receivers

Figure 12-13 shows the predicted maximum 24-hour mean PM_{10} concentrations at all of the community receivers in the project and cumulative scenarios. The predicted maximum 24-hour mean PM_{10} concentration is predicted to exceed the criterion of 50 μg/m^3 under all modelled scenarios due to elevated background concentrations which occur during extreme events such as dust storms, bushfires and hazard reduction burns.

Figure 12-14 shows the predicted change in maximum 24-hour mean PM_{10} concentration as a result of the project and cumulatively with other projects (the difference between the 'Do something' scenarios and the 'Do minimum' scenarios) in 2027 and 2037. The changes were variable and there were no systematic changes by year or by scenario. At several receivers, there would be a predicted increase in concentration, but this would be less than about one μg/m^3.

The background concentration is the largest contributor to predicted peak 24-hour PM_{10} concentrations under all modelled scenarios. The predicted surface road contribution to the maximum 24-hour PM_{10} concentration at each community receiver is relatively small (generally less than about four μg/m^3).

In the 'Do something' scenarios (ie with the operation of the project), the ventilation outlet contribution at all community receivers is predicted to be negligible, with the largest value being slightly greater than 0.1 μg/m^3. The outlet contributions are predicted to be slightly higher in the cumulative scenarios, although they would still be small, with the maximum outlet contribution of around 1.5 per cent of the air quality criterion is a receiver at Balgowlah (CR31)(0.6 – 0.75 μg/m^3). The maximum outlet contribution at all other community receivers would be less than 0.5 per cent of the air quality criterion (less than 0.2 μg/m^3).

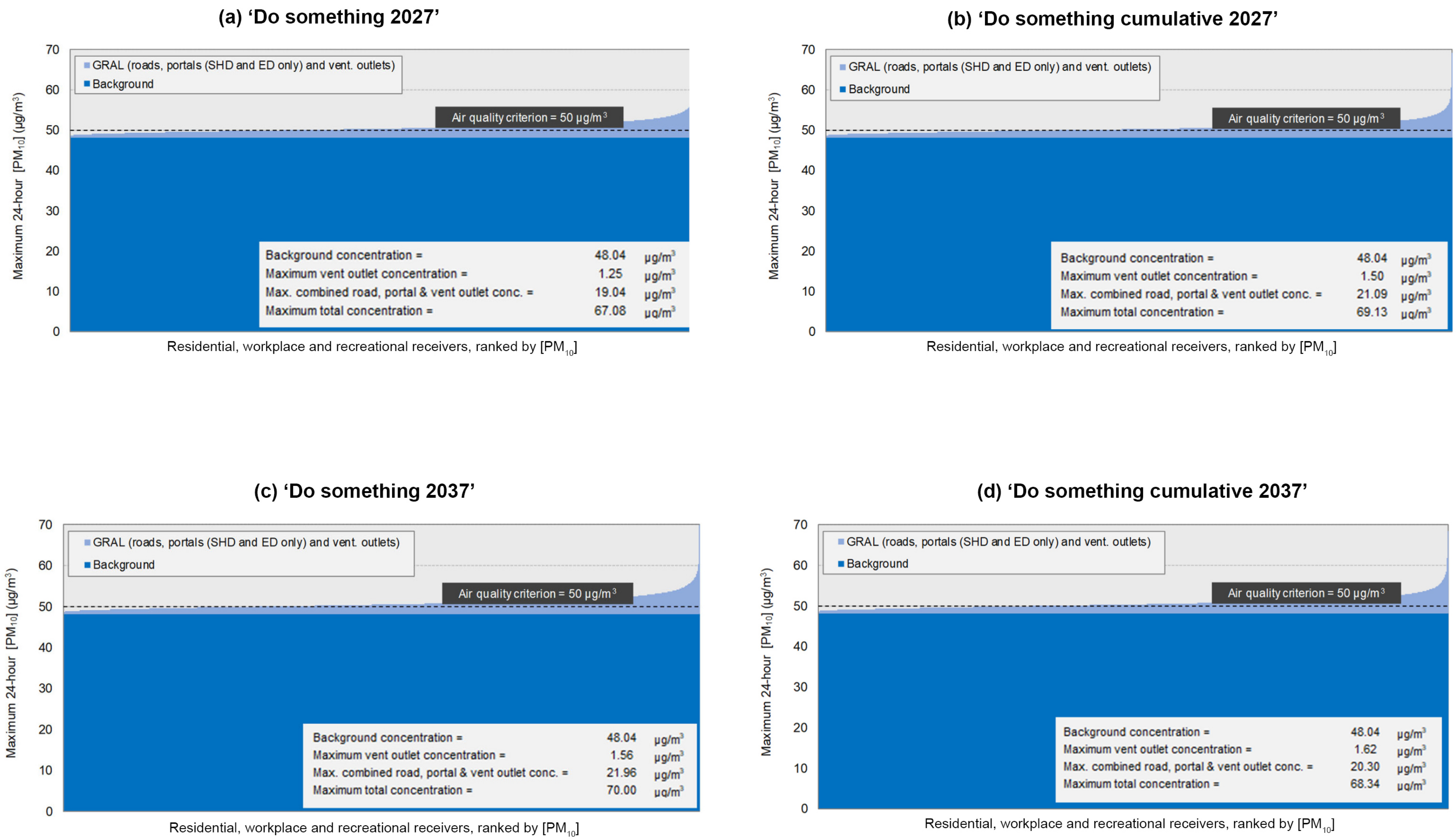

Figure 12-12 Contributions to maximum 24-hour mean PM_{10} concentration at residential, workplace and recreational receiver locations

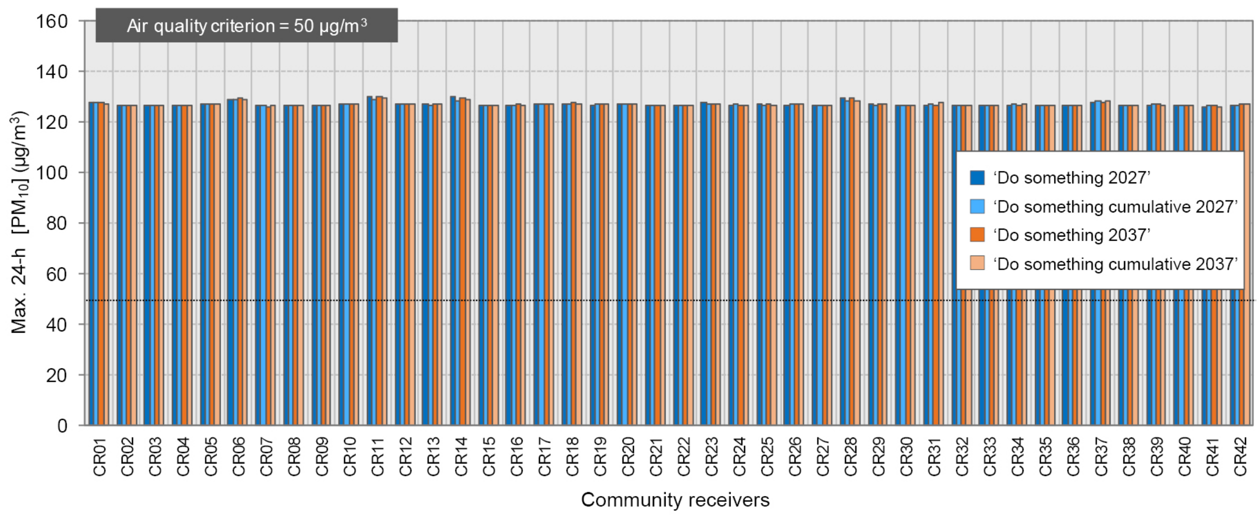

Figure 12-13 Maximum 24-hour mean PM_{10} concentration at community receivers

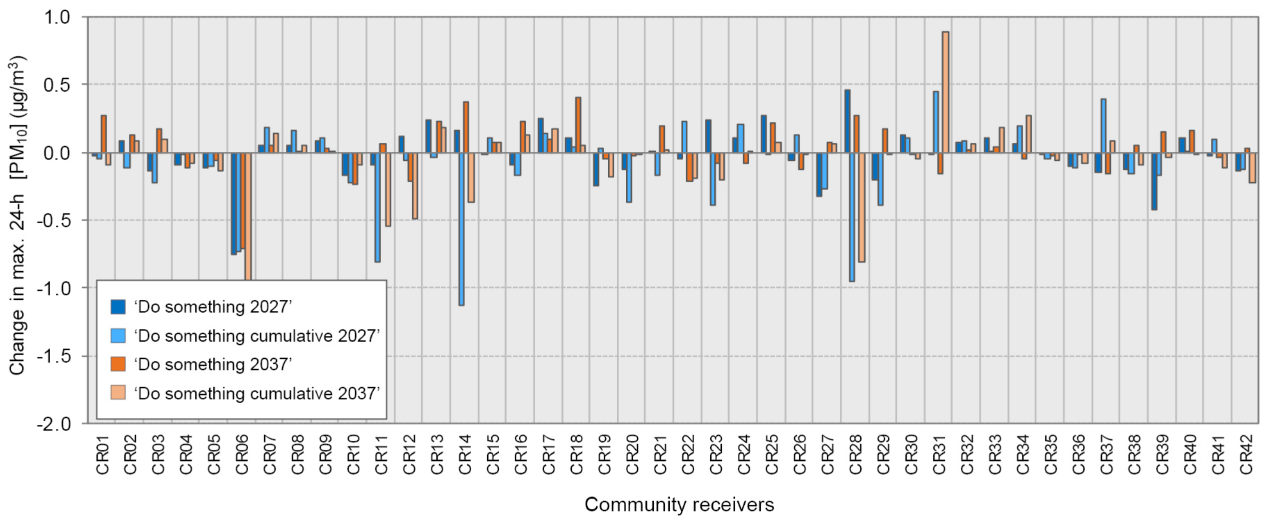

Figure 12-14 Change in maximum 24-hour mean PM_{10} concentration at community receivers

PM_{10} (annual mean)

Residential, workplace and recreational receiver locations

Figure 12-15 shows the with-project and cumulative scenarios predicted contributions to the annual mean PM_{10} concentration at all other residential, workplace and recreational receiver locations. It demonstrates that the concentration at most receivers is predicted to be below 20 µg/m^3, and no receivers are predicted to have a concentration above the criterion of 25 µg/m^3 under all scenarios assessed. The highest predicted concentration at any receiver in a 'Do something' or 'Do something cumulative' scenario for 2027 and 2037 is 23.5 µg/m^3.

The largest predicted surface road contribution would be about 6.6 µg/m^3, with an average of about 0.9 µg/m^3. The largest predicted contribution from the project's ventilation outlets would be 0.3 µg/m^3 in the 'Do something cumulative 2037' scenario.

Community receivers

Figure 12-16 shows the predicted annual mean PM_{10} concentrations at all of the community receivers in the project and cumulative scenarios. PM_{10} concentrations are predicted to be below the criterion of 25 µg/m^3 at all receivers in all scenarios.

Figure 12-17 shows the predicted changes in annual mean PM_{10} concentration as a result of the project and cumulatively with other projects (the difference between the 'Do something' and 'Do something cumulative' scenarios and the 'Do minimum' scenarios) in 2027 and 2037. The largest predicted increase would be about 0.45 µg/m^3 (1.8 per cent of the criterion) at a receiver in Seaforth (CR28) under the 'Do something' scenario, and the largest decrease would be 1.45 µg/m^3, both under the 2037 'Do something cumulative' scenario. Overall, PM_{10} concentrations are predicted to decrease at most of the community receivers under the scenarios assessed.

Annual mean PM_{10} concentrations in the 'Do something' and 'Do something cumulative' scenarios for 2027 and 2037 would be dominated by existing PM_{10} concentrations (background). The predicted contribution from roads at most receivers would be small (up to five µg/m^3) and the contribution from the project's ventilation outlets would be negligible (less than about 0.2 µg/m^3).

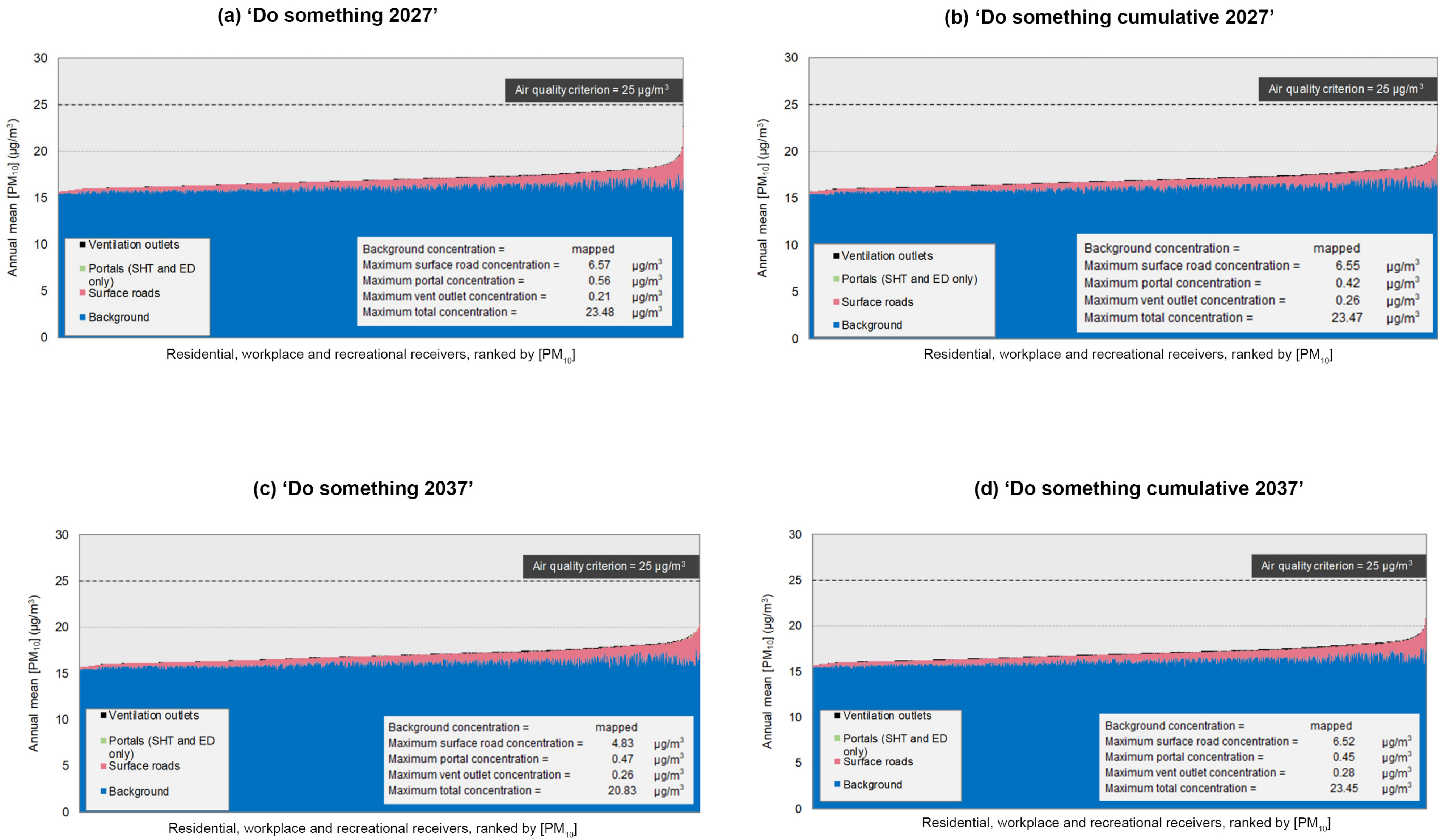

Figure 12-15 Contributions to annual mean PM_{10} concentration at residential, workplace and recreational receiver locations

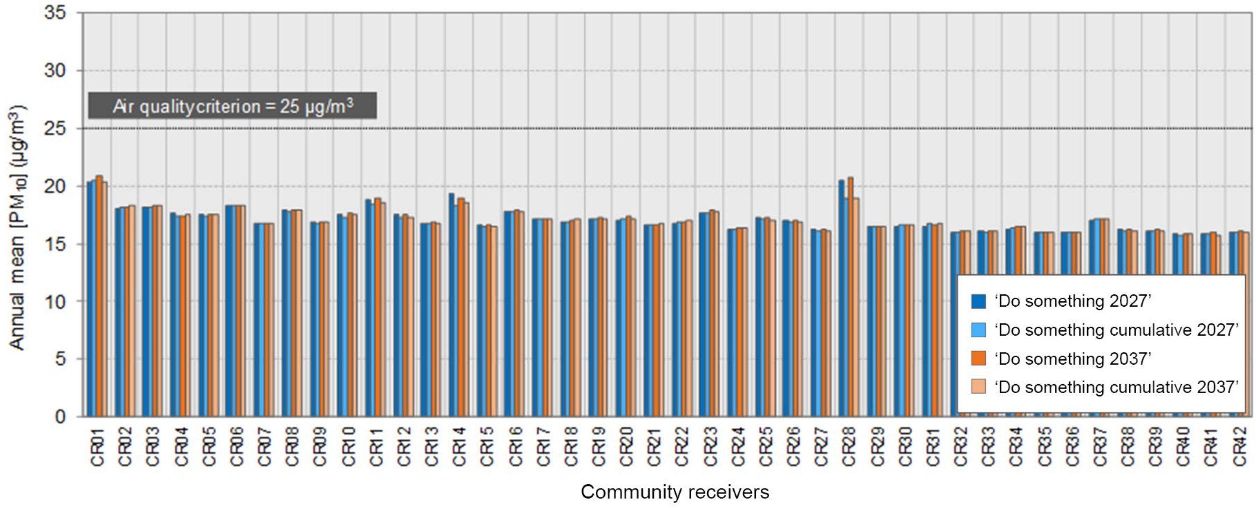

Figure 12-16 Annual mean PM_{10} concentration at community receivers

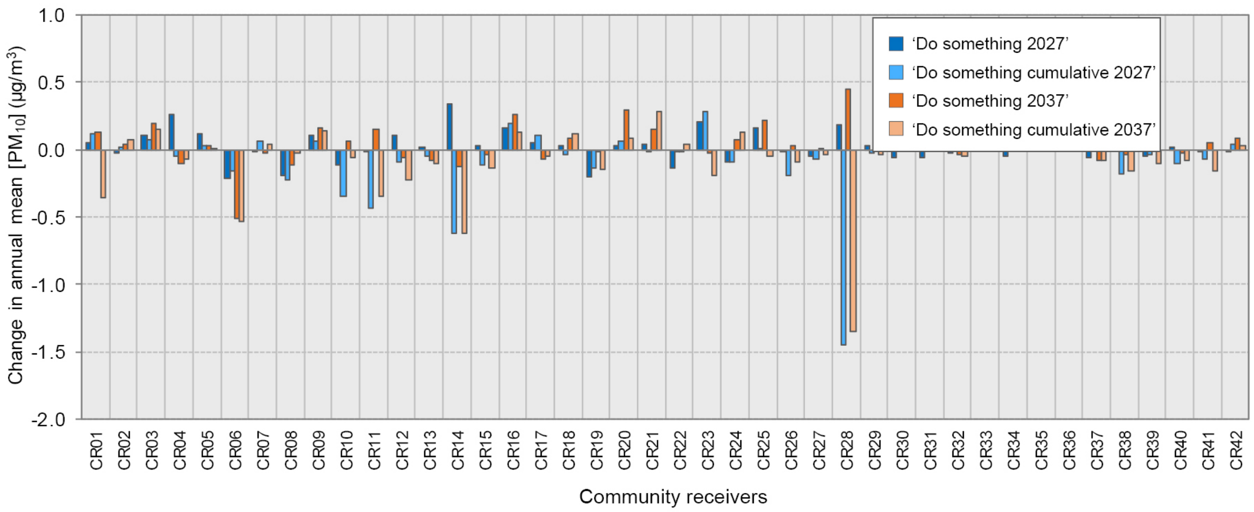

Figure 12-17 Change in annual mean PM_{10} concentration at community receivers

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

Residential, workplace and recreational receiver locations

Figure 12-18 shows predicted contributions of the project to the maximum 24-hour mean $PM_{2.5}$ concentration at all of the residential, workplace and recreational receiver locations. When considering the relatively high background concentration (22.1 µg/m^3), the concentration at a large proportion of receivers were above the criterion of 25 µg/m^3. The predicted maximum contribution of the project's ventilation outlets would be 1.0 µg/m^3 in the 'Do something cumulative 2037' scenario.

At most receivers, the changes in the maximum 24-hour mean $PM_{2.5}$ concentration would be very small. The largest predicted increase in concentration at any receiver as a result of the project is predicted to be 2.2 µg/m^3, and the largest predicted decrease is 6.3 µg/m^3. Where increases are predicted, they are greater than one µg/m^3 at less than one per cent of receivers.

Community receivers

Figure 12-19 shows the maximum 24-hour mean $PM_{2.5}$ concentrations at all of the community receivers in the project and cumulative scenarios. At all receiver locations, the maximum concentration was above the criterion of 25 µg/m^3, although exceedances would already be predicted without the project.

Figure 12-20 shows the predicted change in maximum 24-hour mean $PM_{2.5}$ with the project and cumulative scenarios at community receivers. Most of the increases in concentration would generally be less than one µg/m^3. The largest increase in maximum 24-hour mean $PM_{2.5}$ concentrations is 2.1 µg/m^3 at a receiver in Seaforth (CR28) in the 'Do something 2037' scenario, which is about eight per cent of the air quality criterion.

In the 'Do something' scenarios (ie with the operation of the project), the ventilation outlet contribution at all community receivers is predicted to be negligible, with the largest value being slightly greater than 0.05 µg/m^3. The outlet contributions are predicted to be slightly higher in the 'Do something cumulative' scenarios, although they would still be small, with the maximum outlet contribution of around 0.4 per cent of the air quality criterion at a receiver in North Sydney (CR09) (0.07 – 0.1 µg/m^3). The maximum outlet contribution at all other community receivers would be less than 0.5 per cent of the air quality criterion (less than 0.1 µg/m^3).

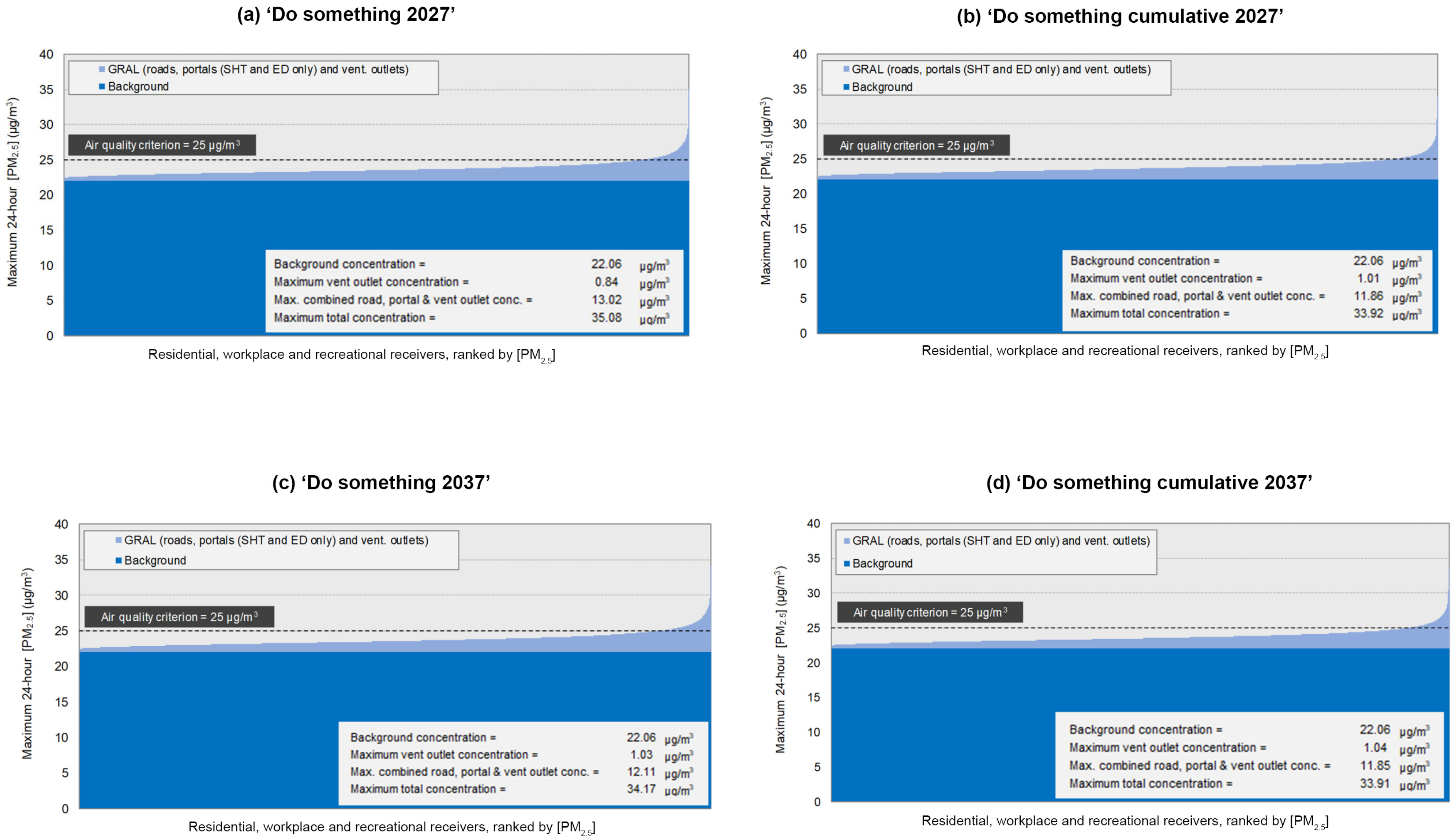

Figure 12-18 Contributions to maximum 24-hour $PM_{2.5}$ mean concentration at residential, workplace and recreational receiver locations

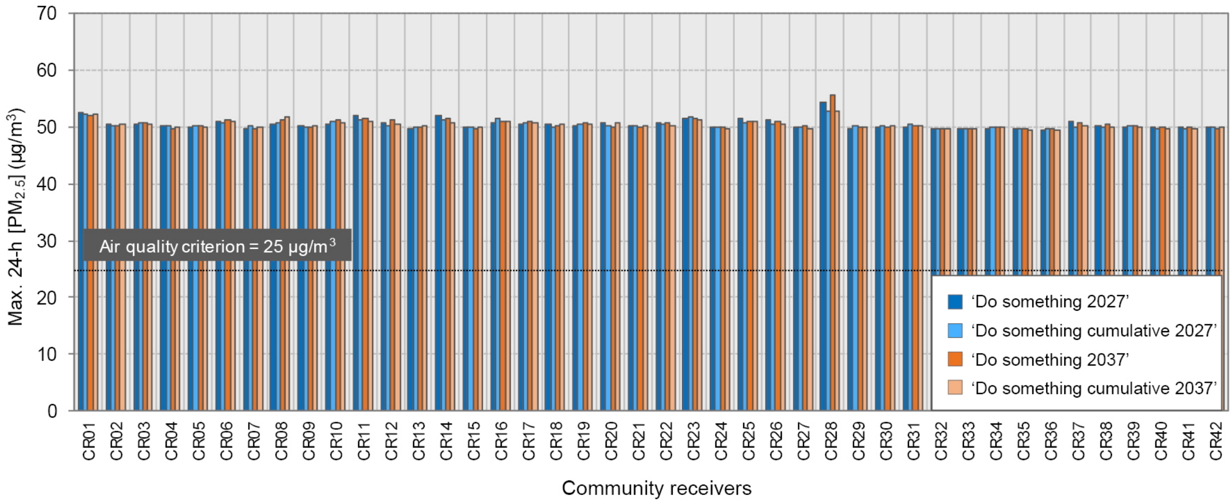

Figure 12-19 Maximum 24-hour $PM_{2.5}$ mean concentration at community receivers

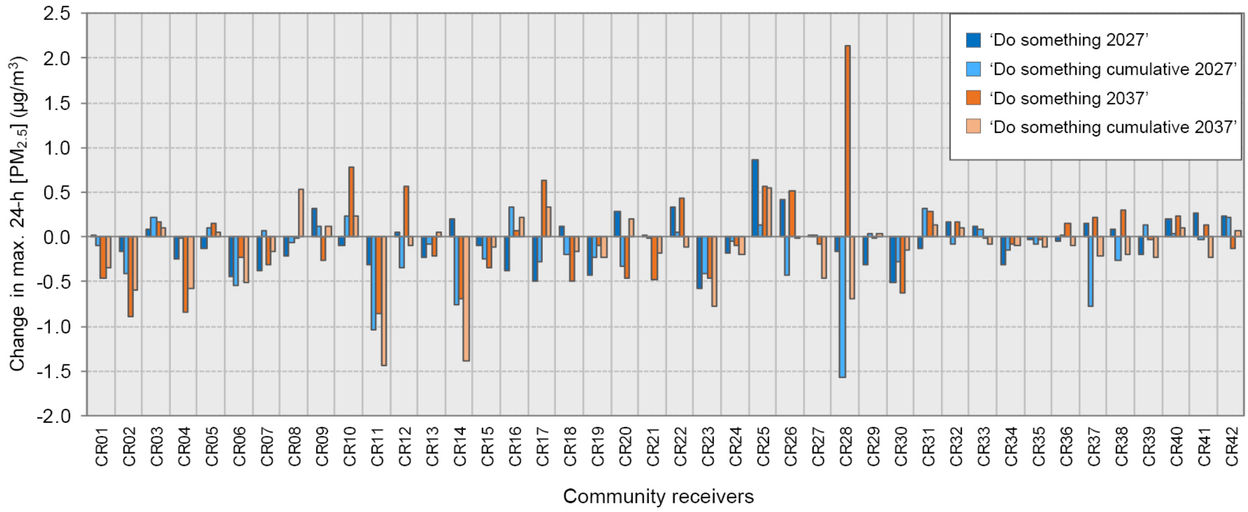

Figure 12-20 Change in maximum 24-hour $PM_{2.5}$ mean concentration at community receivers

$PM_{2.5}$ (annual mean)

Residential, workplace and recreational receiver locations

Figure 12-21 shows predicted contributions of the project to the annual mean $PM_{2.5}$ concentration at all the residential, workplace and recreational receiver locations. It shows that the highest predicted annual mean $PM_{2.5}$ concentration at any receiver location would be 11.9 µg/m^3. In the 'Do something' and 'Do something cumulative' scenarios, the largest surface road contribution at any receiver is predicted to be 4.1 µg/m^3. The largest predicted contribution from the project's ventilation outlets would be 0.18 µg/m^3 in the 'Do something cumulative 2037'.

The largest predicted increase in concentration at any receiver location as a result of the project would be 0.6 µg/m^3, and the largest predicted decrease would be 2.1 µg/m^3.

Community receivers

Figure 12-22 shows the annual mean $PM_{2.5}$ concentrations at all of the community receivers. Given that the mapped background concentration at some community receivers is already very close to the air quality criterion (up to 7.9 µg/m^3), some exceedances of the criterion and the NSW 2025 goal of seven µg/m^3 are predicted as a result of the project. These exceedances also occur in the 'Do minimum' scenarios (ie without the project).

Figure 12-23 shows the predicted change in the annual mean $PM_{2.5}$ as a result of the project and cumulatively with other projects (the difference between the 'Do something' scenarios and the 'Do minimum' scenarios) in 2027 and 2037. Overall, the changes would generally be less than 0.2 µg/m^3. The largest increase in annual mean $PM_{2.5}$ concentration at any community receiver as a result of the project would be 0.19 µg/m^3 in the 'Do something 2037' scenario. This increase is less than 2.5 per cent of the air quality criterion.

The surface road contribution is predicted to be between 0.2 µg/m^3 and 3.2 µg/m^3. The largest predicted contribution from the project's ventilation outlets at any receiver would be 0.1 µg/m^3.

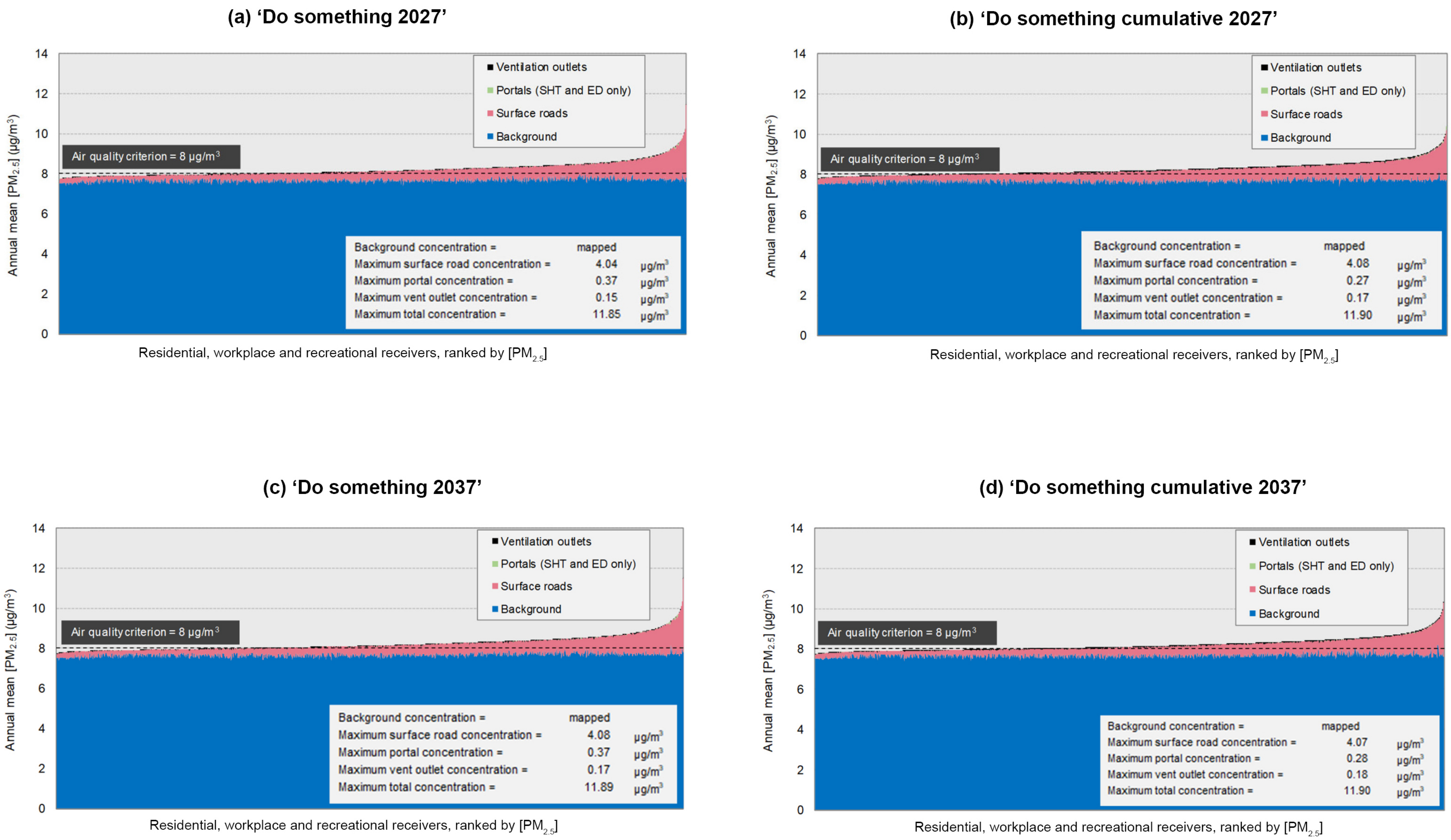

Figure 12-21 Contributions to annual mean $PM_{2.5}$ concentration at residential, workplace and recreational receiver locations

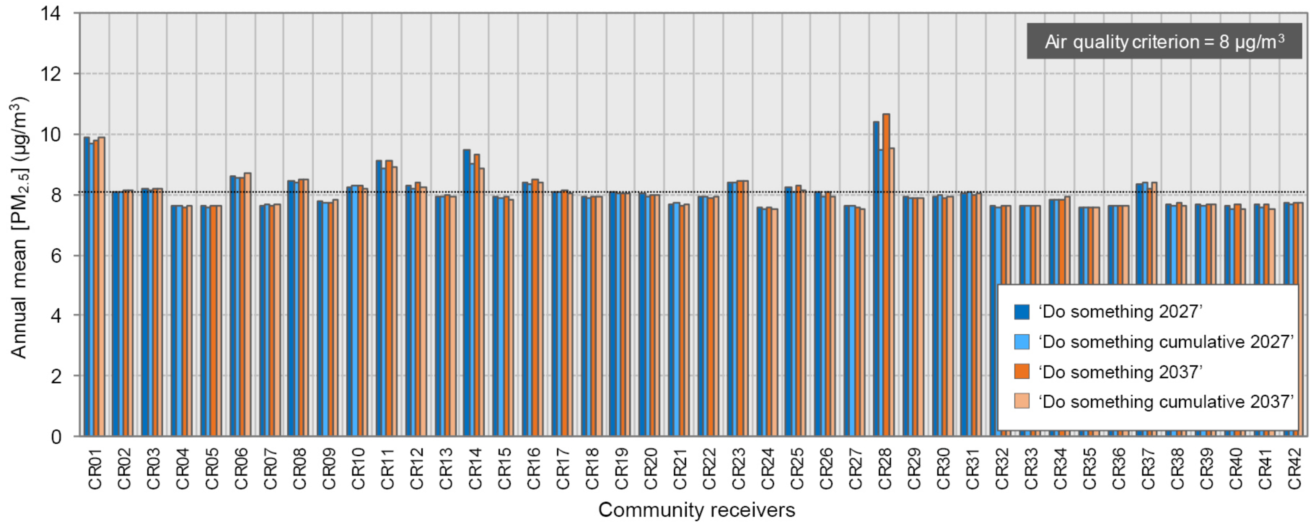

Figure 12-22 Annual mean $PM_{2.5}$ concentration at community receivers

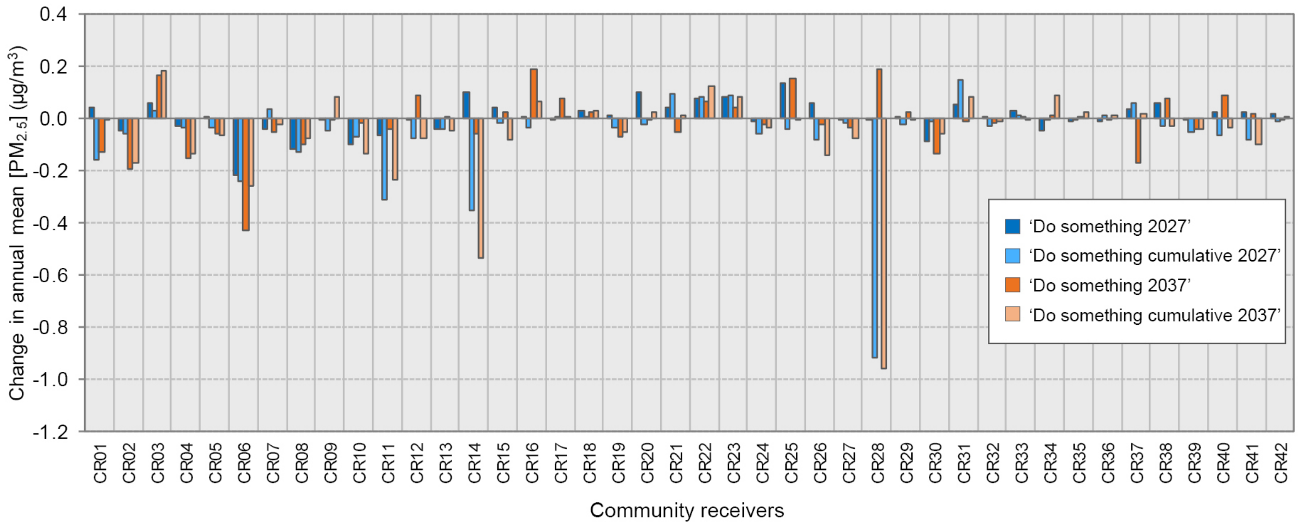

Figure 12-23 Change in annual mean $PM_{2.5}$ concentration at community receivers

Carbon monoxide (CO)

Residential, workplace and recreational receiver locations

The 1-hour and maximum rolling 8-hour mean CO criterion would not be exceeded at any of the receiver locations in any scenario. The highest total 1-hour CO concentrations in any of the 'Do something' or 'Do something cumulative' scenarios is predicted to be 5.5 mg/m^3. The largest predicted contribution from ventilation outlets at any receiver is predicted to be less than 0.1 mg/m^3. Rolling 8-hour mean CO concentrations at all the residential, workplace and recreational receiver locations would be similar to those obtained for maximum 1-hour concentrations.

Community receivers

The CO concentration at all the community receiver locations, is predicted to be well below the impact assessment criterion for both the 1-hour and maximum rolling 8-hour mean CO concentrations.

The largest contribution of surface roads to the maximum total concentration in any of the 'Do something' and 'Do something cumulative' scenarios is predicted to be small for both the 1-hour and maximum rolling 8-hour mean CO concentrations. The contribution of the project's ventilation outlets to the maximum CO concentration is zero or negligible for all receivers.

Polycyclic aromatic hydrocarbons and volatile organic compounds

Five compounds – polycyclic aromatic hydrocarbons, benzene, formaldehyde, 1,3-butadiene and ethylbenzene – were considered in the assessment. These compounds were taken to be representative of the much wider range of air toxics associated with motor vehicles, and have commonly been assessed for road projects.

The predicted changes in the maximum 1-hour concentrations for these compounds showed that there would be minor increases in concentration as a result of the project, however, all concentrations would be well below their respective assessment criterions. The increases (and decreases) for the most affected residential, workplace and recreational receiver locations would be higher for those that are in closer proximity to the surface roads, but in all cases and for all five compounds considered in the assessment, the total predicted concentrations would be well below their respective criteria. For example, the largest change in benzene concentrations at any residential, workplace and recreational receiver location for a 'Do something cumulative' scenario is predicted to be 3.6 $\mu g/m^3$ but the total concentration of 8.0 $\mu g/m^3$ still remains well below the criterion of 29 $\mu g/m^3$ (0.029 mg/m^3).

12.6.3 Redistribution of air quality impacts

Spatial changes in air quality

The spatial changes in pollutant concentrations are assessed with respect to annual mean $PM_{2.5}$ concentration, given its importance in terms of human health risks. However, the spatial changes would be qualitatively similar for all pollutants.

The annual mean $PM_{2.5}$ concentration as a result of the project ('Do something 2027' scenario, relative to 'Do minimum 2027' scenario) is predicted to decrease along the Western Distributor, the Sydney Harbour Bridge and Warringah Freeway due to decreased traffic demand (as more cars would use the Western Harbour Tunnel as an alternative harbour crossing). Decreased traffic demand would result in improved amenity along these built-up road corridors. The human health benefits associated with the decrease in $PM_{2.5}$ concentration as a result of the project is discussed in Chapter 13 (Human health). The changes in $PM_{2.5}$ concentration in the 'Do something 2037' scenario would be broadly similar to the 'Do something 2027' scenario.

For the cumulative scenarios, including the Beaches Link and Gore Hill Freeway Connection project, there would be reductions in $PM_{2.5}$ concentration along Military Road, Spit Road, Manly Road and Warringah Road, due to decreased traffic volumes. Decreased traffic demand on these surface roads (due to more vehicles using the program of works) would result in improved amenity along these roads. There would be an increase in $PM_{2.5}$ concentration along Wakehurst Parkway as a result of the expected increase in traffic demand associated with the Beaches Link and Gore Hill Freeway Connection project. The section of Wakehurst Parkway that would be affected by increased traffic demand, crosses bushland and there are no sensitive receivers close to the road.

Overall, there would be no marked redistribution of air quality impacts, and there would generally be a shift towards lower concentrations. Most notably, there would be no significant increase in concentration at receiver locations which already would have high concentrations in the 'Do minimum' scenarios.

12.6.4 Ambient air quality (elevated receivers)

$PM_{2.5}$ (annual mean)

The changes in annual mean $PM_{2.5}$ concentration in the 'Do something cumulative 2037' scenario was considered for receiver heights of 10 metres, 20 metres, 30 metres and 45 metres above ground level, respectively. Existing buildings at receiver locations are not at all of these heights (eg at a receiver location, an existing building may be up to 10 metres in height, but was assessed at all four selected heights). Statistics relating to the changes in annual mean concentration at all residential, workplace and recreational receiver locations (whether there is an existing building at that location at each height or not) and at receiver locations with an existing building at that height in the model domain are provided in Table 12-9.

Table 12-9 Changes in annual mean $PM_{2.5}$ concentration at elevated receiver locations – 'Do something cumulative 2037' compared with 'Do minimum 2037'

Height	Maximum increase in $PM_{2.5}$ concentration at residential, workplace and recreational receiver locations ($\mu g/m^3$) (1)	Number of residential, workplace and recreational receiver locations with an increase of more than 0.1 $\mu g/m^3$ (1)	Maximum increase in $PM_{2.5}$ concentration at residential, workplace and recreational receivers ($\mu g/m^3$) (2)	Number of residential, workplace and recreational receivers with an increase of more than 0.1 $\mu g/m^3$ (2)
Ground level	0.58	1554 (4.4%)	0.58	1554
10 metres	0.37	998 (2.8%)	0.18	25
20 metres	0.24	590 (1.7%)	0.09	0
30 metres	0.48	447 (1.3%)	0.13	2
45 metres	2.06	499 (1.4%)	0.05	0

Note 1: Assumes all residential, workplace and recreational receiver locations exist at all heights irrespective of existing building heights at those locations
Note 2: Only includes existing buildings that exist at each height.

Modelled annual mean $PM_{2.5}$ concentrations resulting from surface roads and portals have a reduced influence at receivers at 10 metres height, compared with those at ground level. However, because the influence of surface roads and portals without the project was also reduced at 10 metres, the spatial distribution of changes in annual mean $PM_{2.5}$ concentration at 10 metres and ground level would be quite similar. The largest changes in concentration at 10 metres would be slightly smaller than those at ground level. The largest increase at the height of 10 metres for the residential, workplace and recreational receiver locations would be 0.37 μg/m^3, which can be compared with the maximum increase for any ground-level receiver in the 'Do something cumulative 2037' scenario of 0.58 μg/m^3.

For receivers at heights of 20 metres, 30 metres and 45 metres, the changes in annual mean $PM_{2.5}$ concentrations associated with surface roads would be negligible at all locations. The largest increases at receivers at 20 metres, 30 metres and 45 metres (assuming that all receivers would exist at all heights) would be 0.24, 0.48 and 2.06 μg/m^3 respectively.

For existing buildings that are at heights of 10 metres, 20 metres, 30 metres and 45 metres, the maximum increase in annual mean $PM_{2.5}$ concentration is 0.18 μg/m^3. No existing buildings at those heights are predicted to exceed 1.7 μg/m^3.

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

The change in maximum 24-hour mean $PM_{2.5}$ concentration in the 'Do something cumulative 2037' scenario was considered for receiver heights of 10 metres, 20 metres, 30 metres and 45 metres, respectively. As noted previously, existing buildings do not exist at all of these heights at all residential, workplace or recreational receiver locations. Statistics relating to the changes in annual mean concentration at all residential, workplace and recreational receiver locations (whether there is an existing building at that location at those heights or not) and at receiver locations with an existing building at that height in the model domain are provided in Table 12-10.

Table 12-10 Changes in maximum 24-hour $PM_{2.5}$ mean concentration at elevated receivers – 'Do something cumulative 2037' compared with 'Do minimum 2037'

Height	Maximum increase in $PM_{2.5}$ concentration at residential, workplace and recreational receiver locations (μg/m^3) (1)	Number of residential, workplace and recreational receiver locations with an increase of more than 0.5 (μg/m^3) (1)	Maximum increase in $PM_{2.5}$ concentration at residential, workplace and recreational receivers (μg/m^3) (2)	Number of residential, workplace and recreational receivers with an increase of more than 0.5 (μg/m^3) (2)
Ground level	2.20	919 (2.6%)	2.20	919
10 metres	2.07	253 (0.7%)	1.61	43
20 metres	1.46	575 (1.6%)	0.44	0
30 metres	8.67	537 (1.5%)	1.01	2
45 metres	9.02	620 (1.8%)	0.36	0

Note 1: Assumes all residential, workplace and recreational receiver locations exist at all heights
Note 2: Only includes residential, workplace and recreational receiver locations that exist at each height

At modelled receiver heights of 10 metres and 20 metres, the maximum increase in concentration would be slightly lower than at ground level but, as with the annual mean, the spatial distributions of changes would be quite similar. At a height of 30 metres and 45 metres the largest increases in the maximum 24-hour $PM_{2.5}$ concentrations would be near the proposed ventilation outlets, and these large increases would be greater than those at 20 metres, 10 metres and ground level. The largest increase in maximum 24-hour $PM_{2.5}$ concentration at any receiver would be about nine µg/m^3 (18 per cent of the assessment criterion) at a height of 45 metres, while at a height of 30 metres the largest increase was around 8.7 µg/m^3. At heights of both 30 metres and 45 metres, the increase in concentration would be less than 1 µg/m^3 at distances from the outlets of greater than 300 metres (in the worst case).

At a height of 10 metres, there would be only 43 existing receivers at that height with an increase in the maximum 24-hour $PM_{2.5}$ concentration of more than 0.5 µg/m^3. At heights of 20 metres and 45 metres, there would be no existing receivers at those heights with an increase in the maximum 24-hour $PM_{2.5}$ concentration of greater than 0.5 µg/m^3. At a height of 30 metres, there would be two existing receivers with an increase in the maximum 24-hour $PM_{2.5}$ concentration of greater than 0.5 µg/m^3.

Summary of results for elevated receivers

The changes in ambient air quality for elevated receivers can be summarised as follows:

- There are no predicted adverse impacts at any existing buildings at any height
- There are no predicted adverse impacts at any existing or future buildings up to a height of 20 metres
- There are predicted impacts for potential future buildings above 20 metres in height within 300 metres of the ventilation outlets, but this would not necessarily preclude such development. Further consideration at rezoning or development application stage would be required
- There are no restrictions to building heights within 300 metres of the Rozelle Interchange outlet. Within 300 metres of the Warringah Freeway outlet, current planning controls for permissible habitable structures restrict buildings to below 20 metres
- Land use considerations would be required to manage any interaction between the project and future development for buildings with habitable structures above 20 metres and within 300 metres of the ventilation outlet. Further discussion is provided in Chapter 20 (Land use and property).

12.6.5 Regional air quality

The absolute changes in the total emissions resulting from the project can be viewed as a proxy for the project's regional air quality impacts which, based on the results, are likely to be negligible. For example:

- Changes in NO_X emissions for the assessed road network in a given assessment year (2027 and 2037) for the 'Do something' scenario ranged from an increase of one tonne per year to a decrease of around four tonnes per year depending on the scenario. In the 'Do something cumulative' scenarios (2027 and 2037), changes in NO_X emissions ranged from an increase of 28 tonnes per year and an increase of 124 tonnes per year, depending on the scenario. These values equated to small proportions of human activity related NO_X emissions in the Sydney airshed in 2016 (about 53,700 tonnes)
- Any increases in the NO_X emission rate due to the project in a given assessment year (2027 or 2037) would be much smaller than the underlying reduction in the emission rate between 2016 and 2037. This underlying reduction would be about 2000 tonnes per year.

The regional air quality impacts of a project can also relate to capacity to influence ozone production. Project related NO_X emissions are well below the NSW EPA threshold for conducting a further detailed assessment of impacts to ozone.

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

12.6.6 Odour

For each of the residential, workplace and recreational receivers, the change in the maximum one hour total hydrocarbon concentration as a result of the project was calculated. The largest change in the maximum one hour total hydrocarbon concentration across all receivers was then determined, and this was converted into an equivalent change for three of the odorous pollutants identified in the NSW EPA Approved Methods (toluene, xylenes, and acetaldehyde). Some hydrocarbons emitted from the burning of fuel by motor vehicles create odour. These pollutants were taken to be representative of other odorous pollutants from motor vehicles.

The changes in the levels of three odorous pollutants as a result of the project, and the corresponding odour assessment criteria from the NSW EPA Approved Methods, are shown in Table 12-11. The results show that the predicted change in the maximum 1-hour concentration of each pollutant is well below the corresponding odour assessment criterion in the NSW EPA Approved Methods.

Table 12-11 Odorous pollutant concentrations

Scenario	Maximum predicted increase in total hydrocarbon concentration		
	Toluene ($\mu g/m^3$)	Xylenes ($\mu g/m^3$)	Acetaldehyde ($\mu g/m^3$)
'Do something 2027'	4.9	4.1	1.1
'Do something cumulative 2027'	3.6	3.0	0.8
'Do something 2037'	3.6	3.0	1.2
'Do something cumulative 2037'	2.5	2.1	0.8
Odour criterion ($\mu g/m^3$)	**360**	**190**	**42**

12.7 Environmental management measures

12.7.1 Management of construction impacts

Environmental management measures relating to air quality impacts during construction are outlined in Table 12-12.

Table 12-12 Environmental management measures for air quality impacts

Ref	Phase	Impact	Environmental management measure	Location
AQ1	Pre-construction	General	Standard construction air quality mitigation and management measures will be detailed in construction management documentation and implemented during construction, such as: a) Reasonable and feasible dust suppression and/or management measures, including the use of water carts, dust sweepers, sprinklers, dust screens, site exit controls (eg wheel washing systems and rumble grids), stabilisation of exposed areas or stockpiles, and surface treatments b) Selection of construction equipment and/or materials handling techniques that minimise the potential for dust generation c) Management measures to minimise dust generation during the transfer, handling and on site storage of spoil and construction materials (such as sand, aggregates or fine materials) (eg the covering of vehicle loads) d) Adjustment or management of dust generating activities during unfavourable weather conditions, where possible e) Minimisation of exposed areas during construction f) Internal project communication protocols to ensure dust-generating activities in the same area are coordinated and mitigated to manage cumulative dust impacts of the project g) Site inspections will be carried out to monitor compliance with implemented measures.	WHT/WFU
AQ2	Construction	General	Dust and air quality complaints will be managed in accordance with the overarching complaints handling process for the project. Appropriate corrective actions; if required, will be taken to reduce emissions in a timely manner.	WHT/WFU

WHT = Western Harbour Tunnel, WFU = Warringah Freeway Upgrade

12.7.2 Management of operational impacts

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

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

Tunnel design

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

Ventilation design and control

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

- Control of the internal environment. It must be safe and comfortable to drive through the tunnel. Vehicle emissions must be sufficiently diluted so as not to be hazardous during normal operation, or when traffic is moving slowly or stationary
- Protection of the external environment. Ventilation, and the dispersion of pollutants, is the most widely used method for minimising the impacts of tunnels on ambient air quality. Collecting emissions and venting them via elevated ventilation outlets is a very efficient way of dispersing pollutants. Studies show that the process of removing surface traffic from heavily trafficked roads and releasing the same amount of pollution from an elevated location results in substantially lower concentrations at sensitive receivers (PIARC 2008a)
- Emergency situations. When a fire occurs in a tunnel, the ventilation system is able to control the heat and smoke in the tunnel so as to permit safe evacuation of occupants, and to provide the emergency services with a safe route to deal with the fire and to rescue any trapped or injured persons
- The ventilation system design options that were considered for the project are discussed in Chapter 4 (Project development and alternatives) and the system adopted for the project is described in Chapter 5 (Project description).

Air treatment systems

There are several air treatment options for mitigating the effects of tunnel operation on both in-tunnel and ambient air quality. Where in-tunnel treatment technologies have been applied to road tunnels, these technologies have focused on the management and treatment of particulates.

In Australia, the issue of air treatment frequently arises during the development of new tunnel projects. All tunnel projects have, however, gravitated towards a decision not to install an air treatment system, and to rely instead on the primary approach of dilution of air pollution (through ventilation systems) (PIARC 2008a; CETU 2016).

An in-tunnel air treatment system – including electrostatic precipitator (ESP) and denitrification technologies – was trialled in the Sydney M5 East tunnel, although measurement campaigns have indicated that emissions from the tunnel ventilation outlet do not have any significant impact on external air quality. The filtration system was installed 500 metres from the western portal in the westbound tunnel. A structure was built to host the ESP and NO_2 treatment systems, fans, offices and ancillary equipment. A 300 metre ventilation duct to connect the plant to the tunnel was also built. The filtered air from the tunnel, rather than being discharged directly outside, is reinjected into the tunnel and then eventually discharged by the existing ventilation outlet. The end-to-end cost of this treatment project was $65 million. The high cost reflects the fact that the tunnel was not originally designed to accommodate such systems (AMOG 2012).

In November 2018, the ACTAQ published a technical paper which reviewed options for treating road tunnel emissions (ACTAQ 2018b). The review concluded that:

- Decisions on how to best manage tunnel air can only be made at the project level. Health-based air quality standards must be a priority; however, engineering and economic factors also need to be taken into account
- Air filtration systems in tunnels are rare around the world. They have high infrastructure, operating and maintenance costs
- Although filtration for particulates or NO_2 is technically feasible, the available technologies will not lower concentrations of other air pollutants
- Alternatives such as portal air extraction (ie no portal emissions) and dispersion via ventilation outlets may achieve the same outcomes as filtration at a lower cost.

The ACTAQ assessment has demonstrated that the appropriate design of ventilation outlets would achieve the same (or better) outcomes as installing air filtration systems – that is, the contribution of tunnel ventilation outlets to pollutant concentrations would be negligible for all receivers.

Emission controls and other measures

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

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

Detailed design of the in-tunnel monitoring system would be carried out during future project development phases and would include the following:

- Nitrogen oxide, NO_2, CO and visibility. Monitoring of each pollutant will be carried out throughout the tunnel. The locations of monitoring equipment will generally be at the beginning and end of each ventilation section. This would include, for example, monitors at each entry ramp, exit ramp, merge point and ventilation outlet and supply point. The location of monitors will be governed by the need to meet in-tunnel air quality criteria for all possible journeys through the tunnel system, especially for NO_2. This will require sufficient, appropriately placed monitors to calculate a journey average

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

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