7.3 Air quality

A technical working paper: air quality (refer to **Appendix G**) has been prepared to assess the potential impacts from the project on air quality. This section provides a summary of the technical working paper.

Table 7-87 sets out the Director-General's Requirements as they relate to air quality, and where in the environmental impact statement these have been addressed.

Table 7-87 Director-General's Requirements – air quality

Director-General's requirement	Where addressed
An assessment of construction and operation activities that have the potential to impact on local and regional air quality. The assessment should provide an assessment of the risk associated with potential discharges of fugitive and point source emissions, and include:	Operational and construction air quality impacts, including construction activities with the potential to impact on air quality, are identified and addressed in **Section 7.3.4** and **Appendix G**.
• details of the proposed methods to minimise adverse impacts on air quality during construction, particularly in relation to mobile plant,	Measures to manage and mitigate construction air quality impacts are provided in **Section 7.3.5** and **Appendix G**.
• air quality impact assessment and air dispersion modelling conducted in accordance with the *Approved Methods for the Modelling and Assessment of Air Pollutants in NSW* (EPA, 2005) where there is a risk of adverse air quality impacts, or where there is sufficient uncertainty as to the potential level of risk, including a particle assessment addressing PM_{10} and $PM_{2.5}$ values, consideration of impacts from dispersal of TSP, CO, NO_2 and other nitrogen oxides, volatile organic compounds (eg BTEX), details of the proposed mitigation measures to address air quality in tunnels and in the vicinity of portals and any mechanical ventilation systems (ie ventilation stacks), including details of proposed monitoring,	Detailed description of the methodology of the air quality assessment, including description of modelling is provided in **Section 7.3.2** and **Appendix G**. Measures to manage and mitigate air quality during operation are provided in **Section 7.3.5** and **Appendix G**.
• consideration of the requirements of Environmental Health Risk Assessment: Guidelines for assessing human health risks from environmental hazards (enHealth, 2012), and	Requirements of these guidelines are discussed in **Section 7.4** (Human health) and **Appendix H**.
• take into account any applicable advice provided by the Independent Advisory Committee on Tunnel Air Quality.	Engagement with the Independent Advisory Committee on Tunnel Air Quality is discussed in **Section 7.3.2** and **Appendix G**.

7.3.1 Tunnel ventilation system

The design of the tunnel ventilation system is an important component in the operational air quality assessment. Details of the ventilation system are provided in **Chapter 5** with a summary below.

The tunnel ventilation system would maintain appropriate air quality that is protective of the health and amenity of motorists within the tunnels during normal operation and emergency conditions. .

During operation, the ventilation system would draw fresh air into the tunnels and emit air from within the tunnels via two ventilation facilities. One of the ventilation facilities would be located near the northern tunnel portal and one would be located near the southern tunnel portal.

The most efficient location for ventilation outlets is close to the main alignment tunnel exit portals. This is because vehicles travelling through the tunnels create a piston effect, which draws air into the tunnel and pushes it forward in the direction of traffic flow. Locating the ventilation outlets near the main alignment tunnel exit portals maximises the benefit of the piston effect and minimises the need for additional energy consumption to operate tunnel jet fans and to transport the exhaust air from the tunnel to the outlet. This approach provides environmental benefits through the reduction in energy consumption and greenhouse gas emissions from the project.

The location of ventilation outlets for the project have been determined based on proximity to the main alignment tunnel exit portals, as well as consideration of other factors including land access and acquisition requirements, geology, engineering and construction constraints, potential landscape and visual impacts, and the location of other major infrastructure.

The project does not currently propose portal emissions from the main alignment tunnels, however this approach may be considered in the future and would be subject to appropriate assessment and approval at the relevant time.

During emergency conditions, depending on the location of the incident, the ventilation system would extract smoke from the tunnel which would be emitted from one or more of the following locations:

- Southern ventilation facility.
- Wilson Road tunnel support facility.
- Trelawney Street tunnel support facility.
- Northern ventilation facility.
- The tunnel portals.

Key components of the project's ventilation system are summarised in **Table 7-88**.

Table 7-88 Key components of the project's ventilation system

Ventilation system component	Description
Jet fans	• Jet fans would be mounted in pairs, with each pair separated by a distance of around 90 metres. • A total of around 65 jet fans would be installed in the northbound tunnel and ramps and around 60 jet fans in the southbound tunnel and ramps. • Jet fans would be located throughout the tunnel and would operate on an as required basis to maintain in tunnel air quality requirements.

Ventilation system component	Description
Emergency smoke extraction outlets	• Two emergency smoke extraction outlets would be required, one located on the corner of Wilson Road and Pennant Hills Road (at the Wilson Road tunnel support facility), and one located on the corner of Trelawney Street and Pennant Hills Road (at the Trelawney Street tunnel support facility) (refer to **Figure 5-13**). • Each tunnel support facility would have a maximum exhaust capacity of around 400 cubic metres per second to generate a net flow of around five metres per second along the tunnel. • Each tunnel support facility would consist of four horizontally mounted bidirectional axial fans, each with an exhaust capacity of around 135 cubic metres per second. • Emergency smoke extraction requirements could be achieved with three fans, with the fourth fan on standby. • During low traffic conditions, the tunnel support facilities would be used to supply additional fresh air to the tunnels.
Ventilation facilities	• Two ventilation facilities would be required – one near the northern and the other near the southern main alignment tunnel portals (refer to **Figure 5-13**). • Each ventilation facility would have a maximum exhaust capacity of around 700 cubic metres per second. • Ventilation facilities would consist of five horizontally mounted axial fans, each with an exhaust capacity of around 175 cubic metres per second. • Total ventilation requirements could be achieved with four fans, with the fifth fan on standby. However, during normal operation it is possible that all five fans could be operated at reduced capacity. • Both the southern ventilation outlet and the northern ventilation outlet would be around 15 metres in height.

The tunnel ventilation system would be operated in three principal modes:

- Normal traffic conditions.
- Low speed conditions.
- Emergency conditions.

Normal traffic conditions

During normal operation the tunnel would be longitudinally ventilated. That is, fresh air would be drawn in from the tunnel entry portals and through the tunnels by a vehicle generated piston effect (the suction created behind a moving vehicle which pulls air into and through the tunnel) and pushed towards the tunnel exit portals. Near the portals, tunnel air would be drawn upwards into ventilation facilities with ventilation fans prior to discharge to the environment via a 15 metre high ventilation outlet (relative to the height of neighbouring land).

For the tunnel off-ramps, air would be drawn back down the ramp for extraction via the ventilation facility. This would require jet fans (used to accelerate the movement of air through the tunnel) to maintain the air flow against the direction of traffic flow. A similar approach would be applied to parts of the main alignment tunnels close to the exit portals.

In-tunnel air, containing vehicle emissions, would be extracted from the tunnels prior to reaching the exit portals. Air would be exhausted via a ventilation take off and transferred to the ventilation facility via a vertical shaft. The air would then be discharged from the ventilation facility to the atmosphere.

Low speed traffic conditions

During low speed traffic conditions the vehicle generated piston effect would be lessened. In these situations the airflow may need to be assisted by the tunnel jet fans located throughout the tunnels. Under these conditions, additional fresh air may need to be supplied to the main alignment tunnels via the reverse flow operation of the axial fans in the two emergency smoke extraction points.

The operation of axial fans in the ventilation facilities would be increased to ensure that acceptable air quality is maintained in the tunnels and to achieve acceptable dispersion of tunnel air following discharge to the atmosphere.

Emergency conditions

The two emergency smoke extraction outlets would principally function to maintain air quality in the tunnels in the unlikely event of a fire incident. As a secondary feature, these facilities would also supply fresh air to the tunnels during low speed traffic conditions (discussed above).

During smoke control, air would be extracted from the tunnel and transferred to the emergency smoke extraction outlet via a vertical shaft. The smoke would then be discharged from the facility to the atmosphere.

The emergency smoke extraction outlets are expected to operate infrequently for the extraction of smoke during an emergency, and for a short duration while emergency services and tunnel fire and life safety systems bring the situation under control.

Analysis of the need for tunnel ventilation filtration

Air pollution control technology has been used in a limited number of tunnels in a few countries including Norway, Austria, Germany and Japan as well as the M5 East Motorway tunnel trial in Sydney. This technology includes the use of electrostatic precipitators to remove particles as well as catalytic and biological processes and adsorption technologies to remove nitrogen oxides. Evidence to date suggests that the effectiveness of such measures when applied to road tunnels is questionable.

These technologies are pollutant specific, only address local and not regional transport related air pollution, generate chemical waste and have significant capital and operational costs (NZ Transport Agency, 2013).

The French government undertook an international assessment of the air in road tunnel (CETU, 2010), and concluded that filtration systems are

> *'bulky and less cost-effective than conventional ventilation systems, both in terms of investment and operation. Generally-speaking, these systems are also energy-intensive given the surplus ventilation requirements.'*

A filtration system was constructed to filter the air in the westbound tunnel of the M5 East Motorway. For a period of 18 months an extensive assessment of system performance was carried out by CSIRO and AMOG Consulting. While the system did remove nitrogen oxides and particulate matter, it was expensive to run and did not operate reliably. The M5 East Motorway filtration trial removed 200 kilograms of PM_{10} per year, at an operating cost of around $3.8 million per tonne and a total cost of $17.4 million per tonne (including civil and machinery costs) (AMOG, 2012).

In 2010, the then Department of Environment, Climate Change and Water engaged Sinclair Knight Merz (SKM, 2010) to undertake a study to identify and analyse a range of emissions abatement initiatives. In the Sydney region, 12 emissions reduction measures were identified with costs ranging from $1,000 to $274,000 per tonne of PM_{10} removed. Two emissions reduction programs (the SmartWay program and shifting transport mode to cycling) had a negative cost, ie a cost benefit. The cost of removing PM_{10} using particle filters was $151,000 per tonne. **Table 7-89** provides a comparison of the cost and PM_{10} reductions of these abatement measures and the M5 East Motorway filtration trial.

Table 7-89 Comparison of particulate matter reduction measures

Reduction measures	Cost of reduction per tonne ($)	Annual tonnes reduced
SmartWay program[1]	-54,266,000	5
Two per cent transport mode shift to cycling	-16,146,000	7
National emissions standards for wood heaters (1 g/kg)	$1,000	1,701
National emissions standards for wood heaters (3 g/kg)	$1,000	45
Emission limits for industry	$5,000	359
Tier 4 emissions standards for off-road vehicles and equipment	$12,000	31
Wood heaters – reduce moisture content of firewood	$20,000	93
Small engines (2 stroke to 4 stroke) recreational boating and lawn mowers	$39,000	261
Truck and bus diesel retrofit	$151,000	1
Diesel locomotive replacement (USEPA Tier 0 to Tier 2)	$156,000	53
Diesel locomotive replacement (USEPA Tier 0 to Tier 2) plus Tier 2 locomotives with selective catalytic reduction)	$191,000	72
Euro 5/6 emission standards for new passenger vehicles	$209,000	131
Recommission and electrify Enfield to Port Botany freight line	$244,000	3
Port Botany shore-side power	$274,000	11
M5 East Motorway tunnel filtration (operating costs only)	$3,800,000	0.2
M5 East Motorway tunnel filtration (total cost)	$17,400,000	0.2

Note: 1 USEPA's SmartWay Transport Partnership is a market-driven partnership aimed at helping businesses move goods in the cleanest most efficient way possible

In 2013 the NSW EPA commissioned PAEHolmes to develop a valuation methodology that accounted for the health impacts associated with changes in particulate matter emissions (PAEHolmes, 2013). This study estimated the health benefit of removing one tonne of $PM_{2.5}$ in Sydney to be $280,000.

Nearly all of the particles removed in the M5 East Motorway trial consisted of $PM_{2.5}$. Based on the above valuation, the M5 East Motorway filtration trial had operational costs of more than ten times the estimated health benefit. All of the measures considered by the SKM 2010 study cost more than ten times less than the M5 East Motorway filtration trial and would remove substantially more particulate matter, delivering a much greater health benefit than tunnel filtration. This is consistent with the conclusions of the National Medical and Health Research Council (NH&MRC, 2008). This report found that the most effective method to manage air quality in and around tunnels is through vehicle fleet emission reductions.

As a comparison, Roads and Maritime and the NSW EPA instigated a smoky vehicle strategy on the M5 East Motorway in 2006. This strategy involves the use of smoke detectors, video and still cameras to detect smoky vehicles. Fines and suspensions are issued to encourage vehicles to be repaired or removed from the road network. This strategy has proved to be effective in resulting in improvements to air quality within the M5 East Motorway tunnels, and therefore the air which is exhausted from the M5 East Motorway tunnels to the environment. One measure of in-tunnel air quality is visibility which is measured as an extinction coefficient. Visibility can be used as a measure of in-tunnel particulate matter using a conversion factor from the Permanent International Association of Road Congress (2012) (PIARC). The PIARC definitions of extinction coefficients (visibility) as follows:

- 0.003 m^{-1} means a clear air tunnel (visibility of several hundred metres).
- 0.007 m^{-1} approximates a haziness of in-tunnel air.
- 0.009 m^{-1} approximates a foggy atmosphere.
- 0.012 m^{-1} is the threshold value that should not be exceeded during operation and which results in a very uncomfortable in-tunnel atmosphere. However, there is normally enough visibility to stop safely at an obstacle.

In 2004, prior to the implementation of the strategy, the extinction coefficient (a measure of visibility) within the M5 East Motorway tunnels exceeded 0.004 m^{-1} in the most months. Contemporary data (from April 2013 to April 2014) shows that the M5 East Motorway now operates with an extinction coefficient of less than 0.003 m^{-1} (ie a clear air tunnel) for the majority of the time. The NorthConnex project would also include smoky vehicle regulatory measures similar to the M5 East Motorway. Further details on the improvement in air quality in the M5 East Motorway tunnels since the implementation of the smoky vehicle strategy, and the NorthConnex strategy in relation to smoky vehicles are provided in **Section 7.3.4**.

Based on the above, the use of filtration systems within the tunnel ventilation outlets is not warranted. Such systems have been proven to be costly and inefficient. Further, greater improvements in air quality could be achieved through investment in programs targeting other emission sources that contribute higher levels of pollution to the surrounding environment.

7.3.2 Assessment methodology

This section provides a summary of the methodology applied to the construction and operational air quality assessments, as well as identifying the relevant operational air quality criteria.

Construction assessment methodology

Construction emissions for large linear construction projects are generally difficult to quantify due to the number of construction sites, the distribution of sites across a large geographical area, and the transitory nature of many individual construction activities at particular locations. As such, potential construction air quality impacts have been assessed qualitatively by describing the nature of proposed works, plant and equipment, potential emissions sources and levels. Proactive and reactive mitigation measures have been identified to reduce potential for adverse impacts to local air quality and sensitive receivers.

Operational impact assessment criteria

The assessment criteria for air emissions from the project have been adopted from Approved Methods for the Modelling and Assessment of Air Pollutants (Approved Methods) (DEC, 2005a) and the National Environmental Protection Measure for Ambient Air Quality (Air NEPM) (National Environment Protection Council, 2003).

The Approved Methods provides assessment criteria for key criteria pollutants against which the emissions from development sites or activities are to be assessed. Criteria relevant to this assessment are summarised in **Table 7-90**.

The Director-General's Requirements specify an assessment of $PM_{2.5}$, however there are currently no criteria for the assessment and regulation of $PM_{2.5}$ in NSW. For the purpose of this assessment, the advisory reporting standards and goals for airsheds have been adopted from the Air NEPM. These standards are not criteria for specific facility emissions, but have nonetheless been applied in a similar manner as other air quality criteria for purpose of consistency and completeness. The advisory reporting standards for $PM_{2.5}$ are summarised in **Table 7-91**.

As total suspended particulates (TSP) would essentially comprise the PM_{10} and $PM_{2.5}$ fractions, and because the criterion for total suspended particles is higher than the criteria for PM_{10} and $PM_{2.5}$, total suspended particulates have not been assessed separately. Total suspended particles have nonetheless been considered, and are represented by PM_{10} for the purpose of quantitative assessments presented herein.

Additionally, there are currently no adopted assessment criteria for total volatile organic compounds (VOCs) in NSW. Criteria are provided for the primary individual volatile organic compounds contained in vehicle exhaust (benzene, toluene, ethylbenzene, and xylenes). For the purposes of this assessment, total volatile organic compounds have been assessed using the criteria for benzene as a proxy. The criterion for polycyclic aromatic hydrocarbons (PAHs) as benzo[α]pyrene has been adopted to represent all individual polycyclic aromatic hydrocarbons (refer to **Table 7-90**).

The assessment criteria for PM_{10}, $PM_{2.5}$, total suspended particles, nitrogen dioxide and carbon monoxide (known as 'criteria pollutants') apply to the maximum predicted total pollutant concentrations (ie the incremental contribution from the site or activity, added to the background pollutant concentration). Criteria for volatile organic compounds (benzene, ethylbenzene, toluene and xylenes) apply to incremental concentrations from assessed sources alone. These criteria apply to activities for refined dispersion modelling assessments, such as the operational impact assessment for this project.

Table 7-90 Operational impact assessment criteria (ambient pollutant concentrations)

Pollutant	Averaging period	Criteria (µg/m^3)
PM_{10}	24 hour	50
	Annual	30
Total suspended particles (TSP)	Annual	90
Nitrogen dioxide (NO_2)	1 hour	246
	Annual	62
Carbon monoxide (CO)	15 minute	100,000
	1 hour	30,000
	8 hour	10,000
Benzene (VOC)	1 hour	29
Toluene (VOC)	1 hour	360
Ethylbenzene (VOC)	1 hour	8,000
Xylenes (VOC)	1 hour	190
Polycyclic aromatic hydrocarbons (PAH) (as benzo[α]pyrene)	1 hour	0.4

Table 7-91 Advisory reporting standards for $PM_{2.5}$ (Air NEPM)

Pollutant	Averaging period	Standard (µg/m^3)
$PM_{2.5}$	24 hour	25
	Annual	8

Operational assessment methodology

Modelling of operational air quality dispersion for the project is a complex process which has involved the following inputs:

- Traffic volume scenarios, within the tunnels and for surface roads. Traffic volume changes throughout the day have also been considered.
- Design of the tunnel ventilation system including velocity of air flow and temperature of the air at the point of emission.
- Design of the ventilation facilities and outlets including building characteristics.
- Meteorological data for the surrounding area.
- Existing terrain and land use.

The following provides a summary of the operational air quality assessment methodology.

Traffic data

Assessment of air quality within the main alignment tunnels and potential impacts on the surrounding environment during operation of the ventilation outlets has been based on forecast traffic volumes using the project in 2019 and in 2029. These traffic volumes have been developed from the Strategic Sydney traffic model (refer to **Section 7.1.1**). Forecast traffic flows on surface roads have been determined based on a combination of inputs from the Strategic Sydney traffic model and further traffic modelling, as detailed in **Section 7.1** (Traffic and transport).

The forecast in-tunnel traffic volumes that have been used for a basis for assessment of the air quality impacts of the project are shown in **Figure 7-16** for 2019 and **Figure 7-17** for 2029. Forecast traffic data is presented in terms of hourly traffic volumes across a day in 2019 and in 2029 for the southbound and northbound main alignment tunnels for both heavy vehicles and light vehicles.

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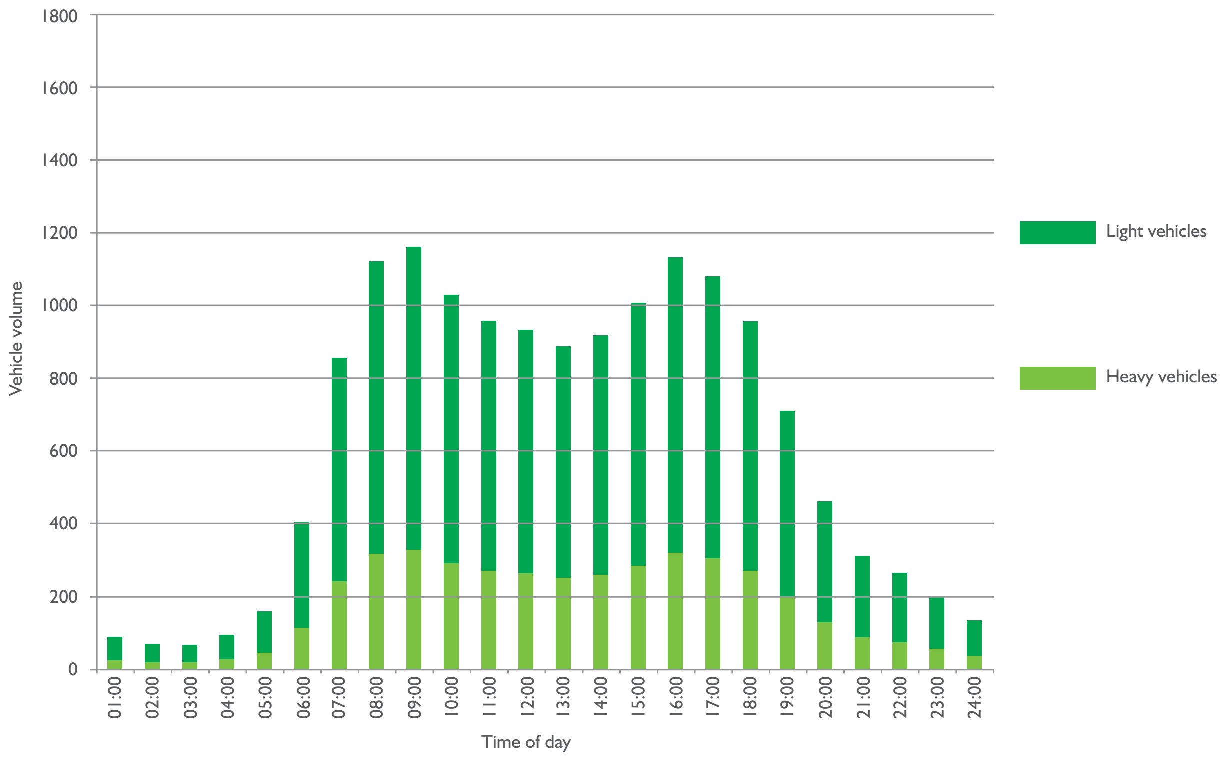
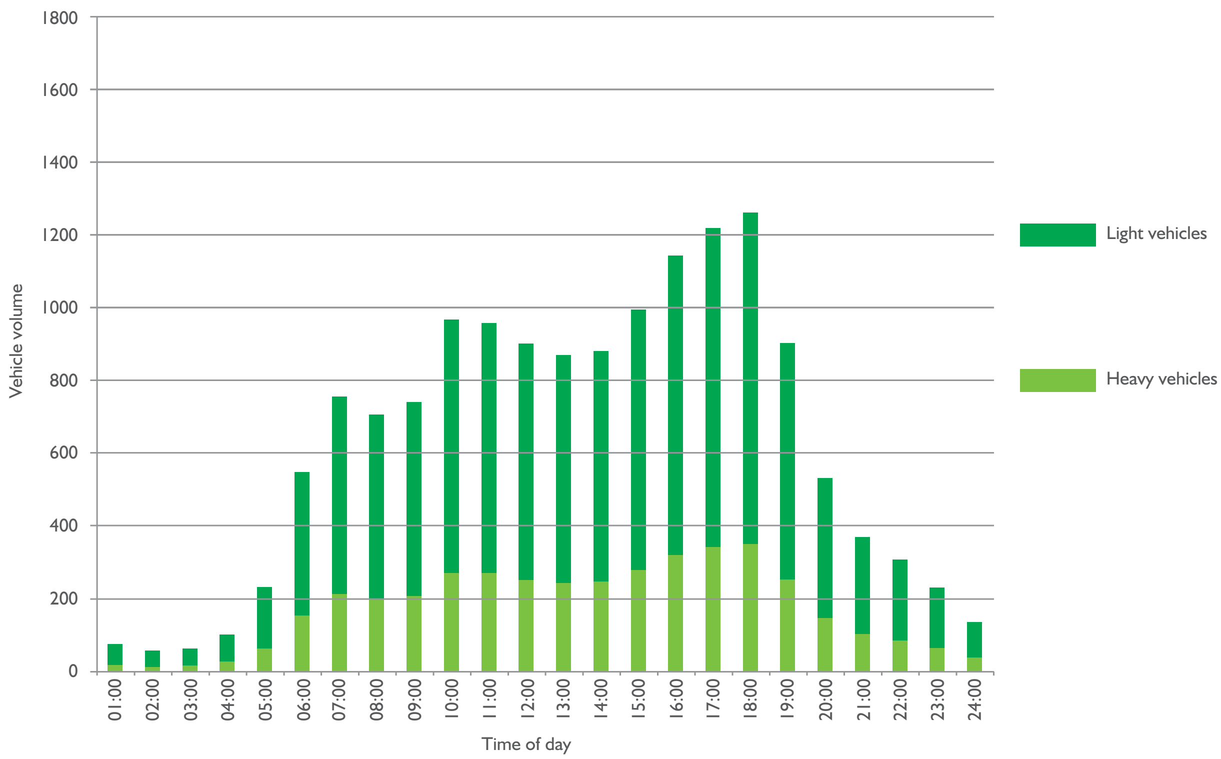


SOUTHBOUND - 2019



NORTHBOUND - 2019

Figure 7-16 2019 hourly traffic flows

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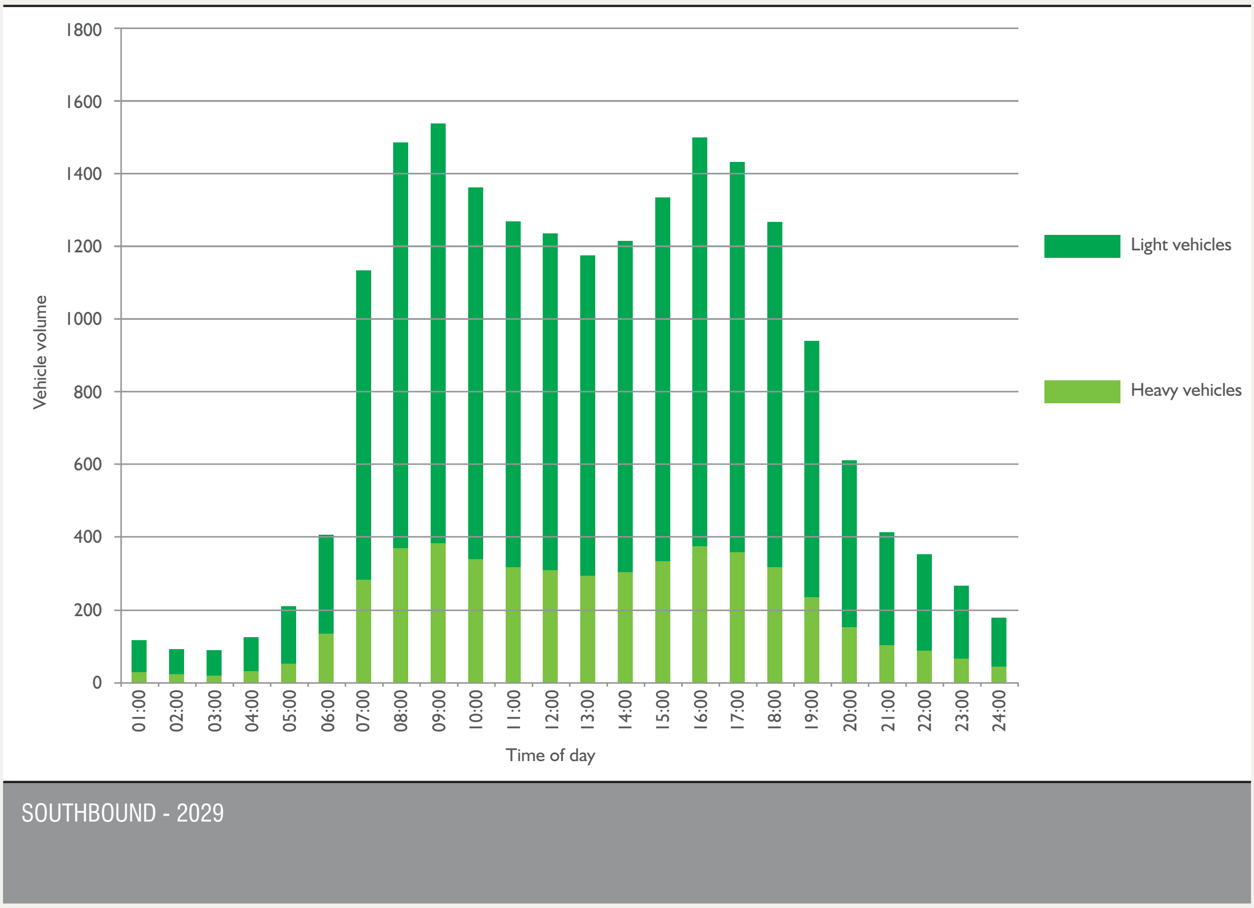

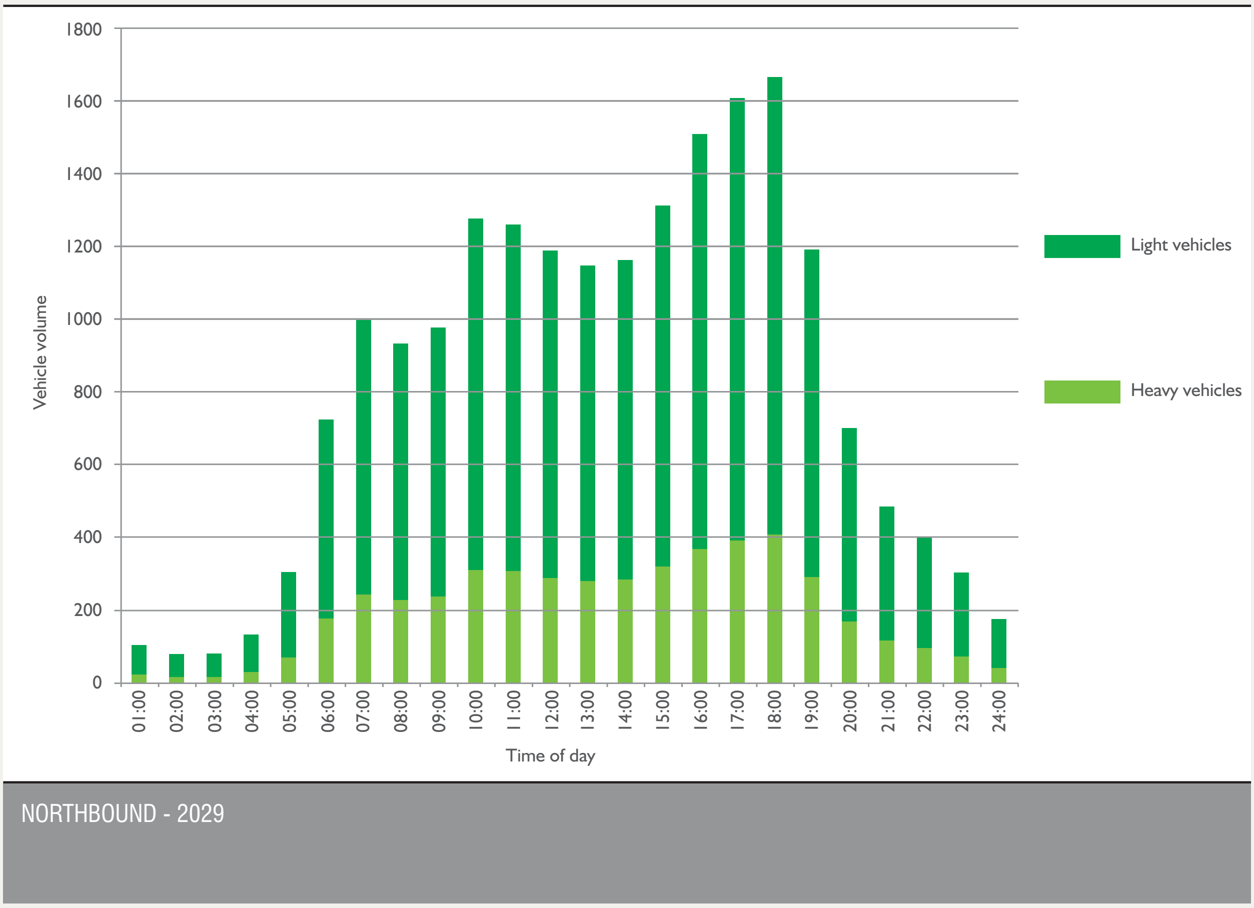

Figure 7-17 2029 hourly traffic flows

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Dispersion models

Air dispersion modelling has been undertaken in accordance with relevant guidance documents (DEC, 2005a; Barclay & Scire, 2011).

The CALPUFF suite of models has been used to estimate pollutant concentrations associated with the ventilation outlet emissions. The CALPUFF suite, including meteorological (CALMET), dispersion (CALPUFF) and post processing modules (CALPOST), is an advanced non-steady state modelling system designed for meteorological and air quality dispersion modelling. CALPUFF is approved for use in NSW by the Environment Protection Authority and internationally by bodies such as the United States Environmental Protection Agency, particularly in applications involving:

- Complex terrain.
- Non-steady-state conditions.
- Areas where coastal effects may occur.
- High frequencies of stable or calm meteorological conditions.

CALPUFF was selected for use in this assessment as the topography of the area surrounding the project is complex and the project is close enough to the coast to be potentially affected by coastal breezes.

CALMET has been used to predict meteorological conditions in the study area. Meteorological data from five meteorological stations located in the Sydney basin (Lindfield, Terrey Hills, Richmond, Prospect and Sydney Airport), as well as data on terrain and land-use have been input into the model to predict the hour-by-hour weather conditions at more than 60,000 locations across northern Sydney over the three year period.

CAL3QHCR is a specialised model for the assessment of road emissions and has been used to model pollutant concentrations associated with emissions from vehicles on surface roads around the project. CAL3QHCR predicts concentrations of carbon monoxide, nitrogen dioxide, particulate matter (PM), and other inert gases from idling or moving motor vehicles. CAL3QHCR has been applied as the most appropriate to model the air quality effects of traffic movements on roads external to the project tunnels due to its ability to process hourly varying data and large numbers of receivers.

The outputs from CALPUFF and CAL3QHCR have been summed, with the adopted background pollutant concentrations where applicable, to provide a cumulative assessment of pollutant concentrations in the vicinity of the project during several operating scenarios.

Further detail on these models is provided in the technical working paper: air quality (**Appendix G**).

Assessment scenarios

The three principal operational air quality scenarios summarised in **Table 7-92** have been developed to assess the operational air quality impacts of the project. These scenarios have been developed to allow:

- Comparison of air quality with and without the project.
- Assessment of air quality around the expected opening of the project (2019), and after ten years of operation (2029), based on forecast traffic volumes for those years.
- Assessment of air quality during a breakdown event in one of the project's main alignment tunnels.

These scenarios demonstrate the most likely performance of the project under relevant operating conditions.

Table 7-92 Operational modelling scenarios

Description	Assessment year	Model	Scenario rationale
Without the project	2019	CAL3QHCR	This scenario has been modelled and assessed to provide a basis for comparison with air quality predictions under scenarios that include operation of the project.
	2029		
With the project – forecast traffic flows	2019	CALPUFF and CAL3QHCR	This scenario has been modelled and assessed as representative of the likely operational performance of the project with expected traffic volumes.
	2029		
Breakdown scenario	N/A	N/A	This scenario has been assessed to provide context to potential air quality impacts in the infrequent event of a breakdown in the project tunnels.

In addition to the operational scenarios summarised in **Table 7-92**, two design analyses have been conducted to test the performance of the project's ventilation system and to assist regulatory agencies in considering air quality performance criteria that may be applied to the project. Both of these analyses represent conditions that are unlikely to occur in practice, but provide confidence that the project has the ability to comply with applicable air quality criteria under all conditions. The design analyses also provide a useful basis to inform further development of the project's ventilation system during detailed design. The design analyses considered for the project are:

- **Design analysis A** – this design analysis has been conducted to ensure that the project's ventilation system is adequately sized to cater for tunnels full of traffic. It assumes that during peak hours, the maximum number of vehicles that can fit into the tunnel (4,000 passenger car units per two lane main alignment tunnel adjusted for speed). This design analysis represents the physical limit of the main alignment tunnels and is based on forecast traffic volumes that are unlikely to eventuate due to a range of factors including traffic management measures, projected land use, employment, demographics and constraints on the surrounding surface road network.

- **Design analysis B** – this design analysis has been conducted to ensure that regardless of when the peak traffic period occurs or for how long it lasts, the project's ventilation system would be able to meet applicable air quality criteria. This design analysis assumes that the project's ventilation outlets emit the maximum concentration of pollutants on a continuous basis. In reality, emissions concentrations would vary during the day depending on the number and type of vehicles using the tunnels at the time.

Meteorological data

The meteorological data used in the dispersion modelling drives the predictions of the transport and dispersion of the air pollutants in the atmosphere. The most critical parameters are:

- Wind direction, which determines the initial direction of transport of pollutants from their sources.
- Wind speed, which dilutes the plume (column of air emitted from the outlet) in the direction of transport and determines the travel time from source to receiver.
- Atmospheric turbulence, which indicates the dispersive ability of the atmosphere.

Three years of meteorological data has been used in the dispersion modelling to account for the effects of yearly variations in data. Meteorological data has been sourced from five meteorological stations located in the Sydney basin (Lindfield, Terrey Hills, Richmond RAAF Base, Prospect and Sydney Airport), operated by the Bureau of Meteorology and the Office of Environment and Heritage. The locations of the meteorological stations are shown in **Figure 7-18**.

Measured meteorological data has been used in conjunction with a regional weather system (mesoscale) model to simulate the three-dimensional complex meteorological patterns that exist within the vicinity of the project, accounting for the effects of local topography and changes in land surface characteristics. Data from the weather system model have been input into CALMET to generate three-dimensional wind fields for use in CALPUFF.

Further detail regarding the meteorological data, and a full list of all model input parameters for CALMET and CALPUFF are provided in the technical working paper: air quality (**Appendix G**).

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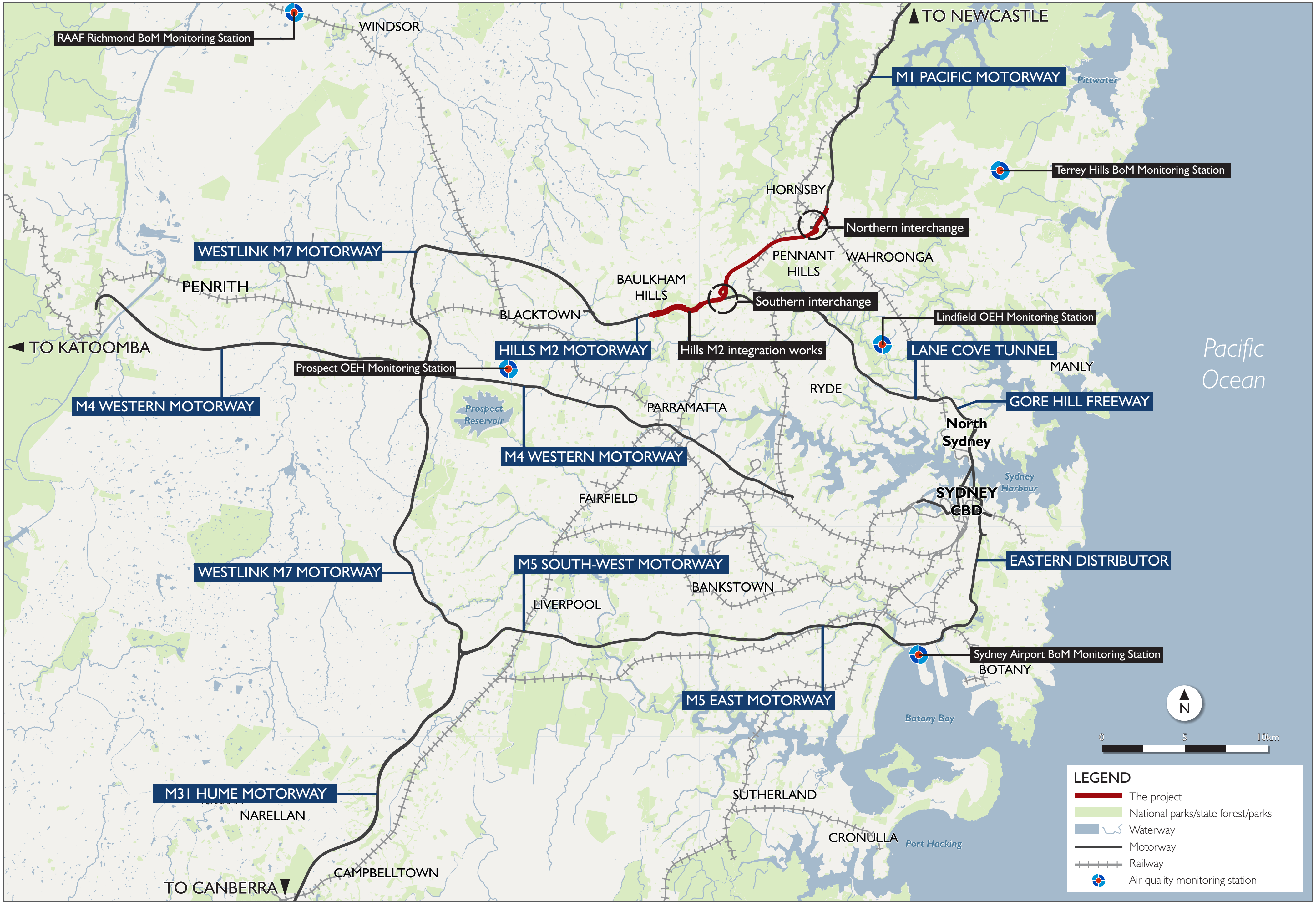

Figure 7-18 Regional air quality monitoring stations

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Project monitoring

Five air quality monitoring stations have been installed along the project corridor and commissioned in late 2013. Monitoring at these stations is ongoing and includes the following meteorological and air quality parameters:

- Temperature.
- Relative humidity.
- Wind speed and direction.
- Ozone.
- Carbon monoxide.
- Nitrogen oxides and nitrogen dioxide.
- Particulate matter (PM_{10} and $PM_{2.5}$).
- Methane.

The air quality monitoring stations have one of two functions:

- Road stations have been located along Pennant Hills Road to enable characterisation of air quality along this road.
- Ambient stations have been used to supplement background air quality data collected at existing Prospect and Lindfield regional air quality stations to characterise air quality at suburban receivers removed from major roads. The locations of these stations were determined with consideration of a number of criteria, including distance from major roads.

The locations of the monitoring stations were selected to gather background air quality information to characterise the subregional airshed and to appreciate the levels of pollutants experienced by suburban receivers. The locations of the monitoring stations were therefore not linked to the location of ventilation facilities or portals.

A statistical review of project monitoring data collected up to May 2014 is provided in the technical working paper: air quality (**Appendix G**). This statistical review was undertaken to determine which data to use within the modelling to appropriately represent background air quality. The pollutant concentrations measured at the Lindfield and Prospect stations are typically higher that those recorded at the project ambient monitoring stations. The assessment approach in the Approved Methods for the Modelling and Assessment of Air Pollutants in NSW (EPA, 2005) requires an assessment of the maximum predicted total pollutant concentrations (ie, the incremental contribution from the project added to the background pollutant concentrations). As such, in order to undertake a conservative assessment, the maximum data recorded for each hour of the relevant monitoring period at Lindfield and Prospect have been adopted as background pollutant concentrations for ambient receivers (away from major roads).

The locations of these air quality monitoring stations are shown on **Figure 7-19**, and details of each station provided in **Table 7-93**.

Table 7-93 Air quality monitoring station details (project monitoring)

Site name	Height above sea (m)	Commencement date	Station designation
Headen Sports Park, Thornleigh	176	20 November 2013	Ambient
James Park, Hornsby	177	3 December 2013	Ambient
Observatory Park, Pennant Hills	193	5 December 2013	Road
Brickpit Park, Thornleigh	235	13 December 2013	Road
Rainbow Farm Reserve, Carlingford	112	16 January 2014	Ambient

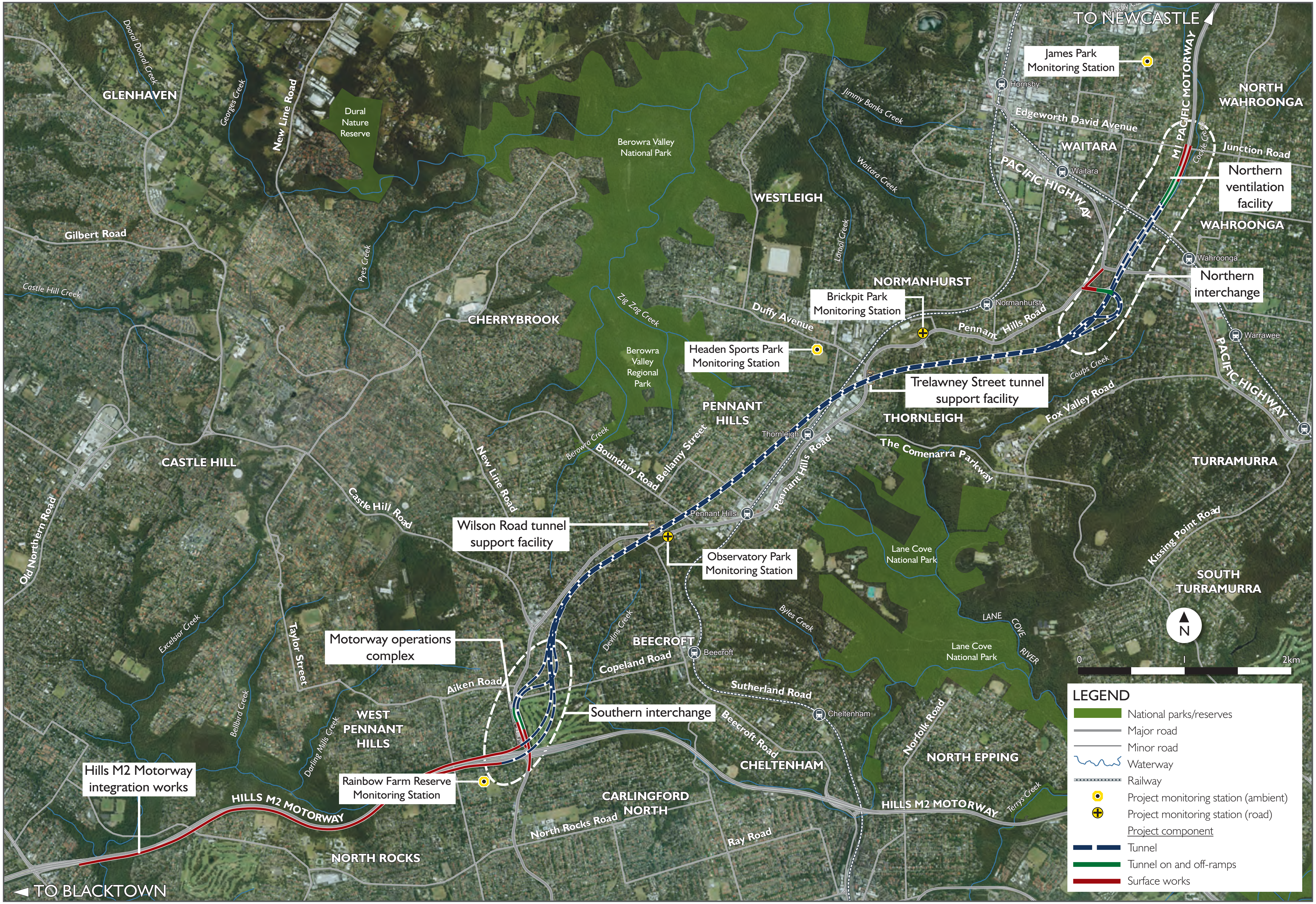

Figure 7-19 Local air quality monitoring stations

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Receivers

In order to account for the project's location in a built-up area, a large number of receivers have been entered into the dispersion model to cover the region around 15 square kilometres from the proposed tunnels. For the purpose of this assessment, each discrete receiver (or grid point) within the modelling domain has been treated as a sensitive receiver. A higher density of discrete receivers has been entered into the model in the vicinity of each ventilation outlet with the resolution of receivers decreasing with increasing distance from each ventilation outlet. Additional receivers have also been included along the roadways close to the proposed tunnel portals.

Terrain and land use

For air quality modelling purposes where a grid system such as CALMET is used, plume transport is an important function of the underlying dominant land use. Land use data within the project area have been derived from the Australian Bureau of Agricultural and Resource Economics and Sciences (ABARES) and supplied by the Office of Environment and Heritage.

This data set has been compiled using the nationally agreed land use mapping principles and procedures of the Australian Land Use and Management (ALUM) Classification version 7. Specific land use characteristics for the Sydney basin have been applied within the data set for bushland, agricultural land, dense urban, new urban and established urban areas, as determined from Gero and Pitman (2006).

Emissions calculation

Pollutant emissions have been calculated using internationally-recognised vehicle emission factors prepared by PIARC (2012), which provide Australian-specific emissions data based on respective fleet compositions. Australian fleet composition data has been obtained from the motor vehicle census carried out by the Australian Bureau of Statistics (ABS, 2013). The emissions factors from PIARC (2012) state that the factors were developed for the purpose of defining the minimum air flows required to achieve adequate air quality within road tunnels rather than for the purpose of developing emissions inventories, so a safety margin is added to the emission factors. This is expected to result in conservative emissions estimates when used for inventory purposes, such as this assessment.

PIARC (2012) provides emissions data for the year 2010 for fine particulate matter (PM_{10}), carbon monoxide and oxides of nitrogen for passenger car, light duty vehicle (< 3.5 tonnes) and heavy duty vehicle (> 3.5 tonnes) classifications. Factors are applied to account for varying vehicle speeds and road gradients. Non-exhaust related particulate emissions ($PM_{2.5}$) based on brake wear and the re-suspension of particulates from road surfaces are also provided in the emissions data.

Adjustment factors provided within PIARC (2012) have been used to forecast emissions for the anticipated opening year of 2019 and ten years after opening in 2029. These adjustment factors are based on the expected continuous improvement in engine technologies, the phase-out of older, less efficient cars, and the gradual tightening of emissions legislation already occurring and expected to continue between 2010 and 2020. The adjustment factors are provided for each year up to the year 2020. As such, 2020 emission data have been used to predict 2029 emissions in this assessment. This is a conservative approach due to the expected continual improvements in vehicle emissions over time and the phase-out of older vehicles, which, subsequently, may result in an overestimation of 2029 emissions and resultant ground level pollutant concentrations.

Additional relevant road vehicle emissions not contained within PIARC (2012) (that is, exhaust-related $PM_{2.5}$ and total volatile organic compounds) have been sourced from the National Pollutant Inventory (DEWHA, 2008).

Forecast vehicle numbers for surface roads used for the purpose of dispersion modelling have been based on outputs from the strategic traffic model and traffic surveys conducted in 2013. These forecast vehicle numbers are provided in **Section 7.1** (Traffic and transport) and the technical working paper: traffic and transport (**Appendix E**).

Vehicle densities within the project tunnels, including heavy vehicle percentages, have been calculated using forecast hourly vehicle and speed data for 2019 and 2029. These densities have been used to estimate total hourly emissions from the tunnel ventilation outlets servicing each tunnel. Road gradients have been accounted for through the use of PIARC (2012) emissions data for both assessment years.

The emissions inventory developed for the project in 2019 and in 2029 has been provided to Pacific Environment Limited for peer review. This review has included:

- Re-calculation of the emissions inventory using the PIARC emission factors to confirm that the PIARC calculations have been appropriately conducted.
- Calculation of the same emissions inventory using the NSW Environment Protection Authority's published emission factors. This calculation has been conducted to assess the conservatism of the PIARC emission factors and its reasonableness for use in this air quality assessment.

Table 7-94 summarises the outcomes of the emissions inventory calculations based on the NSW Environment Protection Authority's emission factors compared with the emissions inventory used for air dispersion modelling for the project. Data are presented in **Table 7-94** for key pollutants at their expected maximum concentrations in the main alignment tunnels. More detailed information about the variability of pollutant concentrations depending on time of day and location within the main alignment tunnels is provided in technical working paper: air quality (refer to **Appendix G**).

Table 7-94 Comparison of emissions inventories

Pollutant	Maximum in-tunnel concentration (mg/m^3)	
	EPA emission factors[1]	PIARC emission factors
Southbound main alignment tunnel at 9 am (2019)		
Carbon monoxide	6.353	3.450
Nitrogen dioxide	0.505	0.374
PM_{10}	0.292	0.377
$PM_{2.5}$	0.214	0.342
Southbound main alignment tunnel at 9 am (2029)		
Carbon monoxide	7.460	4.290
Nitrogen dioxide	0.388	0.411
PM_{10}	0.297	0.439
$PM_{2.5}$	0.195	0.414
Northbound main alignment tunnel at 6 pm (2019)		
Carbon monoxide	14.371	6.260
Nitrogen dioxide	0.877	0.860
PM_{10}	0.355	0.504
$PM_{2.5}$	0.272	0.477
Northbound main alignment tunnel at 6 pm (2029)		
Carbon monoxide	14.999	7.760
Nitrogen dioxide	0.588	0.932
PM_{10}	0.297	0.585
$PM_{2.5}$	0.202	0.553

[1] Note that the EPA emission factors accommodate improvements in fuel standards and vehicle efficiency after 2020, and concentrations of pollutants are therefore lower in 2029 than in 2019. PIARC emission factors do not provide for improvements after 2020 and concentrations of pollutants are therefore conservatively assumed to be higher in 2029 than in 2019.

The review conducted by Pacific Environment Limited has indicated that:

- The PIARC emission factors appear to have been appropriately applied. However, forecast concentrations of particulate matter (PM_{10} and $PM_{2.5}$) appear to be high and this may be a consequence of assumptions around the ratio of PM_{10} / $PM_{2.5}$ in vehicle exhaust.
- The NSW Environment Protection Authority emission factors generate higher concentrations of carbon monoxide (about twice the concentration of the PIARC emission factors).
- The NSW Environment Protection Authority emission factors generate slightly higher concentrations of nitrogen dioxide in 2019, and slightly lower concentrations in 2029 than the PIARC emission factors. Nitrogen dioxide concentrations calculated with the two different methodologies are around the same magnitude.

- The NSW Environment Protection Authority emission factors generate particulate matter concentrations that are around half of the concentrations calculated with the PIARC emissions factors in the case of PM_{10} and less than half in the case of $PM_{2.5}$.

The outcomes of the Pacific Environment Limited review support the view that the emissions inventory is conservative, particularly in the case of calculated concentrations of PM_{10} and $PM_{2.5}$. It has been identified that the PIARC emission factors produce lower carbon monoxide concentrations than the NSW Environment Protection Authority emission factors. This difference is not considered to be material to the air quality impact assessment because of the very low modelled concentrations of this pollutant at surrounding receivers (less than one per cent of the ambient air quality criteria for carbon monoxide in all cases).

Tunnel ventilation outlet parameters

The temperature of tunnel ventilation outlet emissions would influence the ultimate dispersion of pollutants. Emissions with higher temperatures have higher buoyancy, which generally means that the plume is carried higher before dispersion begins, resulting in greater dispersion.

The temperature of tunnel ventilation outlet emissions would be affected by the number of vehicles moving through the tunnel, as the vehicle exhaust emissions would carry some of their heat through to the outlet emissions. In order to estimate the likely temperature of the tunnel ventilation outlet emissions for the project, outlet temperature data from the Lane Cove tunnel have been analysed. Hourly seasonal average temperature differences (ie the difference between the temperature of the ventilation outlet emissions and the ambient temperature) from the Lane Cove tunnel data have been applied to the temperature data predicted for the project tunnel environments to calculate the estimated temperature of tunnel ventilation outlet emissions.

The main alignment tunnels would be serviced by ventilation systems that would vary in operating parameters depending on traffic flows. As such, the volume of air which would be extracted from the tunnels would vary each hour, resulting in hourly-varying outlet emission velocities and flow rates. The tunnel ventilation outlets would be partitioned into two segments (or an equivalent design outcome) so that portions of the outlet can be closed off during low traffic flows in order to increase velocities and maintain necessary plume dispersion.

Background pollutant concentrations

Background pollutant concentrations for PM_{10} and oxides of nitrogen along roadways have been confirmed through comparison of the road modelling results and the results of project monitoring data from the two road stations (refer to **Table 7-93**). The comparison has shown that pollutant concentrations recorded by the road stations are typically lower than the concentrations predicted by the modelling. Therefore it has been concluded that the modelling data would provide a conservative representation of background pollutant concentrations, as this data would overestimate actual pollutant concentrations at those sensitive receivers. As such, road modelling data have been adopted as background pollutant concentrations for road receivers (adjacent to major roads).

Measured pollutant concentrations at the three project ambient monitoring stations have been compared to the relevant periods of monitoring data obtained from the Lindfield and Prospect monitoring stations. These locations have been chosen as they are the closest stations to the project site which provide the necessary air quality and meteorological data. This comparison has shown that pollutant concentrations measured at the Lindfield and Prospect stations are typically higher that those recorded at the project ambient monitoring stations. As such, the maximum data recorded for each hour of the relevant monitoring period at Lindfield and Prospect have been conservatively adopted as background pollutant concentrations for ambient receivers (away from major roads).

To derive background pollutant concentrations for carbon monoxide, predicted concentrations from the ‘without project’ modelling scenario have been compared to concentrations measured at the Prospect monitoring station. The maximum measured concentrations of carbon monoxide at Prospect are substantially higher than those predicted from the road modelling. As such, maximum measured concentrations at Prospect have been conservatively adopted for use as background carbon monoxide concentrations for the purpose of this assessment.

Cumulative pollutant concentrations

The assessment has investigated pollutant concentrations associated with emissions from the tunnel ventilation outlets (using CALPUFF) and from vehicles using the surface road network close to the tunnel portals (CAL3QHCR). Predicted pollutant concentrations for each receiver, from each of the two models, have been summed to provide a total project contribution for each pollutant.

For the criteria pollutants (PM_{10}, carbon monoxide and nitrogen dioxide) and $PM_{2.5}$, predicted concentrations have been added to the relevant background pollutant concentrations to determine cumulative pollutant concentrations. These cumulative concentrations have been compared to the relevant assessment criteria (refer to **Table 7-90**).

For polycyclic aromatic hydrocarbons and volatile organic compounds, cumulative assessment using background data is not required by the Approved Methods (DEC, 2005a). Furthermore, background data are not available to conduct a cumulative assessment of these pollutants. As such, cumulative concentrations for polycyclic aromatic hydrocarbons and volatile organic compounds have been derived by summing the contributions from the ventilation outlets and road sources at sensitive receiver locations.

In-tunnel air quality assessment methodology

The project ventilation system has been designed to achieve acceptable in-tunnel air quality outcomes for carbon monoxide, nitrogen dioxide and visibility (as a measure of in-tunnel particulate matter concentrations). Criteria for the engineering design of the ventilation system have been based on:

- For carbon monoxide, a maximum concentration of 87 parts per million (ppm) (as a 15-minute average) based on the World Health Organisation Guidelines for Indoor Air Quality (2010) which recommend a maximum short-term exposure (15-minute exposure) of 100 mg/m^3 (equivalent to 87 parts per million at 25oC).
- For nitrogen dioxide, a maximum concentration of 1.0 parts per million (as a 15-minute exposure) based on the recommendations of PIARC (2012).

- An extinction coefficient (measure of visibility, or 'in-tunnel' haze) of 0.005 m^{-1} based on the recommendations of PIARC (2012) for free flowing peak traffic traveling at speeds of 50 to 100 kilometres per hour. Based on the correlation factor recommended by PIARC, this extinction coefficient is equivalent to an in-tunnel particulate matter concentration of 1.06 mg/m^3.

To reflect a modern, well designed road tunnel, more stringent ventilation design criteria have been set for carbon monoxide and nitrogen dioxide at higher traffic speeds to deliver a better air quality outcome. These more stringent criteria have been based on in-tunnel air quality outcomes that are feasible and reasonable to achieve with a well designed ventilation system, as summarised in **Table 7-95**. The criteria have been used as a basis for the design of the ventilation system, and it is expected that actual performance during normal operation of the project would be below these levels.

Table 7-95 Ventilation system design criteria for CO and NO_2

Average traffic speed (km/h)	CO design criteria (15-minute exposure) (ppm / mg/m^3)	NO_2 design criteria (15-minute exposure) (ppm / mg/m^3)
80	50 ppm (57.5 mg/m^3)	0.5 ppm (0.94 mg/m^3)
60	50 ppm (57.5 mg/m^3)	0.5 ppm (0.94 mg/m^3)
40	60 ppm (69 mg/m^3)	0.8 ppm (1.51 mg/m^3)
0 to 20	87 ppm (100 mg/m^3)	1.0 ppm (1.88 mg/m^3)

During the engineering design of the project, modelling of in-tunnel concentrations of vehicle emissions was conducted. This modelling was used to determine the capacity and initial operating parameters for the project's ventilation system to ensure that the design criteria for in-tunnel air quality could be met.

Vehicle emissions expected to be emitted from the project's ventilation outlets have been estimated based on the approach recommended by PIARC (2012). This has included estimation of pollutant emission rates at various locations along each of the main alignment tunnels. As well as being an important input into the air dispersion modelling, these calculations have been used to assess and forecast expected in-tunnel air quality against the ventilation design criteria outlined above.

An important design goal of the project has been to ensure that the lessons learnt from the M5 East Motorway tunnel are taken into account, and that the historical ventilation issues with that tunnel are not repeated during design or operation of the NorthConnex project. In particular, the in-tunnel 'haze' issues experienced during historical operation of the M5 East Motorway tunnel have been identified as a key outcome to avoid.

Current in-tunnel air quality within the M5 East Motorway tunnel has significantly improved from recorded historical performance. A principal driver for this improvement has been the attention given to smoky vehicles, and particularly the installation of smoky vehicle cameras. The tunnels currently experience reduced incidence of poor in-tunnel air quality, and less frequently experience 'hazy' in-tunnel conditions than has historically been the case. Further details of the improvement in the M5 East Motorway tunnels are provided in **Section 7.3.4**.

To confirm that the lessons learnt from the M5 East Motorway tunnel have been applied to the design of NorthConnex, in-tunnel visibility (measured as an ‘extinction coefficient’) has been calculated at various locations along the main alignment tunnels and compared to visibility data recorded within the M5 East Motorway tunnels since April 2013. Therefore, the comparison is provided against the current M5 East Motorway tunnel air quality after the implementation of the smoky vehicle strategy and the improvements in in-tunnel air quality. This comparison has been conducted relative to PIARC definitions of extinction coefficients (visibility) as follows:

- 0.003 m^{-1} means a clear air tunnel (visibility of several hundred metres).
- 0.007 m^{-1} approximates a haziness of in-tunnel air.
- 0.009 m^{-1} approximates a foggy atmosphere.
- 0.012 m^{-1} is the threshold value that should not be exceeded during operation and which results in a very uncomfortable in-tunnel atmosphere. However, there is normally enough visibility to stop safely at an obstacle.

PIARC (2012) identifies that an extinction coefficient of 0.007 m^{-1} is widely used as a tunnel design criteria, although some countries impose a design criteria of 0.005 m^{-1}. NorthConnex has adopted a design criterion of 0.005 m^{-1} which may result in in-tunnel visibility of vehicle emissions under heavily congested traffic conditions, but not to the extent of a hazy in-tunnel atmosphere (0.007 m^{-1}). This design criterion has been used for the purpose of designing the project’s ventilation system, although under free flowing traffic conditions, in-tunnel air quality is predicted to achieve extinction coefficients of 0.003 m^{-1} or less.

Advisory Committee on Tunnel Air Quality

The NSW Government has established an Advisory Committee on Tunnel Air Quality chaired by the NSW Chief Scientist Professor Mary O’Kane to review national and international practice and experience with motorway tunnels to safeguard the health and safety of the community and motorists. The Advisory Committee on Tunnel Air Quality has been briefed (in February 2014) on the project and the air quality impact assessment approach by Roads and Maritime.

7.3.3 Existing environment

Background air quality

The most recent NSW State of the Environment Report (EPA, 2012) states that transport emissions are the most important human-related source of air pollution in Sydney. In 2008, motor vehicles were the largest source of emissions of oxides of nitrogen (63 per cent of total emissions) and the second largest source of volatile organic compounds emissions (24 per cent of total emissions) in the Sydney region.

NSW is considered to have generally good air quality in relation to international standards. Concentrations of carbon monoxide, nitrogen dioxide and volatile organic compounds are consistently lower than national standards in most areas and emissions of these pollutants in the Sydney region have decreased by 20 to 40 per cent since the early 1990s (EPA, 2012). These reductions are considered to primarily be a result of initiatives to reduce air pollution associated with industry, businesses, motor vehicles and residential premises, which have been implemented since the 1980s. Concentrations of measured pollutants appear to have been stable over the past few years (EPA, 2012). Exceedences of PM_{10} criteria do, however, occur in Sydney, primarily as a result of occasional bushfires and dust storms.

Regional air quality in Sydney is monitored through a network of existing monitoring stations. The closest stations to the project are at Lindfield and Prospect. Relevant monitoring data recorded by these stations between 2009 and 2011 are provided in the technical working paper: air quality (**Appendix G**).

Exceedences of the 24 hour average ambient air quality criterion for PM_{10} occurred at Lindfield and Prospect in 2009. No exceedances were recorded in 2010 or 2011. The PM_{10} data for 2009 were affected by severe dust storms and, as such, the maxima are not indicative of typical ambient PM_{10} concentrations in Sydney. Recorded carbon monoxide concentrations at Lindfield did not exceed the criterion.

Carbon monoxide is not monitored at Prospect. No exceedences of the one hour nitrogen dioxide criterion were recorded at either Prospect or Lindfield.

The EPA undertook ambient monitoring of a number of air toxics between 1996 and 2001 at 25 sites (DEC, 2004). Samples were collected for 81 pollutants, including volatile organic compounds. Of the measured pollutants, only three required further investigation to ensure they remained at acceptable levels in the future: benzene, 1,3-butadiene and benzo[α]pyrene. Additional testing conducted between 2008 and 2009 measured concentrations of a number of pollutants including benzene, toluene and xylenes at Turella and Rozelle. Concentrations of all measured pollutants were recorded to be well below the monitoring investigation levels. As such, concentrations of air toxics in the Sydney region are not an issue of concern.

Terrain and land use

The topography and land use of the area is an important input into the air dispersion modelling as it can influence the way in which a plume travels.

The terrain along the project corridor rises from an elevation of around 144 metres (Australian Height Datum) at the southern interchange to an elevation of around 180 metres (Australian Height Datum) at the northern interchange. A number of elevated peaks occur along the project corridor, with terrain generally falling to the south-east and to the north-west away from the Pennant Hills Road ridge line.

Land use within proximity of the project primarily consists of urban areas, with pockets of open space and native vegetation. While the main alignment tunnels traverse a variety of land use zonings, surface works would only occur at a small number of discrete locations. Operational facilities such as tunnel support facilities and ventilation outlets would be located in areas surrounded by residential dwellings, interspersed with commercial, light industrial and recreational land uses.

Further descriptions of land use within the vicinity of each proposed tunnel ventilation outlet, are provided in **Section 8.1** (Land use and property)

Sensitive receivers

Sensitive receivers are defined by the Environment Protection Authority as anywhere someone works or resides or may work or reside, including residential areas, hospitals, hotels, shopping centres, play grounds, recreational centres, and the like. Due to its location in a built-up area, there are a large number of sensitive receivers located in the project area. Sensitive receivers that are located adjacent to the existing road network would be most affected by emissions from the vehicles using the road network. Receivers located at a greater distance from the main roads would potentially be affected by emissions from the ventilation facilities.

7.3.4 Assessment of potential impacts

Construction air quality

Construction activities have the potential to impact on the surrounding air quality from activities which may generate dust, and from exhaust emissions from construction plant and equipment. These activities are discussed below, with the construction compounds and locations where the activities would be carried out summarised in **Table 7-96**.

Dust generating activities

Dust generating activities during construction would include:

- Worksite establishment activities such as vegetation clearing and earthworks.
- Demolition of buildings, structures and road pavement.
- General earthworks.
- Exposure of surfaces which may be susceptible to wind erosion.
- Handling and stockpiling of spoil material.
- Vehicle movements on unsealed roads, resulting in wheel generated dust.
- Drilling and blasting.
- Tunnelling activities and tunnel ventilation during construction.

The potential for dust emissions from above-ground construction works would be managed through standard mitigation measures identified in **Section 7.3.5** such as water spraying of unsealed areas, wetting down of dusty activities and progressive stabilisation works.

Spoil at the four tunnelling support compounds would be primarily managed within enclosed acoustic sheds which would limit the potential for dust generation. Spoil trucks would enter the site on sealed access road, would be loaded within the acoustic sheds and would then leave the site on sealed roads. Additionally, spoil trucks would be covered when they leave the acoustic shed and when on public roads.

The underground tunnels would be ventilated during construction in order to provide safe working environment for the construction workforce. Tunnel ventilation would be provided at the four tunnel support sites, being:

- Southern interchange compound (C5).
- Wilson Road compound (C6).
- Trelawney Street compound (C7).
- Northern interchange compound (C9).

This ventilation equipment would have dust extraction and filtration systems installed to minimise dust impacts. Additionally, as the road headers would use water for dust suppression while cutting rock, dust generation (beyond the tunnel) from tunnelling activities is expected to be minimal.

Localised blasting works may be carried out underground depending of the geological conditions encountered. As blasting works would only be carried out underground, the potential for dust impacts from this activity is negligible.

Plant and equipment exhaust emissions

The main sources of emissions from heavy vehicles, mobile excavation machinery and stationary plant would be related to diesel combustion. Construction plant would generally be diesel powered and would emit gaseous and particulate matter into the air. Road headers would be driven by mains power supply and would therefore not generate exhaust emissions.

Plant and equipment used during construction would comply with the emissions concentration limits outlined in the *Protection of the Environment Operations (Clean Air) Regulation 2010*. With the implementation of mitigation measures listed in **Section 7.3.5**, vehicular and plant emissions arising from the civil construction works are unlikely to have a significant impact on surrounding air quality. The construction compounds would be connected to the mains power supply. As such, the use of diesel generators has not been considered.

Groundwater treatment

Groundwater treatment plants are proposed for the southern interchange compound (C5), Wilson Street compound (C6), Trelawney Street compound (C7) and the northern interchange compound (C8) to treat groundwater inflow into the tunnels. Emissions to air associated with groundwater treatment depend on the nature of the contamination of the groundwater being treated and the treatment process. Primary air emissions associated with groundwater treatment are odorous compounds, such as ammonia and volatile organic compounds, which are associated with aeration (primary treatment), aerobic digestion, sludge thickening, anaerobic digestion and sludge drying (NPI, 2011).

The nature of any odours would depend on the degree and type of any contamination present in the groundwater. Management measures would be developed, and incorporated into the Air Quality Management Plan, to address any odours should contamination be encountered and if odours arise. The plan would include identification of odours, identification of the extent to which the odours are detectable, and, if necessary, mitigation measures to reduce any odours affecting sensitive receivers. Such mitigation measures could include modifications to the operating process, or the installation of carbon filters to capture odorous compounds before they are emitted.

Table 7-96 Construction emission sources

Emissions source	Surface construction locations														
	Windsor Road compound (C1)	Darling Mills Creek compound (C2)	Barclay Road compound (C3)	Yale Close compound (C4)	Southern interchange compound (C5)	Wilson Road compound (C6)	Trelawney Street compound (C7)	Pioneer Avenue compound (C8)	Northern interchange compound (C9)	Bareena Avenue compound (C10)	Junction Road compound (C11)	Interchange construction	M1 Pacific Motorway tie-in	Hills M2 Motorway integration	Tunnelling
Site preparation (vegetation clearance and earthworks)	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
Drilling and blasting															✓
Earthworks		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
Material haulage	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
Exposed surfaces (wind erosion)	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
Exhaust (plant and equipment)	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
Construction ventilation					✓	✓	✓		✓						
Demolition					✓	✓	✓	✓		✓		✓	✓	✓	
Spoil handling and stockpiling	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓				
Tunnel spoil handling and stockpiling					✓	✓	✓		✓						
Vehicle movements (unsealed roads / wheel-generated dust)	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
Wastewater treatment					✓	✓	✓		✓						

Operational air quality (external receivers)

Operational air quality modelling results from the ventilation outlets for forecast traffic in 2019 and 2029 (the ‘with project – forecast traffic flows’ scenario) are presented in **Table 7-97**. The breakdown scenario is discussed in this section, and a summary of the outcomes of design analyses is also provided.

Comparison of air quality improvements for Pennant Hills Road as a result of changes to traffic flows along the corridor is provided in **Table 7-99** (2019) and **Table 7-100** (2029). The combined air quality changes from the effects of the ventilation outlets and the improvements along Pennant Hills Road are also presented.

As discussed in **Section 7.3.3**, background values refer to either surface road modelling concentrations (for road receivers) and / or maximum background concentrations measurements at the Lindfield and / or Prospect stations for the relevant time period (for ambient receivers).

With project – forecast traffic volumes

Table 7-97 summarises the outcomes of air quality modelling from the project ventilation outlets for operation of the project in 2019 and 2029 with forecast traffic volumes. The table includes the maximum concentration of each pollutant contributed by the project to the atmosphere, and cumulative air quality impacts with the addition of contributions from surface roads and background air quality.

Table 7-97 demonstrates that in both 2019 and 2029, the contribution of the project to concentrations of air pollutants and cumulative concentrations of air pollutants taking into account conservative background air quality data are well below applicable air quality assessment criteria. The only exception to this is cumulative $PM_{2.5}$ (annual average) concentrations, which have been modelled to exceed the 8 $\mu g/m^3$ advisory reporting standard. As shown in **Table 7-97**, the predicted exceedence of the $PM_{2.5}$ (annual average) advisory reporting standard is the result of elevated background concentrations. The project contributes less than two per cent of the advisory reporting standard under expected traffic conditions in 2019 and in 2029.

Table 7-97 identifies that the project contribution of nitrogen dioxide would be around 25 per cent to 30 per cent of the applicable air quality assessment criteria. A frequency analysis has been undertaken for this pollutant which identified that the project contributions would be negligible for around 70 per cent of the modelling outcomes. Further details are provided in the technical working paper: air quality (**Appendix G**).

Because background concentrations for PM_{10} (24-hour average) are already elevated across the Sydney airshed, the 24-hour average PM_{10} air quality outcomes for the project have been subject to a more detailed ‘contemporaneous analysis’. The contemporaneous analysis considers the actual modelled contribution of the project for a particular period with the actual background concentration for that same period, rather than combining the maximum in both cases. This approach allows a more refined assessment of air quality impacts, taking into account the likelihood of maximum project contributions and maximum background concentrations occurring at the same time. Contemporaneous analyses have also been carried out for $PM_{2.5}$, given that this pollutant is key to the air quality performance of the project (refer to **Figure 7-20** to **Figure 7-27**).

Table 7-97 Predicted air quality outcomes for project operation in 2019 and 2029 with forecast traffic volumes

Pollutant	Source	Averaging period	Predicted maximum concentrations (µg/m³) With project – forecast traffic in 2019 Northern ventilation outlet	Predicted maximum concentrations (µg/m³) With project – forecast traffic in 2019 Southern ventilation outlet	With project – forecast traffic in 2029 Northern ventilation outlet	With project – forecast traffic in 2029 Southern ventilation outlet	Impact assessment criteria (µg/m³)
PM_{10}	Peak project contribution	24 hour maximum	1.0	1.4	1.4	2.1	N/A*
		Annual average	0.09	0.11	0.11	0.13	N/A*
	Peak cumulative concentration (project plus background)	24 hour maximum	Cumulative concentrations assessed contemporaneously in **Figure 7-20** to **Figure 7-23**.				50
		Annual average	21.27	21.31	21.29	21.35	30
	Project contribution (% of criteria)	24 hour maximum	2.0%	2.8%	2.8%	4.2%	N/A*
		Annual average	0.30%	0.37%	0.37%	0.43%	N/A*
$PM_{2.5}$	Peak project contribution	24 hour maximum	0.9	1.3	1.3	2.0	N/A*
		Annual average	0.08	0.11	0.10	0.13	N/A*
	Peak cumulative concentration (project plus background)	24 hour maximum	Cumulative concentrations assessed contemporaneously in **Figure 7-24** to **Figure 7-27**.				25
		Annual average	8.70	10.28	8.71	10.29	8
	Project contribution (% of criteria)	24 hour maximum	3.6%	5.2%	5.2%	8.0%	N/A*
		Annual average	1.00%	1.38%	1.25%	1.63%	N/A*
NO_2	Peak project contribution	1 hour maximum	68.9	61.8	74.6	65.0	N/A*
		Annual average	1.4	1.2	1.7	1.4	N/A*
	Peak cumulative concentration (project plus background)	1 hour maximum	150.8	165.1	159.3	166.7	246
		Annual average	38.7	42.4	39.9	42.8	62

Pollutant	Source	Averaging period	Predicted maximum concentrations ($\mu g/m^3$) With project – forecast traffic in 2019 Northern ventilation outlet	With project – forecast traffic in 2019 Southern ventilation outlet	With project – forecast traffic in 2029 Northern ventilation outlet	With project – forecast traffic in 2029 Southern ventilation outlet	Impact assessment criteria ($\mu g/m^3$)
	Project contribution (% of criteria)	1 hour maximum	28%	25%	30%	26%	N/A*
		Annual average	2.3%	1.9%	2.7%	2.3%	N/A*
CO	Peak project contribution	1 hour maximum	86.6	70.1	107.4	90.3	N/A*
		8 hour maximum	32.4	33.1	54.2	57.9	N/A*
	Peak cumulative concentration (project plus background)	1 hour maximum	3,712	3,695	3,732	3,715	30,000
		8 hour maximum	2,634	2,635	2,656	2,660	10,000
	Project contribution (% of criteria)	1 hour maximum	0.29%	0.23%	0.36%	0.30%	N/A*
		8 hour maximum	0.32%	0.33%	0.54%	0.58%	N/A*
Total VOC	Peak project contribution	1 hour 99.9%	4.07	3.72	5.38	5.36	29**
	Project contribution (% of criteria)	1 hour 99.9%	14.0%	12.8%	18.6%	18.5%	N/A*
PAH	Peak project contribution	1 hour 99.9%	0.00074	0.00068	0.00089	0.00092	0.4***
	Project contribution (% of criteria)	1 hour 99.9%	0.02%	0.17%	0.22%	0.23%	N/A*

* Impact assessment criteria are goals for airsheds. As such, they are not applicable to the project contributions.

** as benzo[a]pyrene

*** as benzene

Figure 7-20 to **Figure 7-27** show results for PM_{10} and $PM_{2.5}$ for the northern and southern ventilation outlets over the 24-hour averaging period for the 'with project – forecast traffic flows' scenario for 2019 and 2029.

As identified in **Section 7.3.3**, there are days when the background pollutant levels are elevated due to the events such as bushfires and dust storms. On these days the maximum background concentrations of PM_{10} are around 220 µg/m^3 and the maximum concentrations of $PM_{2.5}$ are around 80 µg/m^3.

These results show:

- On the days (in both 2019 and 2029) when the project would be contributing the highest contributions of PM_{10} and $PM_{2.5}$, the cumulative concentrations of these pollutants are well below the relevant criteria.
- On the days (in both 2019 and 2029) when background concentrations of PM_{10} and $PM_{2.5}$ are recorded to be the highest, there would be exceedences of the relevant criteria as a result of non-project sources. On these days, project contributions of these pollutants are predicted to be very low.

Overall, the results indicate that the project is expected to contribute very little PM_{10} or $PM_{2.5}$ to the local airshed.

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