APPENDIX

G

AIR QUALITY ASSESSMENT

Tripoli Way Extension

Air Quality Assessment

19 August 2021

Project No.: 0429164

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Tripoli Way Extension

Air Quality Assessment

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1. INTRODUCTION

Shellharbour City Council (Council) is seeking approval upgrade and extend the existing Tripoli Way alignment to connect major arterial roads, Terry Street (Illawarra Highway) and Tongarra Road (Illawarra Highway), without passing through the Albion Park Town Centre.

ERM has been commissioned by Cardno to carry out an air quality impact assessment for the Tripoli Way Extension, to determine the potential impacts of vehicle emissions from the new alignment on any nearby sensitive receptors.

The proposed Tripoli Way extension encompasses the full length of these existing access roads and extends them east to link into the future Albion Park Rail Bypass and west into Tongarra Road (Illawarra Highway) at the roundabout intersection with Broughton Avenue. The extension would be through a majority of undeveloped rural properties and will have limited impact on existing residential lots (shown in Figure 1.1).

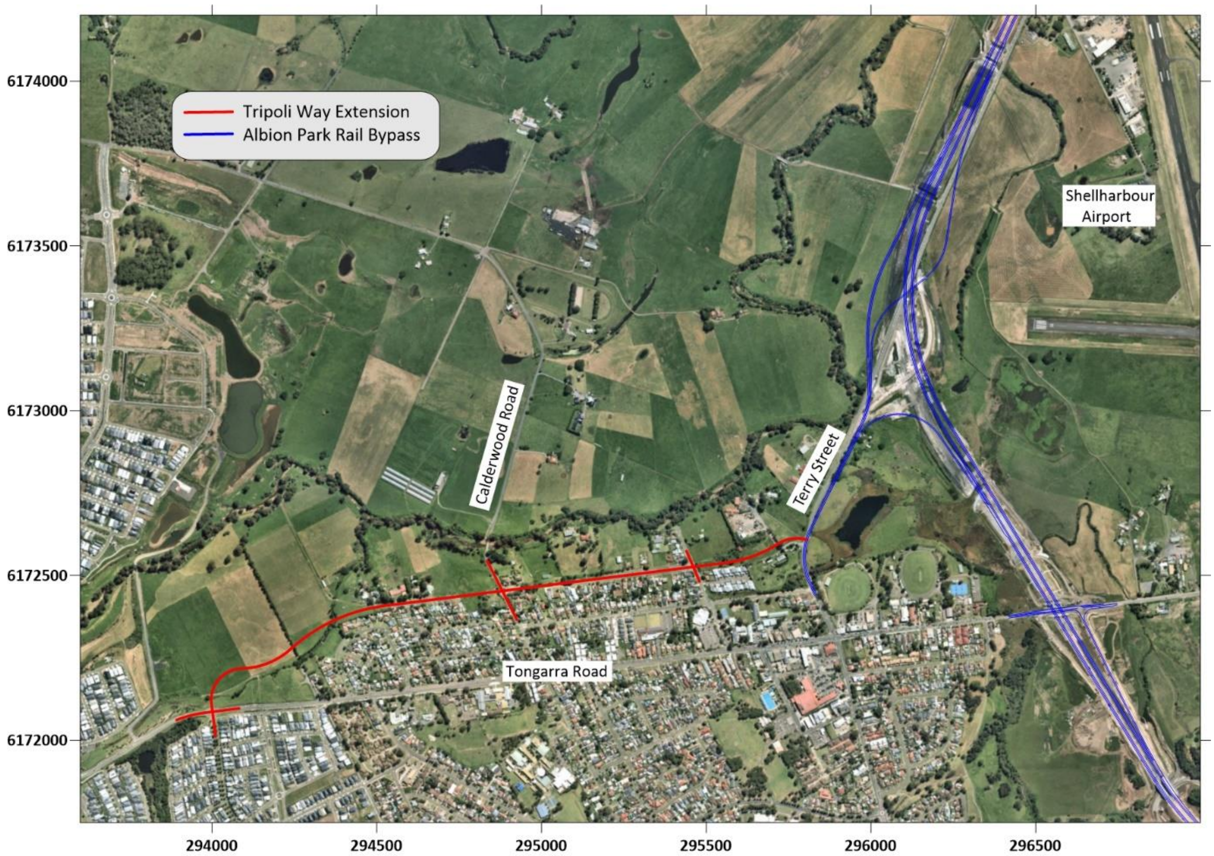

Figure 1.1: Proposed Tripoli Way Extension alignment

2. PROJECT DESCRIPTION

2.1 Project location

The project is located within the Shellharbour City Council Local Government Area (LGA) within the Illawarra region of New South Wales (NSW). The project will begin in the west at the roundabout intersection of Tongarra Road and Broughton Avenue, continuing along an extended Tripoli Way before connecting to the future Albion Park Rail Bypass in the east, without passing through the Albion Park Town Centre.

The existing access roads within the proposed alignment would be upgraded to allow catering of the projected traffic volumes. Significant road widening of the existing Tripoli Way would be done to allow four travel lanes (two in each direction) for the section of the proposed Tripoli Way east of Calderwood Road. The section of the proposed Tripoli Way west of Calderwood Road would consist of two travel lanes (one in each direction), and incorporate a bridge and culverts to cross the existing Hazleton Creek at two locations. A 2.5m shared path on the northern side of the alignment, a 1.2m footpath on the southern side for a section of the alignment, kerb and gutter, a minor and major stormwater drainage network and water treatment devices would also be installed as part of the upgrade.

The intent of the proposed road is to help alleviate traffic impacts through the Albion Park Township, as a result of predicted traffic growth along Tongarra Road, both from background traffic and land development in the local area, including Calderwood, Tullimbar and Albion Park.

3. ROAD TRAFFIC POLLUTANTS AND AIR QUALITY CRITERIA

3.1 Road traffic and air pollution

Road traffic is the dominant source of several important air pollutants in Australian cities. The pollutants released from motor vehicles are implicated in a variety of detrimental effects on amenity, health, ecosystems and cultural heritage. The main focus in both research and project assessment is currently on the short-term and long-term effects of road transport pollution on human health. Repeated exposure to vehicle exhaust gases and particles is linked to, amongst other things, aggravated respiratory and cardiovascular disease, changes to lung tissue, changes in the function of the nervous system, and cancer **(IARC, 2012; WHO Regional Office for Europe, 2013)**. Such effects are likely to be exacerbated by the proximity of the population to road traffic[1] and may increase in prevalence as the volume of traffic increases and congestion becomes more frequent. Moreover, health effects account for the majority of the external costs associated with air pollution. The health costs of air pollution in Australia are estimated to be in the order of $11.1 billion to $24.3 billion annually, solely as a result of mortality **(Begg et al., 2007; Access Economics, 2008)**. Road transport is an important contributor; the health costs of emissions from road transport in Australia have been estimated to be $2.7 billion per year **(BTRE, 2005)**.

Many different air pollutants are emitted directly from road vehicles. These are termed 'primary' pollutants. In terms of local air quality and health, as well as the quantity emitted, the main primary pollutants from road vehicles are:

- Carbon monoxide (CO)
- Hydrocarbons (HC). In this context the term 'hydrocarbons' covers a wide range of compounds which contain carbon and hydrogen
- Oxides of nitrogen (NO_X). By convention, NO_X is the sum of nitric oxide (NO) and nitrogen dioxide (NO_2), and is stated as NO_2-equivalents

[1] The ubiquity of motor vehicles in urban areas, and the discharge of pollution at ground level and near to the population, mean that they tend to be a more important source of human exposure than other sources such as industry **(DSEWPaC, 2011)**.

- Particulate matter (PM). PM is emitted from vehicle exhaust and as a result of non-exhaust processes such as tyre wear, brake wear and the resuspension of dust on the road surface. The two metrics that are most commonly used are PM_{10} and $PM_{2.5}$, which are particles with an aerodynamic diameter of less than or equal to 10 µm and 2.5 µm respectively.

For many years the emissions of primary pollutants have been regulated through vehicle emission standards. Other pollutants – notably ozone (O_3) and important components of airborne particulate matter – are formed through chemical reactions in the atmosphere. These are termed 'secondary' pollutants. Most of the NO_2 in the atmosphere is also secondary in nature.

Of those primary pollutants listed above, only NO_X and PM are emitted at high enough concentrations to warrant detailed modelling and assessment such as that provided in this report. The assessment criteria for these are discussed in Section 3.2.

3.2 Air quality criteria

Regulated air pollutants are often divided into 'criteria' pollutants and 'air toxics'. Criteria pollutants tend to be ubiquitous and emitted in relatively large quantities, and their health effects have been studied in some detail. Air toxics are gaseous or particulate organic pollutants that are present in the air in low concentrations with characteristics such as toxicity or persistence so as to be a hazard to humans, plants or animal life. Some of the health issues associated with vehicle pollutants are discussed in Appendix A.

In NSW the statutory methods that are used to assess the air pollution impacts of projects are detailed in the document *Approved Methods for the Modelling and Assessment of Air Pollutants in NSW* **(NSW EPA, 2017)**. Air quality must be assessed in relation to criteria and averaging periods for specific pollutants. However, the Approved Methods do not contain specific information on the assessment of transport projects.

The pollutant, metrics and standards set out for criteria pollutants in the Approved Methods are listed in Table 3.1 for the pollutants assessed. These are drawn from a number of sources, including the National Environment Protection (Ambient Air Quality) Measures for Ambient Air Quality (AAQ NEPM) (NEPC, 2016).

Table 3.1: Air quality criteria for assessed pollutants

Pollutant	Concentration	Averaging period
Nitrogen dioxide (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
	8 µg/m^3	1 year

4. EXISTING ENVIRONMENT

4.1 Local climatic conditions

Dispersion models require information about the meteorology (dispersion characteristics) of a study area. In particular, data are required on wind speed, wind direction, temperature, atmospheric stability class[2] and mixing height[3]

The Bureau of Meteorology (BoM) collects climatic information in the vicinity of the Project. A range of climatic information collected from the Albion Park AWS (Site Number 062841) which is located in the middle of the Project area, is presented in Table 4.1. Temperature and humidity data consist of monthly averages of 9am and 3pm readings. Monthly daily averages of maximum and minimum temperatures are also provided. Rainfall data consist of mean monthly rainfall and the average number of rain days per month.

The annual average maximum and minimum temperatures recorded at the Albion Park AWS are 22.5°C and 11.4°C respectively. On average, January is the hottest month, with an average maximum and minimum temperatures of 27.1°C and 17.1°C, respectively. July is the coldest month, with average maximum and minimum temperatures of 17.8°C and 6.2°C, respectively. The annual average relative humidity reading collected at 9am from the Albion Park AWS is 67% and at 3pm the annual average is 59%.

Rainfall data collected at the Albion Park AWS shows that February is the wettest month, with an average rainfall of 145.5 mm over an average of 12.0 rain days. The average annual rainfall is 893 mm with an average of 120.6 rain days per year.

The measurements of wind speed and direction from this station were used to compile wind roses for the year of modelling, 2014, and these are shown in Figure 4.1. Some guidance on the interpretation of wind roses is provided in Appendix B.

On an annual basis, the most common winds were from the west and are above 7.5 m/s. The winds are also more frequent from the western and northeastern quadrants. Seasonally the westerly winds dominate through the autumn, winter and spring. During summer months the northeasterly component is more common and also appears to a lesser extent during autumn spring.

The mean wind speed in 2014 was 3.8 metres per second (m/s) and the annual mean percentage of calms (wind speeds of less than 0.5 m/s) was 6.3%.

[2] The term mixing height refers to the height of the turbulent layer of air near the earth's surface into which ground-level emissions will be rapidly mixed. A plume emitted above the mixed-layer will remain isolated from the ground until such time as the mixed-layer reaches the height of the plume. The height of the mixed-layer is controlled mainly by convection (resulting from solar heating of the ground) and by mechanically generated turbulence as the wind blows over the rough ground.

[3] In dispersion modelling stability class is used to categorise the rate at which a plume will disperse. In the Pasquill-Gifford stability class assignment scheme, as used in this study, there are six stability classes A through to F. Class A relates to unstable conditions such as might be found on a sunny day with light winds. In such conditions plumes will spread rapidly. Class F relates to stable conditions, such as occur when the sky is clear, the winds are light and an inversion is present. Plume spreading is slow in these circumstances. The intermediate classes B, C, D and E relate to intermediate dispersion conditions.

Table 4.1: Climate Averages for the Albion Park AWS

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
9am Mean Dry-bulb and Wet-bulb Temperatures (ºC) and Relative Humidity (%)													
Dry-bulb	22.5	22.0	20.2	19.2	15.8	13.0	12.5	14.0	17.1	19.0	19.7	21.4	18.0
Humidity	68	74	76	68	69	73	68	61	57	58	67	66	67
3pm Mean Dry-bulb and Wet-bulb Temperatures (ºC) and Relative Humidity (%)													
Dry-bulb	24.8	24.5	23.5	21.3	18.8	16.7	16.2	17.3	19.3	20.4	21.6	23.5	20.7
Humidity	63	67	64	61	58	57	54	49	53	58	63	61	59
Daily Maximum Temperature (ºC)													
Mean	27.1	26.4	25.3	23.3	20.7	18.1	17.8	18.8	21.3	23.1	24.1	25.7	22.6
Daily Minimum Temperature (ºC)													
Mean	17.1	17.2	15.6	12.2	8.8	7.2	6.2	6.5	8.5	10.8	13.3	15.3	11.6
Rainfall (mm)													
Mean	74.3	145.5	120.7	71.5	53.1	93.6	47.6	52.7	42.7	65.7	80.2	63.0	893.0
Rain days (Number)													
Mean	11.0	12.0	12.7	10.8	7.9	10.2	7.2	7.6	8.0	9.9	12.1	11.2	120.6

Source: BOM (2020) Climate average for Station: 068241; Commenced: 1999 - present; Latitude: 24.56ºS; Longitude: 151.79º

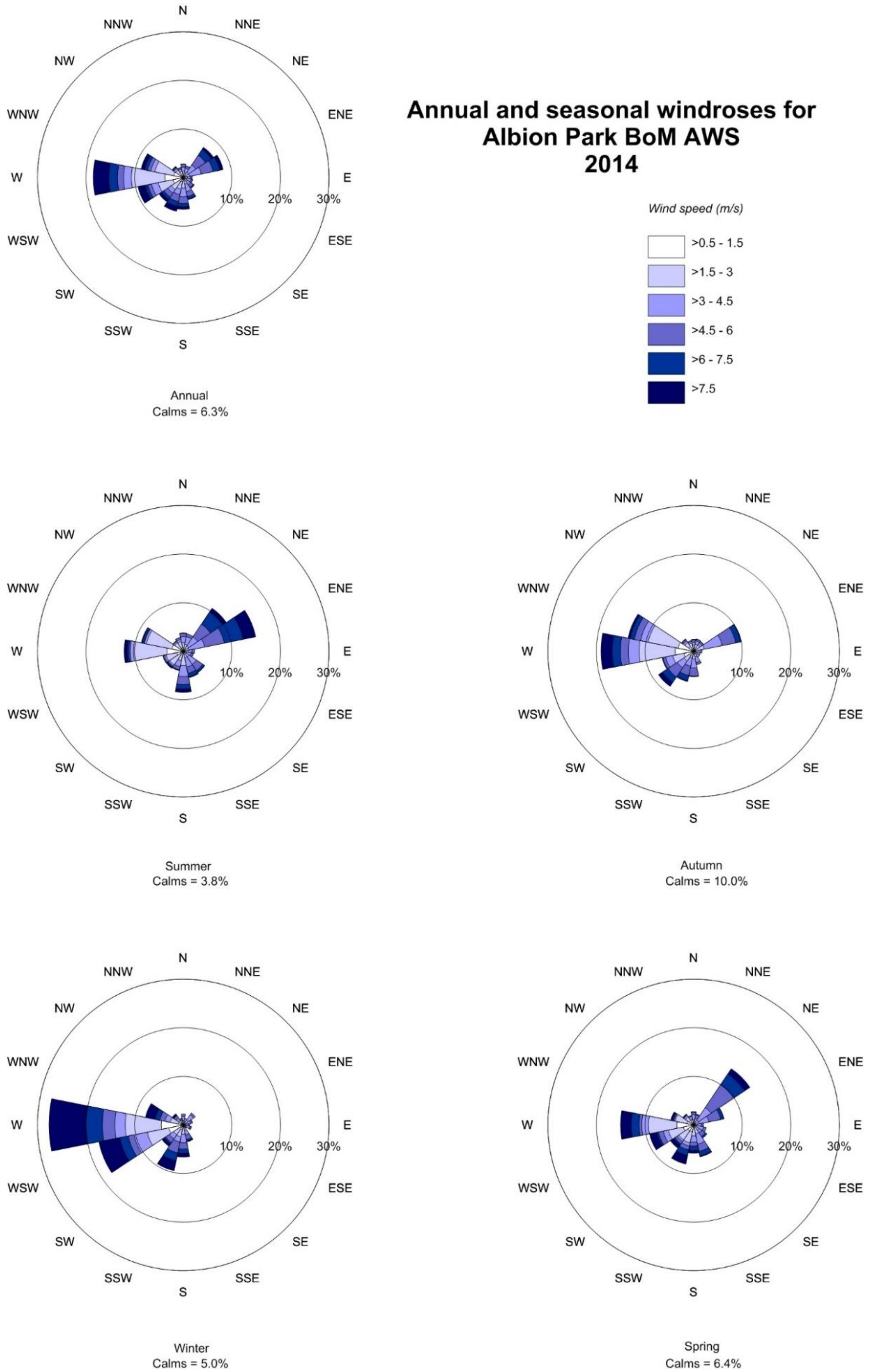

Figure 4.1: Annual and seasonal wind roses for BoM Albion Park South for 2014

4.2 Existing air quality and background concentrations

No air quality monitoring has been undertaken specifically for the Project. However, the NSW Department of Planning, Industry and Environment (DPIE) monitors air quality at one site in Albion Park South, located south of the Airport. The concentrations at Albion Park South were therefore considered to be the representative of background air quality in the study area. The assumptions made concerning background values using the Albion Park South data are described below.

Table 4.2 summarises the NO_2, NOx and PM_{10} data from the Albion Park South monitoring station for the years 2014 to 2018 inclusive, and for 2015 – 2018 inclusive for $PM_{2.5}$. Due to the extreme bushfire conditions in the latter half of 2019, monitoring data for 2019 has not been included in the assessment.

Table 4.2: Summary of monitoring data from the DPIE Albion Park South site

Year	NO_2 (µg/m^3)		NOx (µg/m^3)		PM_{10} (µg/m^3)		$PM_{2.5}$ (µg/m^3)	
	Max 1-hour	Annual mean	Max 1-hour	Annual mean	Max 24-hour	Annual mean	Max 24-hour	Annual mean
2014	78	8.0	133	8.2	48	16.2	-	-
2015	96	7.1	115	7.8	41	14.0	21	6.4
2016	88	7.7	133	8.9	43	14.9	31	7.2
2017	78	7.4	119	9.0	45	15.3	19	6.6
2018	80	8.2	179	10.8	94	17.8	29	6.8

The highest annual mean NO_2 concentration was 8.2 µg/m^3 measured in 2018, which is well below the air quality criterion of 62 µg/m^3. The highest one-hour mean NO_2 concentration was 96 µg/m^3, measured in 2015, which again is well below the one-hour mean air quality criterion of 246 µg/m^3. The highest NOx measurements were 10.8 µg/m^3 (annual) and 179 µg/m^3 (1-hour), both recorded in 2018. These are used for calculation of total NO2, as described in Section 5.4.

The highest annual mean PM_{10} concentration was 17.8 µg/m^3, measured in 2018, and this was taken to be the background annual mean PM_{10} concentration for the Project. This value is well below the annual mean air quality criterion of 30 µg/m^3.

The highest annual mean $PM_{2.5}$ concentration was 7.2 µg/m^3 and this was taken to be the background annual mean $PM_{2.5}$ concentration for the Project. This value falls below the annual mean air quality criterion of 8 µg/m^3.

As shown in Table 4.2 above, the 24 hour mean PM_{10} criterion of 50 µg/m^3 was exceeded at the Albion Park South site in 2011, 2014, 2018 and 2019. These exceedances were generally due to regional events such as bushfires or dust storms rather than specific local sources. Using the maximum monitored concentrations as background levels to which the contribution from the Project can be added is therefore an overly conservative and unrealistic approach, especially in the case of particulate matter.

Figure 4.2 presents a time series of the 24-hour mean PM_{10} measurements at Albion Park South from 2014 to 2018 and shows that the majority of concentrations are well below 40 µg/m^3, with a number of spikes during the severe bushfires and dust storms in Sydney in October 2013 and the summer of 2018. In fact, there were only 20 occasions in the five years (1,825 days) of data presented when the 24-hour mean PM_{10} concentration exceeded 40 µg/m^3. To more appropriately assess the cumulative PM_{10} impacts of the Project, it was therefore necessary to remove the influence of the short-term spikes or peaks in the monitoring data.

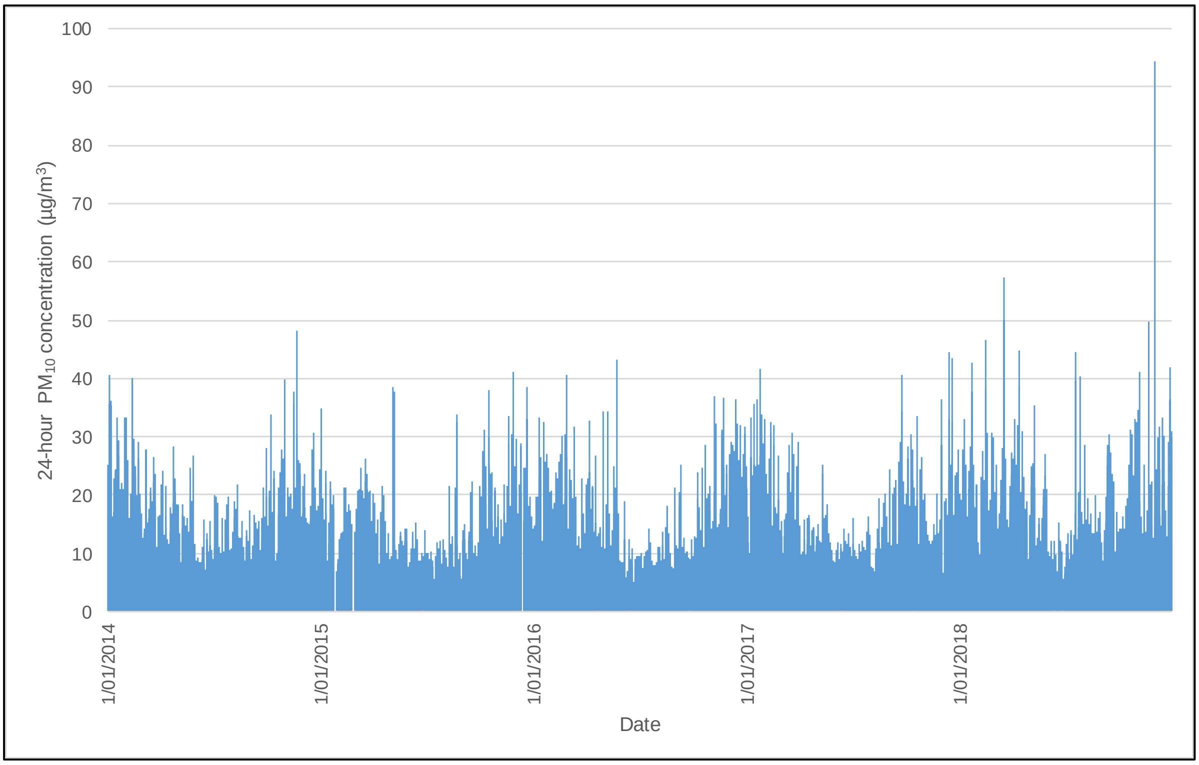

Figure 4.2: 24-hour PM_{10} concentration measured at Albion Park South from 2010 to 2018

Figure 4.3 presents the percentile concentrations for the same five-year dataset. For the purposes of this assessment, it was considered reasonable (and still conservative) to take a background 24-hour mean concentration for PM_{10} as the 99th percentile of these data (i.e. the concentration that would only be exceeded on one per cent of days). This value was 40.5 µg/m³, as shown in Figure 4.3.

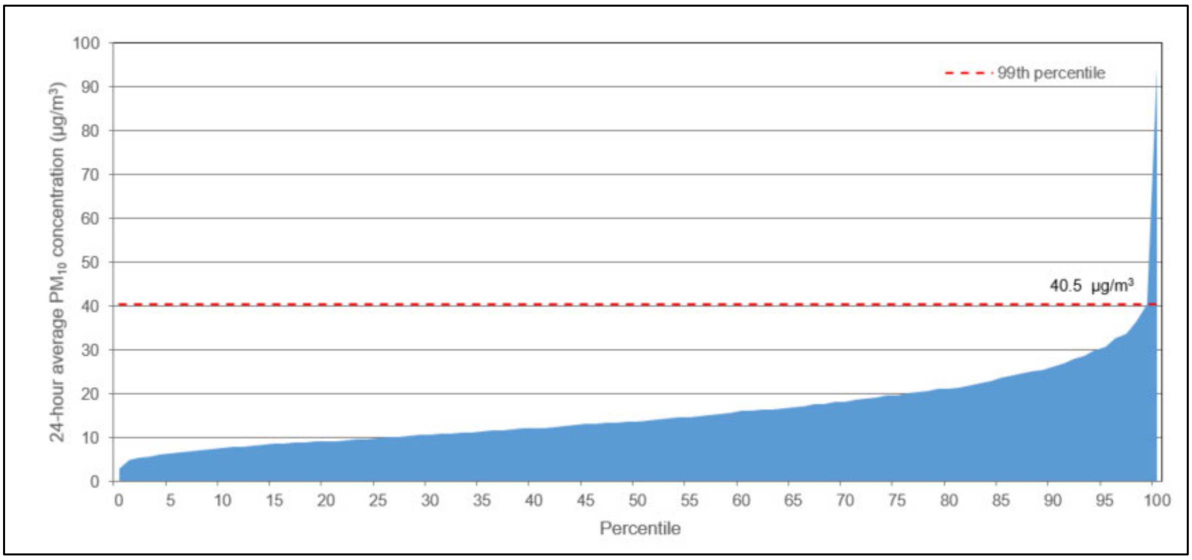

Figure 4.3: Percentile 24-hour PM_{10} concentrations measured at Albion Park South from 2010 to 2018

As shown in Table 4.2 above, the 24 hour mean $PM_{2.5}$ criterion of 25 µg/m³ was exceeded at the Albion Park South site in 2016 and 2018. These exceedances were likely due to regional events such as bushfires or dust storms rather than specific local sources. Using the maximum monitored concentrations as background levels to which the contribution from the Project can be added is therefore an overly conservative and unrealistic approach, especially in the case of particulate matter.

Figure 4.4Figure 4.2 presents a time series of the 24-hour mean $PM_{2.5}$ measurements at Albion Park South from 2015 to 2019 and shows that the majority of concentrations are well below 25 µg/m³, with a number of spikes during the bushfire events in Sydney in the summers of 2016 and 2018. In fact, there were only 3 occasions in the four years (1,460 days) of data presented when the 24-hour mean $PM_{2.5}$ concentration exceeded 25 µg/m³. To more appropriately assess the cumulative $PM_{2.5}$ impacts of the Project, it was therefore necessary to remove the influence of the short-term spikes or peaks in the monitoring data.

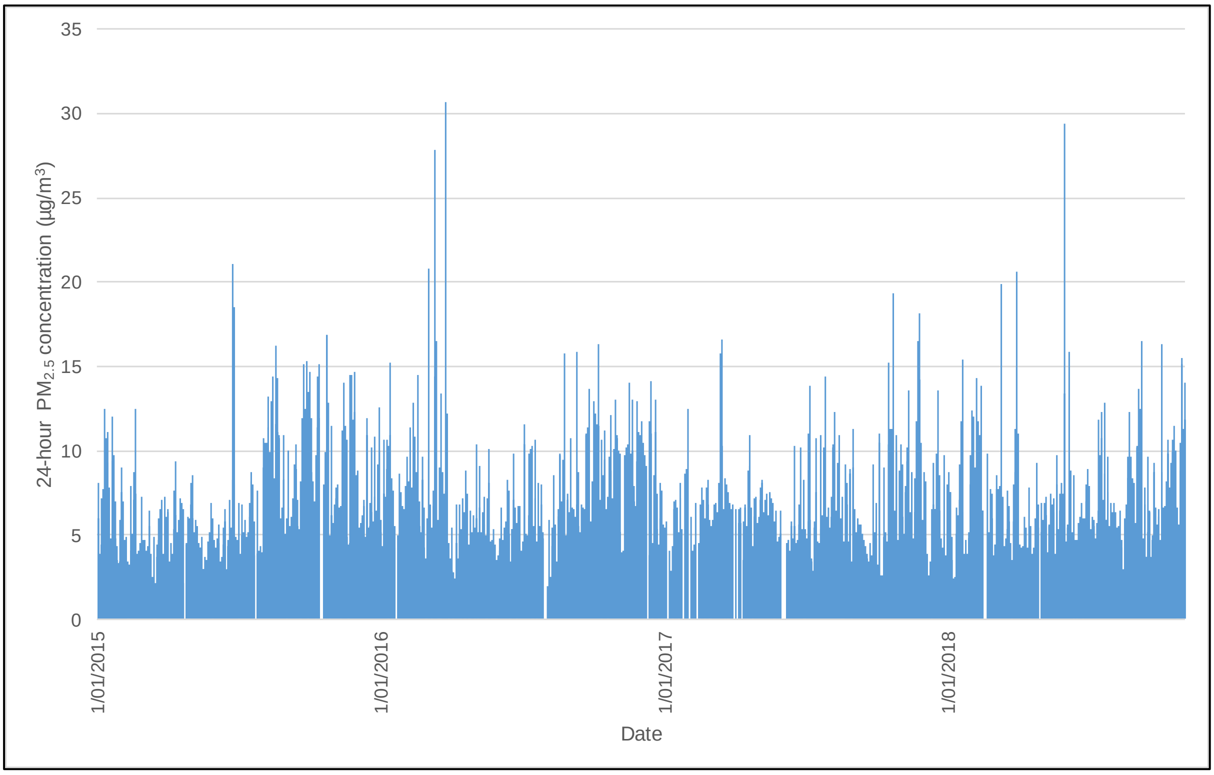

Figure 4.4: 24-hour $PM_{2.5}$ concentration measured at Albion Park South from 2015 to 2018

Figure 4.5 presents the percentile concentrations for the same five-year dataset. For the purposes of this assessment, it was considered reasonable (and still conservative) to take a background 24-hour mean concentration for $PM_{2.5}$ as the 99th percentile of these data (i.e. the concentration that would only be exceeded on one per cent of days). This value was 16.5 µg/m³, as shown in Figure 4.5**.**

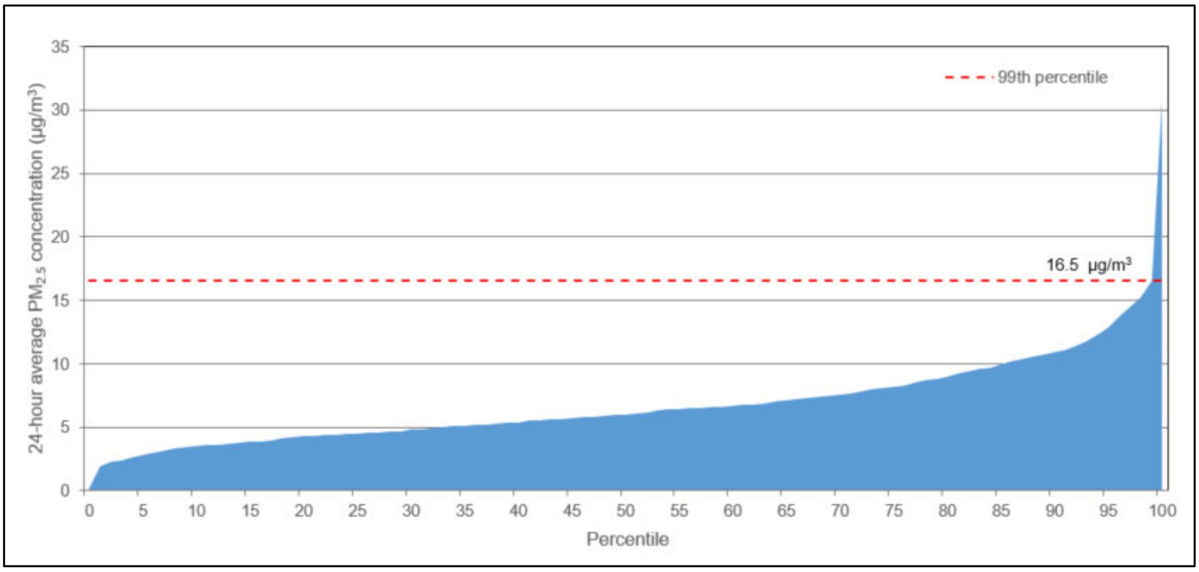

Figure 4.5: Percentile 24-hour $PM_{2.5}$ concentrations measured at Albion Park South from 2015 to 2018

A summary of the background concentrations used in the assessment is provided in Table 4.3.

Table 4.3: Summary of background concentrations

Pollutant	Background concentration (µg/m³)		
	Annual mean	24-hour mean	Maximum 1-hour mean
NO_X (for NO_x to NO_2 conversion)	10.8	Not applicable	179
PM_{10}	17.8	40.5	Not applicable
$PM_{2.5}$	7.2	16.5	Not applicable

5. METHODOLOGY

5.1 Scenarios

This section assesses the predicted pollutant concentrations due to emissions from the Project. The emissions and dispersion models have been run for two different operational scenarios as follows:

- Opening year (2026) with the project
- Opening year +15 years (2041) with the project

5.2 Emission modelling

5.2.1 Model selection

The most appropriate tool for calculating emissions from road traffic was considered to be Roads and Maritime's model TRAQ (Tool for Roadside Air Quality). TRAQ includes simplified algorithms and emission factors from the NSW Greater Metropolitan Region (GMR) emission inventory model (NSW EPA, 2012). The inventory was updated in 2012, with significant refinements to the road transport methodology. The inventory model is specifically designed for use in NSW, and takes into account the characteristics of vehicle fleets in the NSW GMR. Many of the emission factors were derived using an extensive database of Australian measurements. The algorithms in TRAQ were converted by ERM into a spreadsheet tool which could be used for multiple road links and any year between 2008 and 2050.

The TRAQ model was used to calculate emissions of the following pollutants:

- NOx
- PM_{10}
- $PM_{2.5}$

The method for calculating hot running[4] emissions involves the use of average-speed emission factors for various vehicle types (CP, CD, LDCP, LDCD, HDCP, RT, AT, BusD and MC). Separate emission factors are provided for five road categories - residential, arterial, commercial arterial, commercial highway and highway/freeway. Correction factors are also applied to allow for the effects of road gradient on hot running emissions.

The method for calculating cold-start emissions[5] involves the application of adjustments to the hot emission factors to take into account the extra emissions which occur before a vehicle's engine and after-treatment system have reached their full operational temperatures. Cold-start emissions are only calculated for light-duty vehicles. No cold-start adjustment is made for particulate matter. The amount of 'cold running' depends on the road category, and no cold running is assumed for residential roads and highways.

Emission factors for non-exhaust PM are provided in TRAQ. The method is drawn from the European Environment Agency's Air Pollutant Emission Inventory Guidebook (**EEA, 2013**), and includes tyre wear, brake wear and road surface wear.

[4] Exhaust emissions which are produced when a vehicle's engine and after-treatment system have reached their full operational temperatures.

[5] CP = petrol passenger vehicles; CD = diesel passenger vehicles; LDCP = light-duty commercial petrol vehicles (<=3500 kg); LDCD = light-duty commercial diesel vehicles (<=3500 kg); HDCP = heavy-duty commercial petrol vehicles (>3500kg); RT = rigid trucks (3.5-25 tonnes, diesel only); AT = articulated trucks (> 25 tonnes, diesel only); BusD = heavy public transport buses (diesel only); MC = motorcycles.

5.2.2 Road category

In TRAQ, the road category influences the operation of vehicles, and hence emissions. The road categories in TRAQ are defined in terms of a number of criteria, including the level in the network hierarchy, the number of lanes, the speed limit and the frequency of intersections/signals. Based on these considerations, the allocation of a road category used for the Tripoli Way Extension was commercial highway.

5.2.3 Traffic volume and composition

Hourly modelled traffic volumes and percentage of heavy-duty vehicles (HDVs) on each road section were provided by Cardno. An example of the diurnal variation in the traffic volumes on a link is shown in Figure 5.1. The total daily traffic volumes for each section and each modelled scenario are shown in Table 5.1.

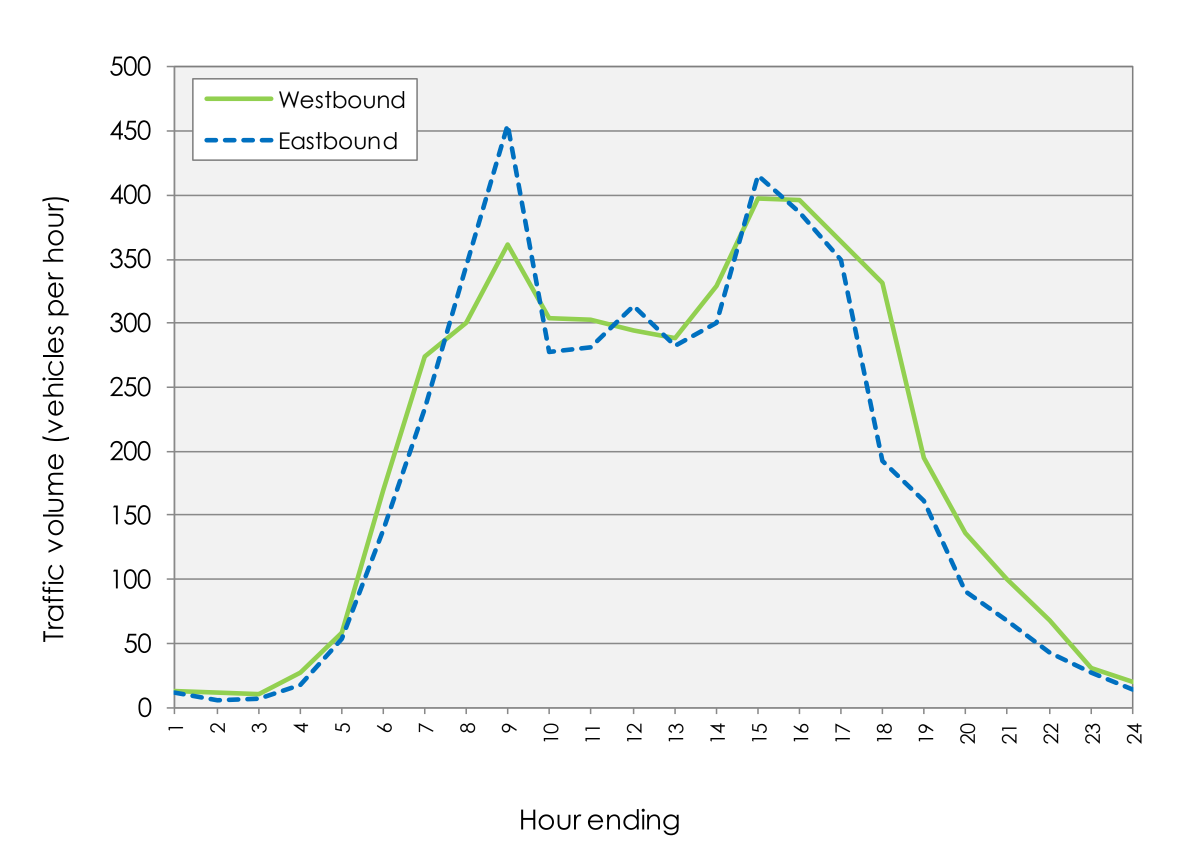

Figure 5.1: Example of diurnal traffic variation

Table 5.1: Total daily traffic volumes used for each link (vehicles per day)

Section	2026	2041
Tongarra Road to Calderwood Road	9,253	14,648
Calderwood Road to Hamilton Road	15,457	27,878
Hamilton Road to Terry Street	17,058	27,261

5.2.4 Vehicle emission rates

Emissions were estimated for each hour using TRAQ in conjunction with the traffic data and assumptions. Figure 5.2 shows some examples of the emission factors that were used as input to the CAL3QHCR dispersion model (described in Section 5.3). The figure shows the diurnal variation in the average vehicle emission factor for NOx for a specific link (Calderwood Road to Hamilton Road). The average emission factor for a given year is a function of the speed and composition (percentage of HDVs) of the traffic, and these vary by time of day. The emission factors in 2041 are lower than those in 2026 as a result of assumed improvements in emission-control technologies and the penetration of these into the fleet.

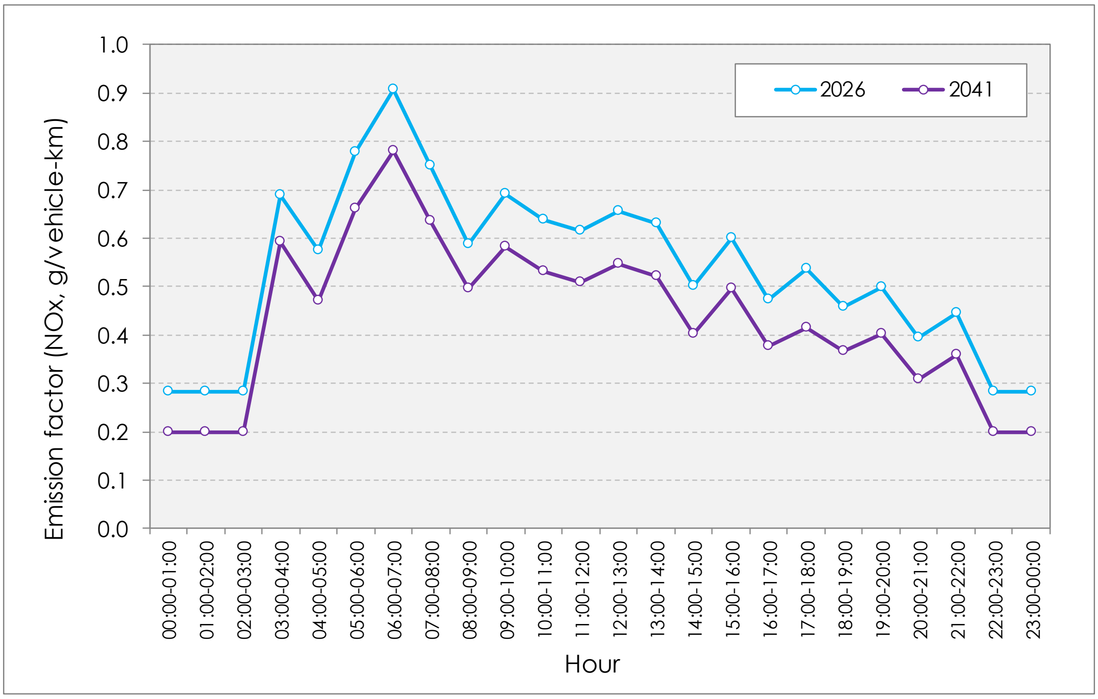

Figure 5.2: Unit vehicle emission factor by hour: NOx, Calderwood Road to Hamilton Road – Westbound

5.3 Dispersion modelling

5.3.1 Model selection

The USEPA-approved[6] CAL3QHCR[7] dispersion model was used to assess the impacts of the project on ambient concentrations of NO_X, PM_{10}, and $PM_{2.5}$. CAL3QHCR is an enhanced version of the CALINE Gaussian dispersion model, and is designed specifically for the assessment of road traffic emissions. CALINE has been widely used in road traffic pollution studies across Australia, and has been validated for Australian conditions. CAL3QHCR determines pollutant concentrations at receptors downwind of roads located in relatively uncomplicated terrain. The model is applicable for any wind direction, road orientation and receptor location, and the model is able to process up to a year of meteorological data. For the project the model was set up and run using the CALRoads View software.

[6] http://www.epa.gov/scram001/dispersion_prefrec.htm

[7] CAL3QHC is a CALINE3 based model with queuing and hot spot calculations and with a traffic model to calculate delays and queues that occur at signalized intersections. CAL3QHCR is a more refined version of CAL3QHC that requires local meteorological data.

The following information was required as input to the model:

- Link type. Different link types can be defined in CAL3QHCR (e.g. 'at grade', 'fill', 'bridge' and 'cut section'). It should be noted the link type (which influences pollutant dispersion) is not the same as the road category used to estimate emissions
- Meteorological conditions
- Receptor locations
- Traffic volume by road link
- Vehicle emission rate (grams per vehicle-kilometre per hour)[8] of each pollutant for each road link.

5.3.2 Meteorological conditions

As discussed in Section 4.1, the closest meteorological station to the project was the BoM AWS at Albion Park. These data were very close to the Project area and contained all the required parameters for dispersion modelling.

5.3.3 Receptor locations

Predictions of pollutant concentrations were made for worst-case sensitive receivers along the existing and proposed alignments. These receivers included mainly residential properties, and are shown in Figure 5.3.

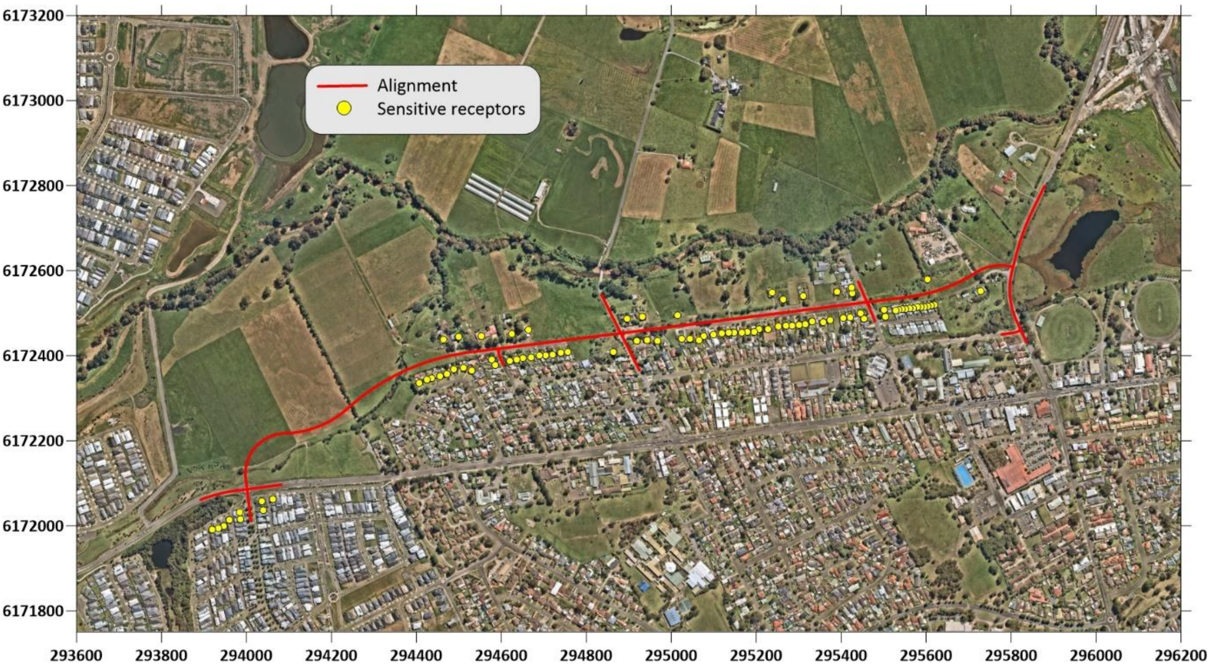

Figure 5.3: Location of sensitive receptors in relation to the proposed alignment

[8] CAL3QHRC actually requires unit emission rates in grams per vehicle-mile, but in this report metric units have been used for consistency.

5.4 NOx to NO_2 conversion

The CAL3QHCR model was used to predict concentrations of NO_X. To determine the NO_2 concentrations at receptors an empirical conversion method has been applied. This approach was taken and accepted in the recently approved WestConnex Air Quality Assessments, and is summarised here in Sections 5.4.1 and 5.4.2.

NOx and NO_2 have been measured for several years at a range of locations across Sydney, and the data were analysed with a view to developing empirical assessment methods for NO_2 for road projects. One reason for this analysis was to quantify and address the conservatism in some of the other methods in use, whereby exceedances of NO_2 air quality standards can be predicted even though the monitoring data show that this situation is far from reality.

An upper bound estimate approach was developed for both annual mean and one-hour mean NO_2 concentrations which are above the maximum possible NO_2 value for a given NOx concentration.

5.4.1 Annual mean concentrations

Figure 5.4 shows the relationship between the annual mean concentrations of NO_X and NO_2 at the monitoring stations in Sydney (both roadside and background sites) between 2004 and 2016. While it is noted that Tripoli Way is some distance from Sydney, there is a significant amount of data available which can be analysed to show the relationship between NOx and NO_2, which would apply to the area. As the values shown are measurements, they equate to $[NO_X]_{total}$ and $[NO_2]_{total}$. In the low-NO_X range of the graph there is an excess of ozone and therefore NO_2 formation is limited by the availability of NO. In the high-NO_X range there is an excess of NO, and therefore NO_2 formation is limited by the availability of ozone. The Figure also shows that there is not a large amount of scatter in the data, and for this reason a central-estimate approach was considered to be appropriate. This is represented by the solid blue in the figure, which will give the most likely NO_2 concentration for a given NO_X concentration. The dashed lines represent the extrapolation of the function to values below and above the range of measurements.

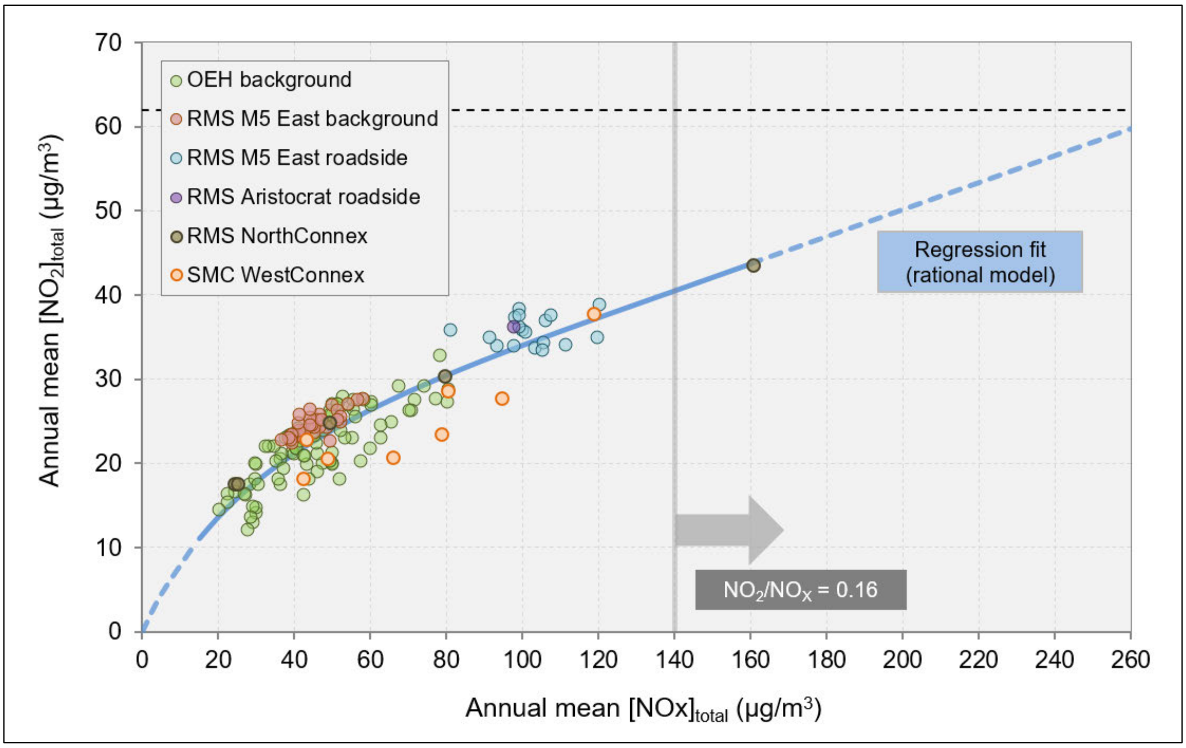

Figure 5.4: Annual mean NOx and NO_2 concentrations at monitoring sites in Sydney

For a given project contribution to NOx at a receptor, the higher the background NOx the lower the project NO_2 increment will tend to be, as less ozone will generally be available for converting the NO from the project to NO_2.

The use of the function could theoretically lead to exceedances of the annual mean criterion for NO_2 in NSW of 62 µg/m^3. However, a very high annual mean NOx concentration – more than 260 µg/m^3 – would be required. This is much higher than the measurements in NSW have yielded to date.

5.4.2 One-hour mean concentrations

One-hour mean NOx and NO_2 concentrations are much more variable than annual mean concentrations. Patterns in the hourly data can be most easily visualised by plotting the one-hour mean NO_2/NOx ratio against the one-hour mean NOx concentration.

The data from all Sydney monitoring sites (background and roadside) between 2004 and 2016 and used for the WestConnex Project, are shown in Figure 5.5.

The solid orange line in Figure 5.5 represents the outer envelope of all data points, and approximates to a conservative upper bound estimate for 2016, or in other words the maximum NO_2/NOx ratio for a given NOx concentration in 2016.

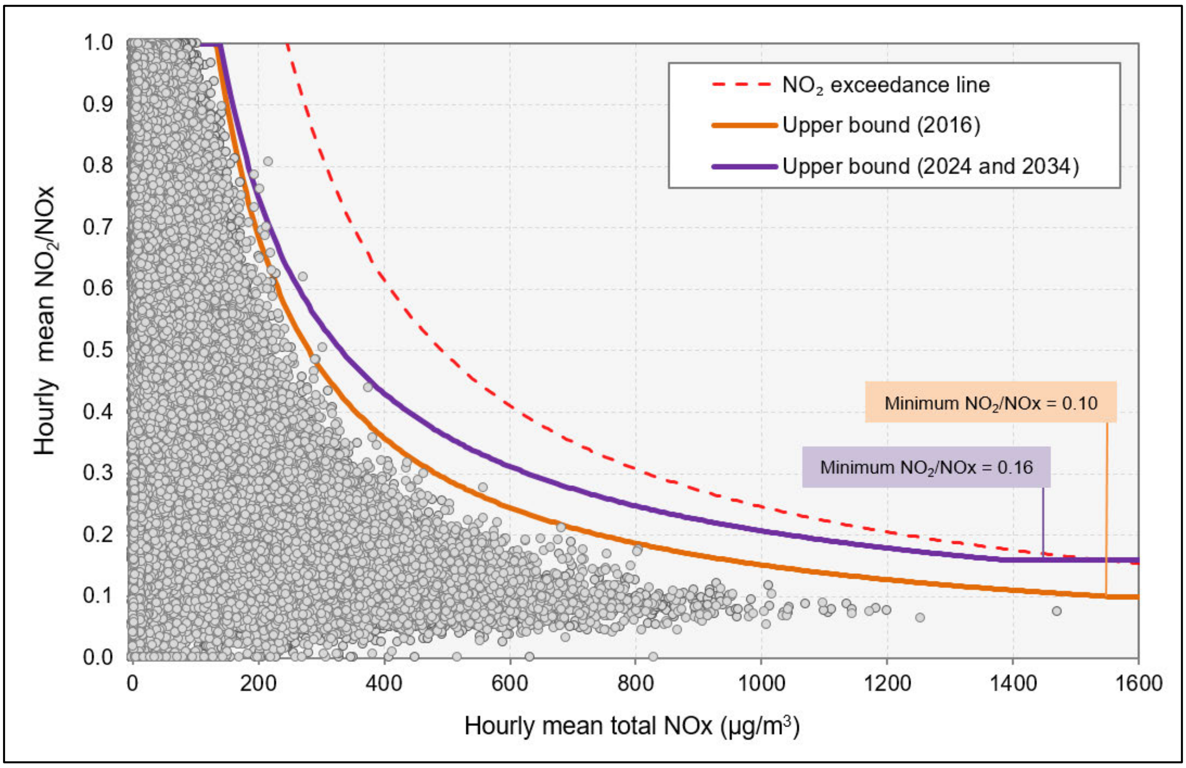

Figure 5.5: Hourly mean NOx and NO_2 ratio for monitoring sites at various locations in Sydney

The dashed red line in Figure 5.5 shows the NO_2/NOx ratio that would be required for an exceedance of the NO_2 criterion of 246 µg/m^3 at each NOx concentration. It is clear from Figure 5.5 that an exceedance of the one-hour criterion for NO_2 cannot be predicted using the upper bound curve for 2016 across a wide range of NOx concentrations.

It has been assumed that a minimum value for the NO_2/NOx ratio of 0.16 would be appropriate for the 2026 and 2041 scenarios, and a corresponding conservative upper bound function (the purple line) is shown in Figure 5.5.

6. OPERATIONAL ASSESSMENT

This section assesses the predicted pollutant concentrations due to emissions from both the existing roads and the Project. The maximum predicted concentrations at the most affected receptor, are provided in Table 6.1.

These values include both the background and Project contributions, and therefore represent the predicted cumulative impacts of the Project. Note that for NO_2, the background and modelled NOx values were combined and then converted to NO_2.

There are no predicted exceedances of the air quality criteria at any sensitive receptors for any of the modelled scenarios.

Table 6.1: Total daily traffic volumes used for each link (vehicles per day)

Pollutant	Background	Project	Cumulative	Criterion
Maximum 1-hour average NO_2 ($\mu g/m^3$)	179 (NOx)	75.7 (NOx)	157.5 (NO_2)	246
Annual average NO_2 ($\mu g/m^3$)	8.2 (NOx)	3.9 (NOx)	10.9 (NO_2)	62
Maximum 24-hour average PM_{10} ($\mu g/m^3$)	40.5	0.6	41.1	50
Annual average PM_{10} ($\mu g/m^3$)	17.8	0.2	18.0	25
Maximum 24-hour average $PM_{2.5}$ ($\mu g/m^3$)	16.5	0.4	16.9	25
Annual average $PM_{2.5}$ ($\mu g/m^3$)	7.2	0.1	7.3	8

7. CONSIDERATIONS DURING CONSTRUCTION

The main air pollution and amenity risks at road construction sites are:

- Annoyance impacts due to dust deposition (soiling of surfaces) and visible dust plumes (annoyance impacts include such things as dust on surfaces like cars, washing, swimming pools, rainwater tanks etc.),
- Elevated PM_{10} concentrations due to dust-generating activities, and
- Exhaust emissions from diesel-powered construction equipment.

Dust emissions can occur during the preparation of the land (eg clearing and earth moving) and during construction itself, and can vary substantially from day to day depending on the level of activity, the specific operations being undertaken, and the weather conditions. A significant portion of the emissions result from site plant and road vehicles moving over temporary unsealed roads and open ground or disturbed areas. If dirt or mud is tracked onto public roads, dust emissions can occur at some distance from the construction site (**IAQM, 2014**). Other sources will include land clearing, crushing and screening rock, wind erosion, crushing and screening as well as excavating and loading spoil material.

It is very difficult to quantify dust emissions from construction activities. Dust emissions can vary substantially from day to day depending on the level of activity, the operations being undertaken, and the local weather conditions (which may result in dust generation even when there is no construction activity at the site). It is difficult to predict what the weather conditions would be when specific construction activities are undertaken, and it is therefore very difficult to accurately quantify dust emissions from construction using a model. Any effects of construction on PM concentrations would also tend to be temporary and relatively short-lived. The assessment and control of construction-related air quality therefore focused on managing risk.

An Air Quality Management Plan would therefore be produced for the construction of the project. This would contain details of the site-specific mitigation measures to be applied. The main recommended mitigation measures are summarised in Table 7.1. The table is generally consistent with the standard measures used by NSW Roads and Maritime. Additional guidance on the control of dust at construction sites in NSW is provided as part of the NSW EPA Local Government Air Quality Toolkit[9]. Detailed guidance is also available from the UK (**GLA, 2006**) and the United States (**Countess Environmental, 2006**).

[9] https://www.epa.nsw.gov.au/your-environment/air/air-nsw-overview/local-government-air-quality-toolkit

Table 7.1. Main mitigation measures to consider before and during construction

Aspect	Measure	Responsibility	Phase
General air quality impacts	An Air Quality Management Plan will be prepared to detail the air quality control measures and procedures to be undertaken during construction, including: - Air quality and dust management objectives that are consistent with DPIE guidelines - Potential sources and impacts of dust, identifying all dust-sensitive receptors - Mitigation measures to minimise dust impacts on sensitive receptors and the environment - A dust monitoring program to assess compliance with the identified objectives - Contingency plans to be implemented in the event of non-compliances and/or complaints about dust.	Contractor	Pre-construction
Impacts on local air quality during construction	Areas of exposed surface are to be minimised throughout the construction site planning and programming, to reduce the area of potential construction dust emission sources.	Contractor	Construction
	Control measures, such as stabilisation or covering will be implemented in order to minimise dust from stockpile sites.	Contractor	Construction
	Dust suppression measures, such as the use of water carts, will be used in any unsealed road surfaces and other exposed areas.	Contractor	Construction
	All trucks will be covered when transporting materials to and from the site.	Contractor	Construction
	Activities that generate dust will be avoided or modified during high wind periods.	Contractor	Construction
	Work activities will be reviewed if the dust suppression measures are not adequately restricting dust generation.	Contractor	Construction
	Rehabilitation of completed sections, where practical, will be progressively undertaken.	Contractor	Construction
Exhaust emissions	Construction plant and equipment will be maintained in good working condition to limit impacts on air quality.	Contractor	Construction
	Where practicable, vehicles will be fitted with pollution reduction devices and switched off when not in use.	Contractor	Construction

8. CONCLUSIONS

In this air quality assessment the CAL3QHCR dispersion model was used to predict the concentrations of NO_2, PM_{10} and $PM_{2.5}$ due to emissions from the proposed Tripoli Way Extension at the nearest sensitive receptors for two dispersion modelling scenarios 2026 and 2041.

The estimated concentrations of NO_2, PM_{10} and $PM_{2.5}$, were found to be well below the relevant NSW EPA air quality assessment criteria even when added to likely existing concentrations.

Dust generation during construction activities has also been considered. While construction dust is unlikely to represent a serious ongoing problem, the report provides a list of mitigation measures which can be put in place to address short-term impacts on the nearest sensitive receptors. Any effects would most likely arise during high winds blowing towards a receptor, at a time when dust is being generated and mitigation measures are not being fully effective. However, it is recommended that an Air Quality Management Plan be developed and implemented to cover the construction of the project, and recommendations for elements of this plan have been provided.

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APPENDIX A HEALTH ISSUES ASSOCIATED WITH VEHICLE POLLUTANTS

A1.1 Overview

Road vehicles emit a complex mixture of pollutants. These are generated though combustion processes (exhaust emissions of CO, NO_X, PM and many different hydrocarbons), evaporation processes (VOC) and abrasion processes (tyre wear, brake wear, etc). Many of the pollutants emitted from road vehicles have significant effects on health and the environment. They can also react together, and with pollutants from other sources, to form secondary pollutants which can also have adverse effects.

This Appendix provides a brief summary of the impacts of traffic pollutants on health and the environment. Various epidemiological and toxicological studies have linked road traffic emissions to adverse effects on health.

A1.2 Carbon monoxide

Carbon monoxide (CO) is a colourless, odourless gas. It can be harmful to humans because, when inhaled, it is taken up by haemoglobin in the blood (forming carboxyhaemoglobin) in preference to oxygen, thus reducing the capacity of the blood to transport oxygen. The affinity of CO for haemoglobin is more than 200 times greater than that of oxygen. At low concentrations the symptoms of CO intoxication in healthy adults include lethargy, and chest pain in people with heart disease. At higher concentrations CO leads to impaired vision and coordination, headaches, dizziness, confusion and nausea. CO is fatal at very high concentrations[10]. Symptoms are not generally reported until the carboxyhaemoglobin level in the blood exceeds 10%. This is approximately the equilibrium value achieved with an ambient atmospheric concentration of 70 mg/m^3 for a person engaged in light activity. There is evidence that there is a risk for individuals with cardiovascular disease at lower carboxyhaemoglobin levels. A carboxyhaemoglobin level in the blood of 40-50% usually leads to death. However, in most Australian towns and cities the levels of CO in ambient air are well below those that are hazardous to human health. Only larger cities do CO levels have the potential to have harmful effects[11].

A1.3 Nitrogen dioxide

NO_2 is one of the most important pollutants associated with road transport. It is an irritant and oxidant which has been linked to a range of adverse effects, including decrements in lung function, lung function growth, respiratory symptoms, asthma prevalence and incidence, cancer incidence, and birth outcomes (e.g. birth weight). Its most consistent association, however, has been found with respiratory outcomes.

The evidence of associations between ambient NO_2 concentrations and various health effects has strengthened in recent years. In a recent review of health evidence, the **WHO Regional Office for Europe (2013)** noted that many studies have documented associations between day-to-day variations in NO_2 concentration and variations in mortality, hospital admissions, and respiratory symptoms. There are associations between long-term exposure to NO_2 and mortality and morbidity at concentrations that were at or below the current EU annual mean limit value (40 µg/m^3). Although it is possible that, to some extent, NO_2 acts as a marker of the effects of other traffic pollutants, NO_2 can be regarded as causing some of the health impacts found to be associated with it in epidemiological studies **COMEAP (2015)**.

A1.4 Particulate Matter

The biological effects of inhaled particles are determined by their physical and chemical properties, by their sites of deposition, and by their mechanisms of action. The extent to which particles can penetrate the respiratory tract, and their potential for causing health effects, is directly related to their size. With normal nasal breathing, larger particles (those greater than 10 µm) are generally deposited in the extrathoracic part (nose, mouth and throat) of the respiratory tract. They adhere to the mucus in the

[10] http://www.epa.gov/iaq/co.html#Health_Effects

[11] http://www.environment.gov.au/protection/publications/factsheet-carbon-monoxide-co

nose, mouth, pharynx and larger bronchi, and from there are removed by either swallowing or expectorating. Particles between 10 and 2.5 µm can enter bronchial and pulmonary regions of the respiratory tract, with increased deposition during mouth breathing which increases during exercise. However, particles with a diameter of less than 2.5 µm can penetrate deep into the human respiratory system. Fine particles can be deposited in the pulmonary region, and it is these which are of particular concern.

In recent years epidemiological evidence has accumulated indicating that airborne particles have a range of adverse effects on health. These effects – which are diverse in scope, severity and duration - include the following **(WHO Regional Office for Europe, 2013; IARC, 2012)**:

- Premature mortality
- Aggravation of cardiovascular disease such as atherosclerosis
- Aggravation of respiratory disease such as asthma
- Changes to lung tissue, structure and function
- Cancer[12]
- Reproductive and developmental effects
- Changes in the function of the nervous system.

Research shows that particle pollution can exacerbate existing respiratory symptoms, and at high concentrations cause respiratory symptoms. Particles can also adversely impact cardiovascular health. No safe threshold has been identified for the human health effects of particles. The health effects of PM are further complicated by the chemical nature of the particles and by the possibility of synergistic effects with other air pollutants such as sulfur dioxide. Airborne particles also reduce visual amenity and visibility. Ambient concentrations of PM are most commonly defined in terms of two metrics: PM_{10} and $PM_{2.5}$, the mass concentrations of particles with an aerodynamic diameter of less than 10 µm and 2.5 µm respectively. There are many natural and anthropogenic sources of airborne particles, and as a consequence particulate matter displays a wide range of physical and chemical characteristics. When discussing PM sources and composition it is essential to distinguish between 'primary' and 'secondary' particles. Primary particles are emitted directly into the atmosphere as a result of natural processes (e.g. wind erosion, marine aerosols) and anthropogenic processes involving either combustion (e.g. industrial activity, domestic wood heaters, vehicle exhaust) or abrasion (e.g. road vehicle tyre wear). Secondary particles are not emitted directly, but are formed by reactions involving gas-phase components of the atmosphere. Various studies have shown that secondary particles contribute significantly to PM concentrations, especially $PM_{2.5}$ at background sites, although their characteristics vary significantly with both location and time.

A1.5 Ozone

Ozone is a strongly oxidising gas, and human exposure to it damages lung tissue and reduces lung function. High concentrations therefore lead to increases in the frequency of respiratory symptoms and in deaths. Ground-level ozone is not produced directly from emission sources but is created by photochemical reactions involving NO_X and VOCs in the atmosphere. Ozone is an important component of summer-time smog. It can be transported over long distances, and is therefore regarded as a regional air pollution problem. High concentrations are typically observed downwind of large cities in the summer when photochemical formation is enhanced. Because road transport is a major source of ozone precursors (e.g. NOx and hydrocarbons) it is an important contributor to ground-level concentrations.

[12] Particles may contain carcinogenic substances such as polycyclic aromatic hydrocarbons (PAHs) or heavy metals.

APPENDIX B INTERPRETING WINDROSES

How to read a wind rose

A wind rose shows the frequency of occurrence of winds by direction and strength, presented as 16 bars that correspond to the compass points (N, NNE, NE, etc). The length of each bar represents the frequency of occurrence of winds <u>from</u> that direction, and the colours of the bar sections correspond to wind speed categories, the darker colours representing stronger winds.

In this example, 30% of winds are from the ESE direction, and the winds from this direction have the following speed distribution:

- 10% between 1.5 m/s and 3 m/s
- 10% between 3 m/s and 4.5 m/s
- 7% between 4.5 m/s and 6 m/s
- 3% between 6 m/s and 7.5 m/s

Predominant wind direction

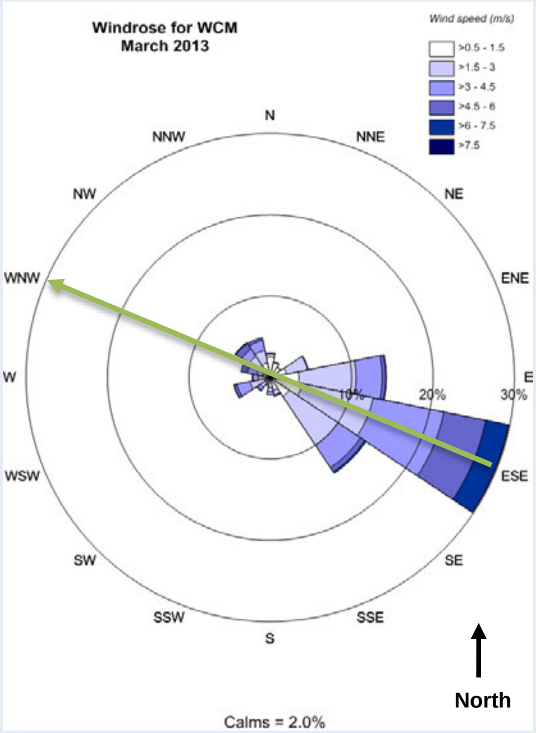

Figure A.1: Interpretation of a wind rose

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