600-660 ELIZABETH STREET, REDFERN

Air Quality Assessment

Prepared for:

NSW Land and Housing Corporation
Level 2, 31-39 Macquarie Street
Parramatta NSW 2150

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BASIS OF REPORT

This report has been prepared by SLR Consulting Australia Pty Ltd with all reasonable skill, care and diligence, and taking account of the timescale and resources allocated to it by agreement with NSW Land and Housing Corporation (the Client). Information reported herein is based on the interpretation of data collected, which has been accepted in good faith as being accurate and valid.

This report is for the exclusive use of the Client. No warranties or guarantees are expressed or should be inferred by any third parties. This report may not be relied upon by other parties without written consent from SLR

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DOCUMENT CONTROL

Reference	Date	Prepared	Checked	Authorised
610.17905-R02-v2.0	25 February 2020	Ali Naghizadeh	K Lawrence	K Lawrence
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EXECUTIVE SUMMARY

SLR Consulting was commissioned by NSW Land and Housing Corporation (LAHC) to conduct an Air Quality Assessment (AQA) for the proposed rezoning and development of 600-660 Elizabeth Street, Redfern (the Project Site).

This AQA has been prepared in general accordance with The Approved Methods (NSW EPA, 2017) with reference to the Infrastructure SEPP and the NSW Department of Planning document "*Development near Rail Corridors and Busy Roads – Interim Guideline*" (DoP, 2008) (the Guideline).

The primary source of air emissions in the area immediately surrounding the Project Site was identified as vehicles travelling along Elizabeth Street and other local roads. In order to gain a better understanding of the potential worst case air pollutant concentrations within the Project Site due to emissions from local traffic, detailed meteorological and air quality dispersion modelling of emissions from vehicles travelling on the surrounding road network was carried out. Emissions of NO_2 and particulate matter (as particulate matter less than 10 microns (PM_{10}) and particulate matter less than 2.5 microns ($PM_{2.5}$)) were estimated using the COPERT Australia software package. The calculated emissions from the surrounding road network were then modelled using the GRAMM/GRAL modelling system.

Mitigation measures consistent with Section 4.4 of the Guideline have been incorporated into the reference scheme of the Project Site. This includes minimising the formation of urban canyons by having buildings of different heights interspersed.

The results of the cumulative impact assessment indicated that while exceedances of the annual $PM_{2.5}$ criterion may occur at approximately 60% of the modelled locations within the Project Site, especially those close to Elizabeth Street, exceedances of PM_{10} criteria, NO_2 criteria and the 24-hour $PM_{2.5}$ criterion are not predicted. It is noted that the predicted exceedances of the annual $PM_{2.5}$ criterion are primarily due to high background concentrations of $PM_{2.5}$ within the local airshed, with the annual average background $PM_{2.5}$ concentration used in this assessment of 7.8 µg/m^3 being only fractionally below the criterion of 8 µg/m^3.

As a result of the assessment undertaken, SLR concludes that from an air quality perspective, the Project Site is suitable for the intended predominately residential, mixed use development.

CONTENTS

CONTENTS

APPENDICES

CONTENTS

DOCUMENT REFERENCES

TABLES

FIGURES

CONTENTS

1 Introduction

SLR Consulting Australia Pty Ltd (SLR) was engaged by NSW Land and Housing Corporation (LAHC) to conduct an Air Quality Assessment (AQA) to accompany a Planning Proposal to be lodged with the City of Sydney (CoS).

This Planning Proposal relates to land at 600-660 Elizabeth Street, Redfern (the Project Site). The Planning Proposal seeks to rezone the Project Site to allow redevelopment for a mix of social, affordable and private housing in an integrated residential community. The aims of the Planning Proposal are to rezone the Site to R1 (General Residential).

The Project Site is located directly east of Redfern Oval and comprises a city block, with a 146 metre (m) frontage to Elizabeth and Walker Street and a 70 m frontage to Kettle and Phillip Streets. **Figure 1** illustrates the location of the Project Site.

Figure 1 Project Site Location

1.1 Scope

This report focuses on the potential for impacts from local and regional air emission sources affecting air quality at the Project Site. The purpose of this report is to identify whether there are any potential constraints or issues relating to air quality that should be considered as part of redeveloping the Project Site for residential use.

The agreed scope of work for this AQA was as follows:

- Review existing relevant background documentation, including studies, strategies and plans to understand context and identify key findings;
- Supplement existing work with additional work, as required, to obtain a complete understanding of the existing air quality characteristics of the existing Project Site;
- Quantify air pollutant emissions from key identified sources within and surrounding the Project Site;
- Model the dispersion of the quantified emissions in order to characterise cumulative maximum concentrations of air pollutants across the Project Site; and
- Compare the model results against relevant guidelines to identify any constraints for the future development of the Project Site.

The New South Wales Environment Protection Authority (EPA) "*Approved Methods for the Modelling and Assessment of Air Pollutants in NSW*" (NSW EPA, 2017) (the Approved Methods) outlines the requirements for conducting an 'air quality impact assessment' as follows. Also indicated are the relevant sections of this report where the requirements are met:

- Description of local topographic features and sensitive receptor locations (**Section 2.1** and **Section 2.3** respectively).
- Establishment of air quality assessment criteria (**Section 5**).
- Analysis of climate and dispersion meteorology for the region (**Section 7.3.5**).
- Description of existing air quality environment (**Section 6**).
- Compilation of a comprehensive emissions inventory for the existing and proposed activities (**Section 7.1**).
- Completion of atmospheric dispersion modelling and analysis of results (**Section 7.2** and **Section 8**).
- Preparation of an air quality impact assessment report comprising the above.

1.2 The Proposal

The Project Site will be transformed into a market-leading, build-to-rent redevelopment featuring contemporary urban and architectural design and creating a high-quality, integrated community of social, affordable and private housing.

1.2.1 Communities Plus Build to Rent

Communities Plus is a key program under NSW Government's *Future Directions for Social Housing in NSW*, delivering integrated social, affordable and private housing by partnering with the private and not for profit sectors including registered Tier 1 or Tier 2 Community Housing Providers (CHPs).

The Redfern project aligns with Future Directions, by providing innovative options for private sector investment in social housing under a long term lease. The project presents an opportunity to renew and increase social housing in a well-located integrated community with good access to education, training, local employment, and close to community facilities such as shopping, health services and transport.

On 6 July 2018, the NSW Government announced the Project Site as the pilot for Communities Plus build-to-rent. The Project provides an opportunity for the private sector, in partnership with the not-for-profit sector, to fund, design, develop and manage the buildings as rental accommodation under a long-term lease.

Build-to-rent is a new residential housing delivery framework that is capable of providing access to broader housing choices. Established in overseas markets such as the UK and the USA, locally, build-to-rent has significant scope to provide increased rental housing supply and the opportunity for investment in residential housing in NSW.

1.2.2 Reference Scheme

An indicative reference scheme and urban design report has been prepared by Architectus, Silvester Fuller and Tyrell (the Project Team) to support the Planning Proposal and demonstrates how the Project Site may be redeveloped. The indicative reference scheme comprises:

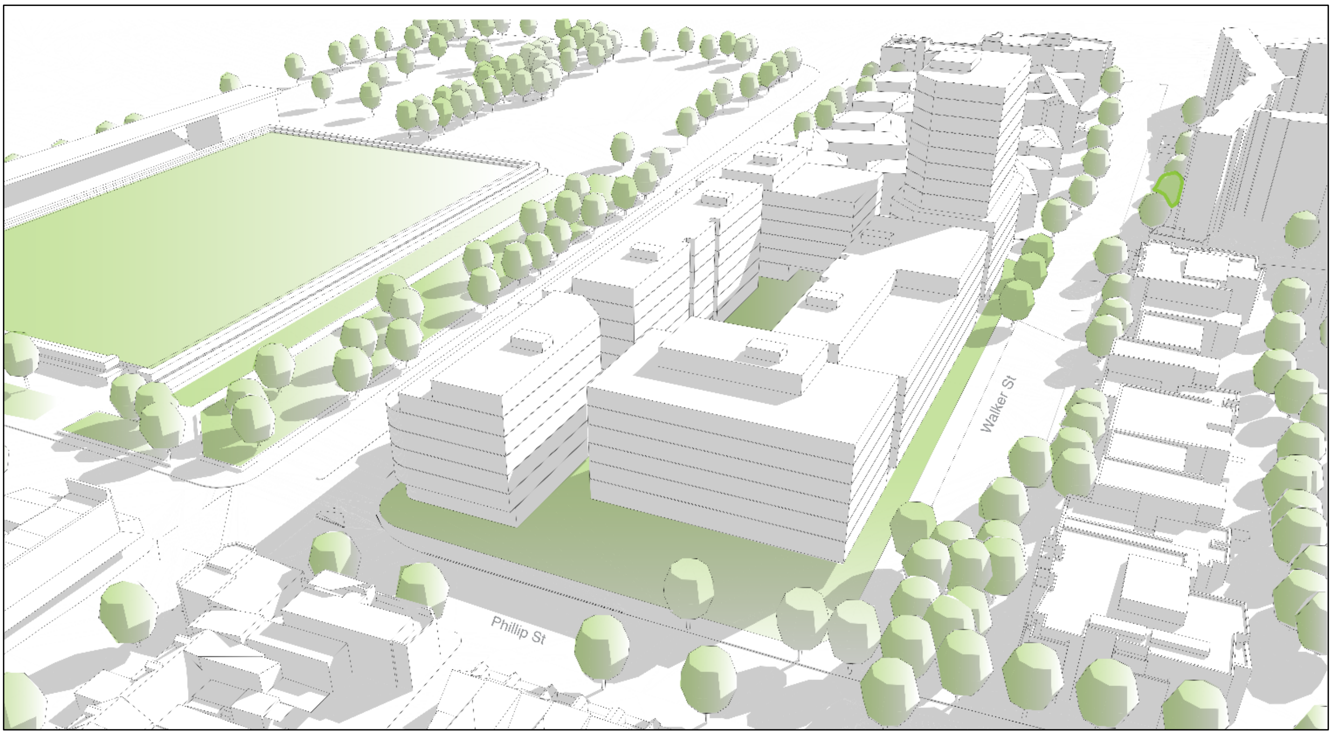
- Approximately 327 dwellings, with building heights ranging between 6 and 14 storeys;
- A mixed-use development, with over 1,500 m^2 of non-residential floor space for local shops, cafes, community space and other services; and
- Three ground floor communal courtyard spaces.

The reference scheme (shown at **Figure 2** and **Figure 3**) balances the challenges and opportunities of the Site, particularly the desire to deliver high quality urban design while providing new and modern social housing in an integrated mixed tenure environment.

It is expected the Site will be developed over a period of three years, once the site has been rezoned.

Figure 2 600-660 Elizabeth St, Redfern Reference Scheme Layout

Figure 3 600-660 Elizabeth St, Redfern Reference Scheme 3D View



2 Project Setting

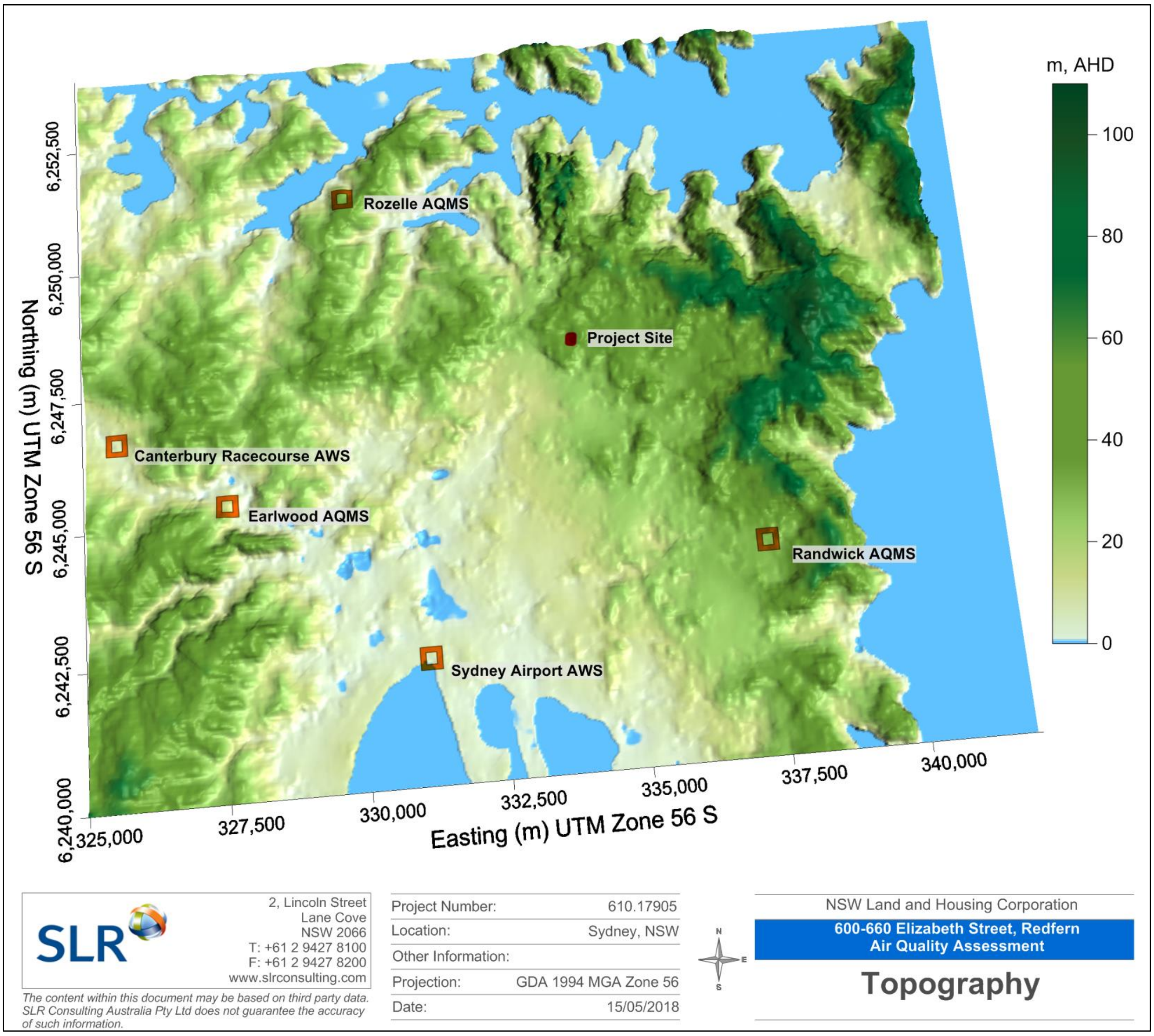
2.1 Local Topography

Topography is important in air quality studies as local atmospheric dispersion can be influenced by night-time katabatic (downhill) drainage flows from elevated terrain or channelling effects in valleys or gullies around the Project Site.

A three dimensional representation of the area is given in **Figure 4**. The topography of the local area within a 7 kilometre (km) radius of the Project Site ranges from an approximate elevation of -10 m to 110 m Australian Height Datum (AHD).

The Project Site and the immediate surrounding area are reasonably flat, with slight increases in elevation towards the north and the east. The area immediately surrounding the Project Site is also relatively open, which will facilitate the dispersion of air emissions and prevent 'pooling' of air pollutants.

Figure 4 Topography of Area Surrounding the Project Site



2.2 Local Meteorology

Local wind speed and direction influence the dispersion of air pollutants. Wind speed determines both the distance of downwind transport and the rate of dilution as a result of 'plume' stretching. Wind direction, and the variability in wind direction, determines the general path pollutants will follow and the extent of crosswind spreading. Surface roughness (characterised by features such as the topography of the land and the presence of buildings, structures and trees) affects the degree of mechanical turbulence, which also influences the rate of dispersion of air pollutants.

The Bureau of Meteorology (BoM) maintains and publishes data from weather stations across Australia. The closest such stations recording wind speed and wind direction data include the Sydney Airport Automatic Weather Station (AWS) (approximately 6 km southwest of the Project Site) and Canterbury Racecourse AWS (approximately 8 km west of the Project Site) (refer **Figure 4**).

Annual and seasonal wind roses for the years 2014-2018 (inclusive), compiled from data recorded by the Sydney Airport AWS and Canterbury Racecourse AWS are presented in **Figure 5** and **Figure 6** respectively. The wind roses show the frequency of occurrence of winds by direction and strength. The bars correspond to the 16 compass points (degrees from north). The bar at the top of each wind rose diagram represents winds blowing from the north (i.e. northerly winds), and so on. The length of the bar represents the frequency of occurrence of winds from that direction, and the widths of the bar sections correspond to wind speed categories, the narrowest representing the lightest winds. Thus it is possible to visualise how often winds of a certain direction and strength occur over a long period, either for all hours of the day, or for particular periods during the day.

A comparison of **Figure 5** and **Figure 6** shows that the Sydney Airport AWS recorded much higher frequencies of stronger winds than the Canterbury Racecourse AWS during the 2014-2018 period. The annual frequency of calm wind conditions was recorded to be 0.2% by the Sydney Airport AWS and 8.0% by the Canterbury Racecourse AWS. This is to be expected given that the Sydney Airport AWS is located close to Botany Bay and in relatively open surroundings.

In terms of wind direction, while there are differences between the data recorded at the two locations, the annual wind rose for the years 2014-2018 for both sites indicates the predominant wind directions in the area are from the northwest, with a low frequency of winds from the east.

Figure 5 Sydney Airport AWS Annual and Seasonal Wind Roses, 2014-2018

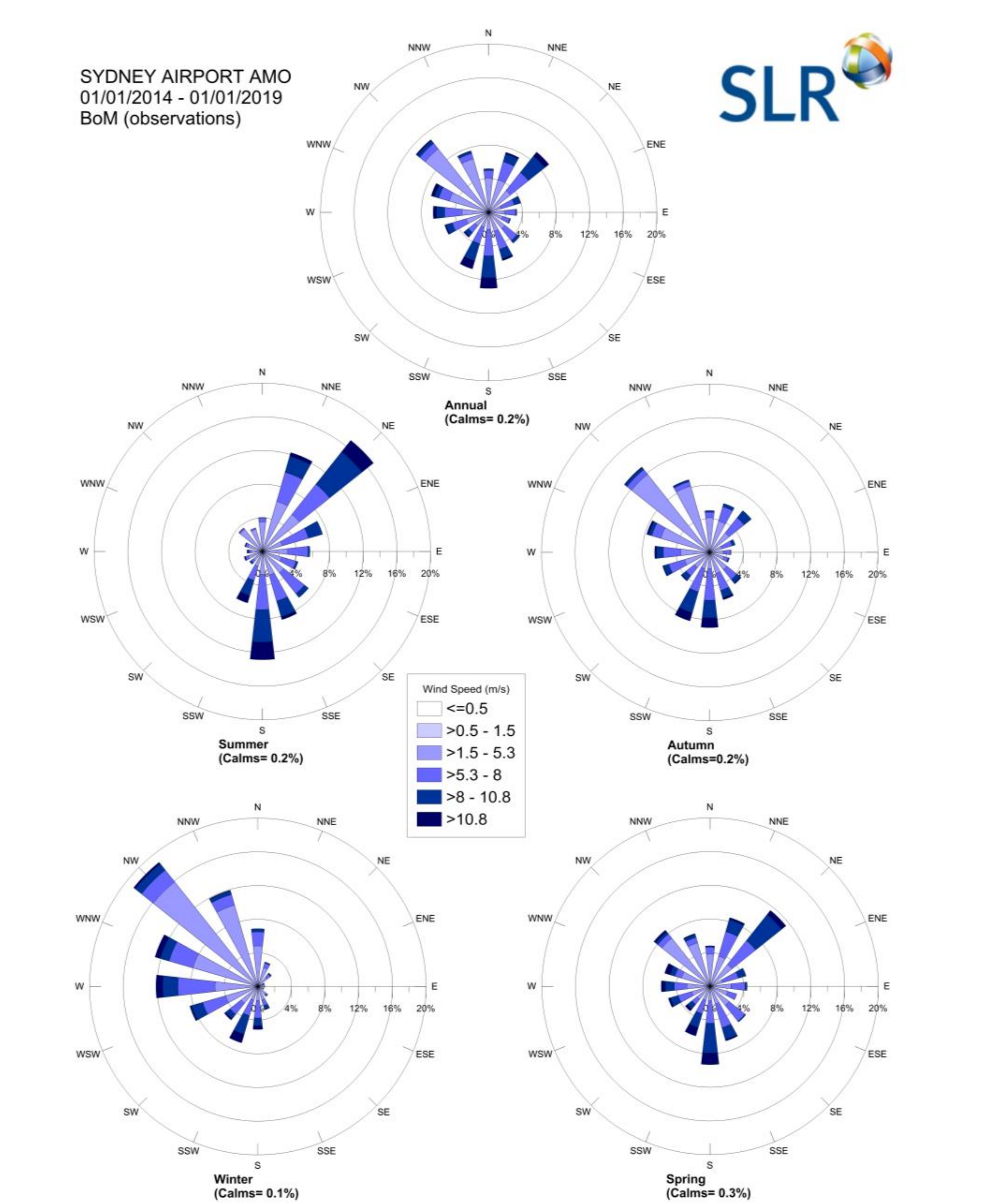


Figure 6 Canterbury Racecourse AWS Annual and Seasonal Wind Roses, 2014-2018

The seasonal wind roses for the 2014-2018 period indicate that:

- In summer, winds are predominantly from the northeast and southeast, with negligible winds from the western quadrant. Calms were recorded to occur approximately 0.2% of the time during the summer months by the Sydney Airport AWS and 5.7% by the Canterbury Racecourse AWS.
- In autumn, winds are predominantly from the northwestern quadrant with few winds from the east and east-southeast. Calms were recorded for approximately 0.2% of the time during the autumn months by the Sydney Airport AWS and 9.1% by the Canterbury Racecourse AWS.
- In winter, winds are predominantly from the northwest with very few winds from the east-northeastern quadrant. Calms were recorded for approximately 0.1% of the time during the winter months by the Sydney Airport AWS and 10.2% by the Canterbury Racecourse AWS.
- In spring, there are winds from all directions, with the highest frequency recorded by the Sydney Airport AWS as being from the northeast quadrant, and by the Canterbury Racecourse AWS as being from the southeast quadrant. Calms were recorded for approximately 0.3% of the time during the spring months by the Sydney Airport AWS and 7% by the Canterbury Racecourse AWS.

From the long term wind patterns recorded by the Sydney Airport AWS and Canterbury Racecourse AWS, and assuming that the same wind conditions will be experienced at the Project Site, it can be concluded that that the Project Site is likely to be subjected to winds from all directions, with the lowest frequency of winds from the east and southwest quadrants.

Considering the relatively complex topographical features of the land between the Project Site and the two BoM weather stations (see **Figure 4**), the actual winds experienced at the Project Site may be different to those recorded by the BoM stations. Therefore, meteorological modelling was carried out to provide site-representative wind data for the Project Site (see **Section 7.3**).

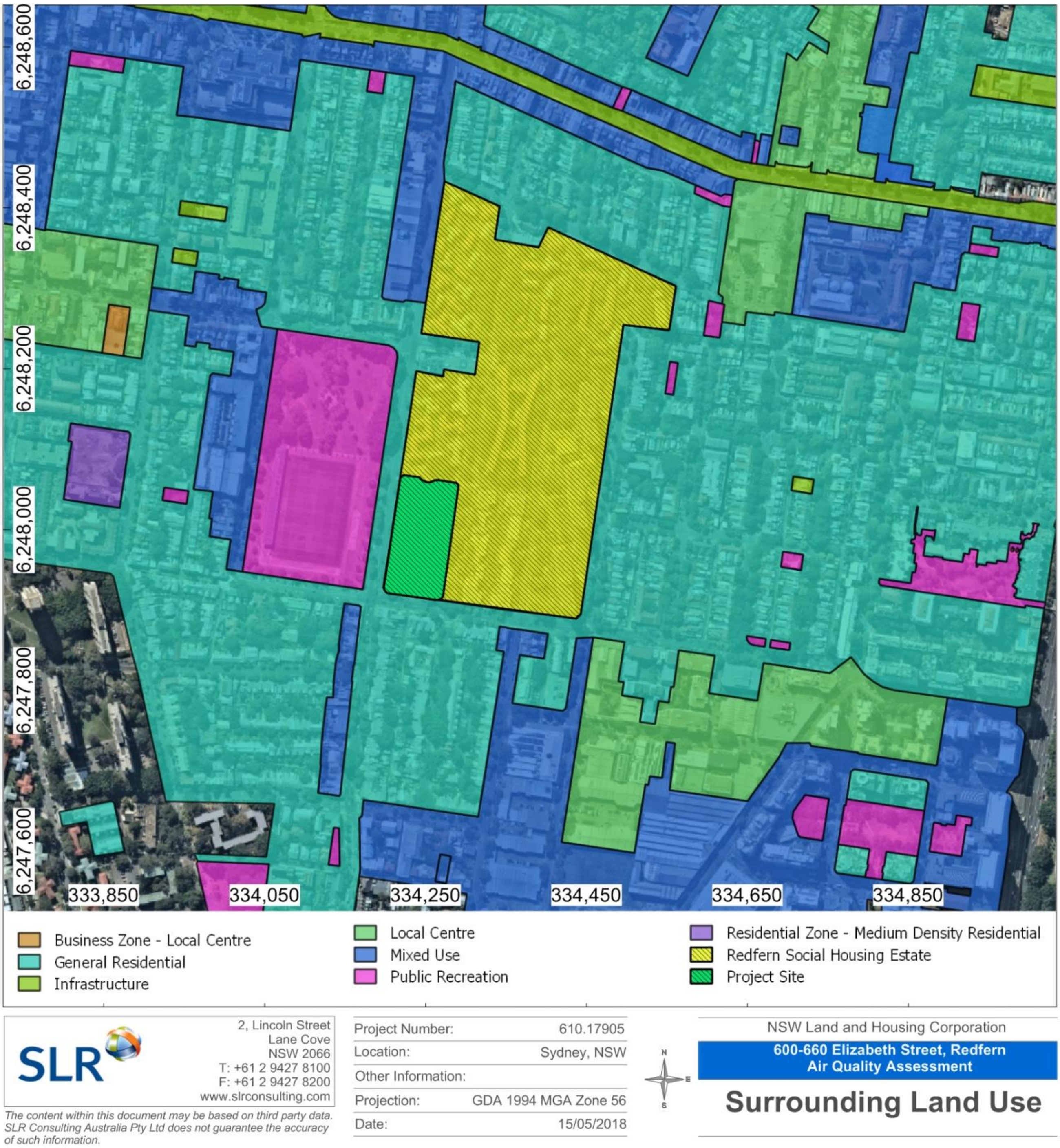
2.3 Surrounding Land Use and Receptors

As illustrated in **Figure 7**, the Project Site is located within the southwest corner of the Redfern Social Housing Estate.

The lots immediately surrounding the Project Site to the north, east and south are developed for residential uses. Within a 500 m radius of the Project Site, the land is zoned as Medium Density Residential, General Residential, Mixed Use, Public Recreation, Local Centre, Business Zone and Infrastructure. Some commercial and light industry uses are located within the Mixed Use zones approximately 200 m to the southeast and 250 m to the northwest. During the site visit, no activities with the potential for impacting the Project Site were identified.

A number of schools and childcare centres also operate within close proximity to the Project Site.

Figure 7 Surrounding Land Use



3 Air Quality Policy and Guidance

The following air quality policy and guidance documents have been referenced within this assessment and have been used to identify the relevant air quality criteria (see **Section 5**).

3.1 Approved Methods

The Approved Methods lists the statutory methods for modelling and assessing air pollutants from stationary sources and specifies criteria which reflect the environmental outcomes adopted by the EPA. The Approved Methods are referred to in the *POEO (Clean Air) Regulation 2002* for assessment of impacts of air pollutants.

The air quality criteria set out in the Approved Methods relevant to the Project Site are reproduced and discussed in **Section 5**.

3.2 Infrastructure SEPP

NSW *State Environmental Planning Policy (Infrastructure) 2007* (the 'Infrastructure SEPP') refers to guidelines which must be taken into account where development is proposed in, or adjacent to, specific roads and railway corridors under clause 101 – *Development with Frontage to a Classified Road*[1]. The objective of clause 101 is to ensure that new development does not compromise the effective and ongoing operation and function of classified roads and to reduce the potential for impacts from traffic noise and vehicle emissions on development adjacent to classified roads.

Reference is also made to the NSW Department of Planning document "*Development near Rail Corridors and Busy Roads – Interim Guideline*" (DoP, 2008) (the Guideline) which supports the specific rail and road provisions of the Infrastructure SEPP.

An aim of the Guideline is to assist in reducing the health impacts of adverse air quality from road traffic on sensitive adjacent development and assists in the planning, design and assessment of development adjacent to busy roads. Section 4.4 of the guideline provides the following guidance on when air quality should be a design consideration and some of the principles that should be considered at the design stage to achieve improved air quality:

When air quality should be a design consideration:

- *Within 10 m of a congested collector road (traffic speeds of less than 40 km/hr at peak hour) or a road grade > 4% or heavy vehicle percentage flows > 5%;*
- *Within 20 m of a freeway or main road (with more than 2,500 vehicles per hour, moderate congestions levels of less than 5% idle time and average speeds of greater than 40 km/hr);*
- *Within 60 m of an area significantly impacted by existing sources of air pollution (road tunnel portals, major intersection / roundabouts, overpasses or adjacent major industrial sources); or*
- *As considered necessary by the approval authority based on consideration of site constraints, and associated air quality issues.*

1 The NSW State Roads Act 1986 No. 85 defines 'Classified Road' as a main road, a secondary road, a state highway, a tourist road, a state work, a freeway or a controlled access road.

Air quality design considerations:

- *Minimising the formation of urban canyons that reduce dispersion. Having buildings of different heights interspersed with open areas, and setting back the upper stories of multi-level buildings helps to avoid urban canyons.*
- *Incorporating an appropriate separation distance between sensitive uses and the road using broad-scale site planning principles such as building siting and orientation. The location of living areas, outdoor space and bedrooms and other sensitive uses (such as childcare centres) should be as far as practicable from the major source of air pollution.*
- *Ventilation design and open-able windows should be considered in the design of development located adjacent to roadway emission sources. When the use of mechanical ventilation is proposed, the air intakes should be sited as far as practicable from the major source of air pollution.*
- *Using vegetative screens, barriers or earth mounds where appropriate to assist in maintaining local ambient air amenity. Landscaping has the added benefit of improving aesthetics and minimising visual intrusion from an adjacent roadway.*

4 Identified Pollutant Sources and Types

4.1 Road Traffic

The primary sources of air emissions in the area immediately surrounding the Project Site is expected to be vehicles travelling along Elizabeth Street and Phillip Street. Elizabeth Street has been classified by the NSW Road and Maritime Services (RMS) as a "secondary Road" (Gazetted Road Number: 2083) whereas Phillip Street is not a classified road. A review of the National Pollutant Inventory Emission Estimation Technique Manual (NPI EET) for Combustion Engines (DEWHA , 2008) identifies the primary pollutants from combustion engines as:

- Total Volatile Organic Compounds (TVOCs)
- Carbon monoxide (CO)
- Oxides of nitrogen (NO_x)
- Particulate matter less than 2.5 µm in aerodynamic diameter ($PM_{2.5}$)
- Particulate matter less than 10 µm in aerodynamic diameter (PM_{10})
- Sulfur dioxide (SO_2)

Other substances that are also emitted from vehicle exhausts in trace amounts include products of incomplete combustion, such as metallic additives which contribute to the particulate content of the exhaust (DEWHA , 2008). In addition, ozone (O_3) is formed as a secondary pollutant from reactions between TVOCs and NO_X, and is used as a key indicator of smog in urban environments.

The rate and composition of air pollutant emissions from road vehicles is a function of a number of factors, including the type, size and age of vehicles within the fleet, the type of fuel combusted, number and speed of vehicles and the road gradient.

The proximity of a classified road to the Project Site means that road traffic emissions have the potential to result in elevated air pollutant concentrations during peak periods in areas within the Project Site closest to Elizabeth Street and Phillip Street.

4.2 Industrial Sources

Industrial sites located in and surrounding the Project Site with the potential to be significant emitters of air pollutants were identified through:

- Desktop mapping of industrial sites regulated by the EPA;
- A review of facilities required to report to the National Pollutant Inventory (NPI); and
- A site visit.

Environment Protection Licences (EPLs) are issued under the POEO Act and are regulated by the NSW EPA. EPLs stipulate emission limits to water, land and/or air and provide operational protocols to ensure industrial emissions/operations comply with relevant standards. General requirements of EPLs relating to air quality include:

- Plant and equipment to be maintained and operated in a proper and efficient manner.
- Emissions of dust and odour from the premises are to be minimised/prevented.

The NPI database provides details on industrial emissions of over 4,000 facilities across Australia. The requirement to return annual reports to the NPI quantifying a facility's emissions is determined by the activities/processes being undertaken at the facility, and also whether those processes exceed process-specific thresholds in terms of activity rates (i.e. throughput and/or consumption). It is not intended to make a statement that the emissions associated with those activities will be significant in terms of their potential for impact and/or generation of complaint, however it provides a tool to identify significant emission sources in a specific area that then may be investigated further to assess their potential to impact on local air quality.

A search of the EPA public register and NPI database for the project area returned several records of industries in the vicinity of the Project Site which could potentially be a source of air pollutant emissions. Details of these facilities are presented in **Table 1** and their location relative to the Project Site is illustrated in **Figure 8**.

As outlined in **Table 1**, considering the separation distances and activity types associated with the identified emission sources, significant air quality impacts at the Project Site due to air emissions from these facilities are considered unlikely.

Table 1 Identified Sources of Air Emissions in the Vicinity of the Project Site

Facility Name	Type of Activity	Approximate Distance from the Project Site	Likelihood of Significant Impact
Alexandria Asphalt Plant	Petroleum and coal product manufacturing	2.9 km (SW)	Low
Australian Refined Alloys Alexandria	Basic non-ferrous metal manufacturing	1.8 km (SW)	Low
Monroe Springs	Metal product manufacturing	2.2 km (SSW)	Low
Spotless Facility Services	Laundry and dry-cleaning services	1.7 km (S)	Low
Dial a Dump Industries	Waste processing (non-thermal treatment)	2.5 km (SW)	Low

Figure 8 Location of Nearby Industrial Sources

4.3 Other Sources

There is potential for additional industrial and commercial activities to be present in the local area, that operate below the activity threshold specified for the relevant industry type, and hence do not need to report under the NPI program and do not have an EPA licence. Sources that potentially fall under this category could potentially impact on air quality within the Project Site, but on a smaller scale than those that are licenced and/or are required to report under the NPI program.

During the site visit, a number of activities including warehousing, automotive workshops and restaurants were identified approximately 200m away from the Project Site. These operations would not be expected to have any significant potential for air quality impacts within the Project Site and have therefore been excluded from the dispersion modelling. No other activities with potential to impact the Project Site (eg service stations) were identified within 500 m from the Project Site.

5 Relevant Air Quality Criteria

A general overview of key air pollutants associated with emission sources identified in the vicinity of the Project Site is provided below. These pollutants are:

- airborne particulate matter; and
- products of combustion such as oxides of nitrogen (NO_X), carbon monoxide (CO), sulphur dioxide (SO_2) and volatile organic compounds (VOCs).

Section 7.1 of the Approved Methods outlines the impact assessment criteria for each of the above pollutants. The criteria listed in the Approved Methods are derived from a range of sources (including NHMRC, NEPC, WHO, ANZEEC and DoE). The criteria specified in the Approved Methods are the defining ambient air quality criteria for NSW, and are considered to be appropriate for the setting.

5.1 Particulate Matter

5.1.1 Suspended Particulate

Airborne contaminants that can be inhaled directly into the lungs can be classified on the basis of their physical properties as gases, vapours or particulate matter. In common usage, the terms “dust” and “particulates” are often used interchangeably. The term “particulate matter” refers to a category of airborne particles, typically less than 30 microns (µm) in diameter and ranging down to 0.1 µm and is termed total suspended particulate (TSP).

The annual goal for TSP recommended by the NSW EPA is 90 micrograms per cubic metre of air (µg/m^3). The TSP goal was developed before the more recent results of epidemiological studies which suggested a relationship between health impacts and exposure to concentrations of finer particulate matter.

Emissions of particulate matter less than 10 µm and 2.5 µm in diameter (referred to as PM_{10} and $PM_{2.5}$ respectively) are considered important pollutants due to their ability to penetrate into the respiratory system. In the case of the $PM_{2.5}$ category, recent health research has shown that this penetration can occur deep into the lungs. Potential adverse health impacts associated with exposure to PM_{10} and $PM_{2.5}$ include increased mortality from cardiovascular and respiratory diseases, chronic obstructive pulmonary disease and heart disease, and reduced lung capacity in asthmatic children.

The NSW EPA PM_{10} assessment goals set out in the Approved Methods are as follows:

- a 24-hour maximum of 50 µg/m^3; and,
- an annual average of 25 µg/m^3.

The NSW EPA $PM_{2.5}$ assessment goals set out in the Approved Methods are as follows:

- a 24-hour maximum of 25 µg/m^3; and,
- an annual average of 8 µg/m^3.

A summary of the particulate guidelines is shown in **Table 2**.

Table 2 EPA Goals for Particulates

Pollutant	Averaging Time	Goal
TSP	Annual	90 µg/m^3
PM_{10}	24 Hours Annual	50 µg/m^3 25 µg/m^3
$PM_{2.5}$	24 Hours Annual	25 µg/m^3 8 µg/m^3

5.1.2 Deposited Particulate

The preceding section is concerned in large part with the health impacts of airborne particulate matter. Nuisance impacts also need to be considered, mainly in relation to deposited dust.

In NSW, accepted practice regarding the nuisance impact of dust is that dust-related nuisance can be expected to impact on residential areas when annual average dust deposition levels exceed 4 grams per square metre per month (g/m^2/month).

Table 3 presents the impact assessment goals set out in the Approved Methods for dust deposition, showing the allowable increase in dust deposition level over the ambient (background) level to avoid dust nuisance.

Table 3 EPA Goals for Allowable Dust Deposition

Averaging Period	Maximum Increase in Deposited Dust Level	Maximum Total Deposited Dust Level
Annual	2 g/m^2/month	4 g/m^2/month

Source: Approved Methods, NSW EPA 2017.

5.2 Oxides of Nitrogen

Oxides of nitrogen (NO_X) is a general term used to describe any mixture of nitrogen oxides formed during combustion. In atmospheric chemistry NO_X generally refers to the total concentration of nitric oxide (NO) and nitrogen dioxide (NO_2).

NO is a colourless and odourless gas that does not significantly affect human health. However, in the presence of oxygen, NO can be oxidised to form NO_2 which can have significant health effects including damage to the respiratory tract and increased susceptibility to respiratory infections and asthma. Long term exposure to NO_2 can lead to lung disease.

The majority of NO_X emissions from vehicles is in the form of NO with only a small proportion emitted as NO_2. However, as noted above, NO will be converted to NO_2 in the atmosphere after leaving a car exhaust and this needs to be considered when assessing potential air quality impacts from traffic emissions.

The goals specified within the Approved Methods for NO_2 are provided in **Table 4**.

Table 4 Assessment Criteria for Nitrogen Dioxide (NO_2)

Pollutant	Averaging Period	Criteria
NO_2	1-hour	12 pphm (246 µg/m^3)
	Annual	3 pphm (62 µg/m^3)

Note: pphm = parts per hundred million

5.3 Carbon Monoxide

Carbon monoxide (CO) is an odourless, colourless gas formed from the incomplete burning of fuels in motor vehicles. CO bonds to the haemoglobin in the blood and reduces the oxygen carrying capacity of red blood cells, thus decreasing the oxygen supply to the tissues and organs, in particular the heart and the brain.

CO can be a common pollutant at the roadside and highest concentrations are found at the kerbside with concentrations decreasing rapidly with increasing distance from the road. Ambient CO concentrations in urban areas result almost entirely from vehicle emissions and its spatial distribution generally follows that of traffic flow. The goals specified within the Approved Methods for CO are provided in **Table 5**.

Table 5 Assessment Criteria for Carbon Monoxide (CO)

Pollutant	Averaging Period	Criteria
CO	15-min	87 ppm (100 mg/m^3)
	1-hour	25 ppm (30 mg/m^3)
	8-hour	9 ppm (10 mg/m^3)

Note: ppm = parts per million

5.4 Sulphur Dioxide

Sulphur dioxide (SO_2) is a colourless, pungent gas with an irritating smell. When present in sufficiently high concentrations, exposure to SO_2 can lead to impacts on the upper airways in humans (i.e. the noise and throat irritation). SO_2 can also mix with water vapour to form sulphuric acid (acid rain) which can damage vegetation, soil quality and corrode materials.

The main sources of SO_2 in the air are industries that process materials containing sulphur (i.e. wood pulping, paper manufacturing, metal refining and smelting, textile bleaching, wineries etc.). SO_2 is also present in motor vehicle emissions, however since Australian fuels are relatively low in sulphur, high ambient concentrations are not common.

Table 6 Assessment Criteria for Sulphur Dioxide (SO_2)

Pollutant	Averaging Period	Criteria
SO_2	10-min	25 pphm (712 µg/m^3)
	1-hour	20 pphm (570 µg/m^3)
	24-hour	8 pphm (228 µg/m^3)
	Annual	2 pphm (60 µg/m^3)

Note: pphm = parts per hundred million

5.5 Volatile Organic Compounds

Volatile Organic Compounds (VOCs) are organic compounds (i.e. contain carbon) that have high vapour pressure at normal room-temperature conditions. Their high vapour pressure leads to evaporation from liquid or solid form and emission release to the atmosphere.

VOCs are emitted by a variety of sources, including motor vehicles, chemical plants, automobile repair services, painting/printing industries, and rubber/plastics industries. VOCs that are often typical of these sources include benzene, , toluene, ethylbenzene and xylenes (often referred to as 'BTEX'). Biogenic (natural) sources of VOC emissions are also significant (e.g. vegetation).

Impacts due to emissions of VOCs can be health or nuisance (odour) related. Benzene is a known carcinogen and a key VOC linked with the combustion of motor vehicle fuels. The impact assessment criteria specified within the Approved Methods for BTEX compounds are provided in **Table 7**.

Table 7 Impact Assessment Criteria for VOCs

Pollutant	Averaging Period	Criterion*
Benzene	1-hour	0.029 mg/m^3
Toluene	1-hour	0.36 mg/m^3
Ethylbenzene	1-hour	8.0 mg/m^3
Xylenes	1-hour	0.19 mg/m^3

* Gas volumes are expressed at 25°C and at an absolute pressure of 1 atmosphere (101.325 kPa)

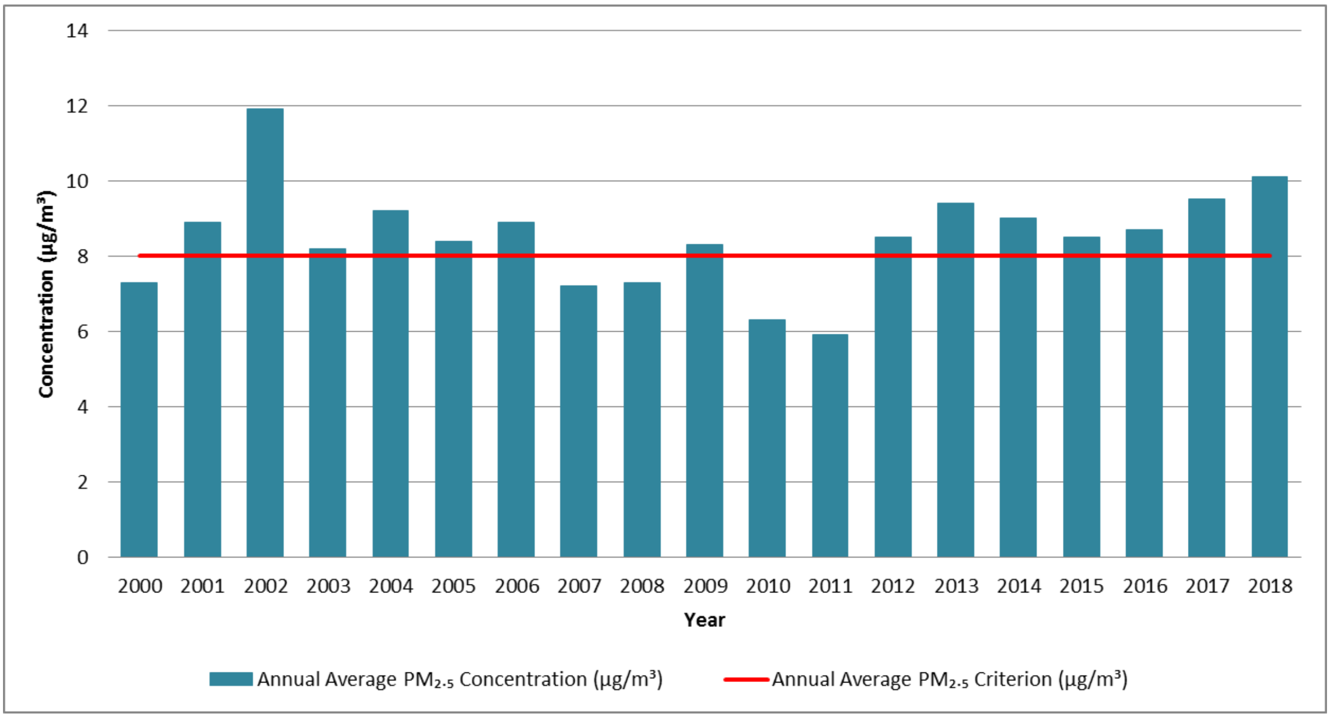
6 Background Air Quality

Air quality is generally good in New South Wales based on information from the 43 station NSW Air Quality Monitoring Network. For 2014-2018, the air quality was 'very good', 'good' or 'fair' for 93% of days in the Sydney central-east region. During this time, exceedances of the national air quality standards for particle pollution have usually been associated with regional dust storms and vegetation fires (NSW Government, 2017) (NSW OEH, 2017b) (NSW OEH, 2019).

PM_{10} concentrations vary across years with higher levels and more exceedances occurring in bushfire and dust storm affected years. Dry El Niño years (2002–2007) have been associated with a greater frequency of bushfires and dust storms, and therefore higher particle pollution levels. Lower particle pollution levels have occurred during wetter La Niña years (2010–2012).

Annual average $PM_{2.5}$ levels in Sydney are comparable to levels in other Australian cities and are low by world standards, according to a global comparison of air pollution levels conducted by the World Health Organisation (WHO) in 2016. The Australian annual average $PM_{2.5}$ standard is more stringent than standards or guideline values set by the European Union, United States and the WHO. As a result, the annual average $PM_{2.5}$ guideline is frequently exceeded in the Sydney Metropolitan area. **Figure 9** illustrates the maximum annual average $PM_{2.5}$ concentrations in the Sydney Region between 2000 and 2018. It is noted that exceedances were recorded for 14 of the last 19 years.

Figure 9 Maximum Annual Average $PM_{2.5}$ Concentrations Recorded at Sydney Monitoring Stations



The NSW EPA has a number of initiatives and strategies in place to address particle pollution and improve air quality. Some major initiatives relevant to the management of ambient $PM_{2.5}$ concentrations include:

- **Leading the Clean Air for NSW strategy** - the NSW Government's 10-year plan to improve air quality across the state includes initiatives relating to industry, transport vehicles and fuels, household emissions, monitoring and forecasting air quality and climate policy co-benefit actions.

- **The Sydney Particle Characterisation Study** involved analysis of existing $PM_{2.5}$ datasets for four Sydney sampling sites. Positive Matrix Factorisation (PMF) source apportionment was undertaken based on samples collected at Lucas Heights, Richmond, Mascot and Liverpool over a 15 year period (2000-2014).
- **Administering the Interagency Taskforce on Air Quality in NSW** that develops cross government recommendations and actions to improve air quality standards, and coordinates communication of government actions to manage significant air quality issues in NSW.
- **Managing the Diesel and Marine Emissions Management Strategy** that sets out measures to reduce emissions from non-road diesel equipment, such as construction and coal mining equipment, locomotives and shipping.
- **Managing particles and improving air quality in NSW** - a strategy to reduce particle pollution from sources such as coal mines, non-road diesel machinery, shipping and wood smoke.
- **Managing the Dust Stop program** that aims to ensure coal mines implement the most reasonable and feasible particulate control options. The program is being implemented through a series of pollution reduction programs attached to each coal mine licence.
- **Managing and updating the Air Emissions Inventory for the Greater Metropolitan Region (GMR) in NSW** which informs the community about emissions and their sources for hundreds of different air pollutants in the GMR, where about 75% of the NSW population lives.
- **Coordinating or contributing to various air quality studies** to add to evidence and improve knowledge related to air quality and its impacts, for use in future planning decisions and to inform policy development.
- **Managing the load-based licensing scheme and pollution reduction programs** to support industries in reducing emissions.

Through these programmes, sources of $PM_{2.5}$ in NSW are being studied and managed to ensure that the regional background concentrations that residents within Sydney, including future residents of the Project Site, are exposed to, are minimised as much as practicable.

6.1 Review of NSW ESS Ambient Air Quality Monitoring Data

The NSW Department of Planning, Industry and Environment's Environment, Energy and Science group (EES) maintains a network of air quality monitoring stations (AQMS)across NSW. The nearest such ESS station is located at Rozelle, approximately 5.0 km to the northwest of the Project Site. Other nearby stations include Randwick and Earlwood, which are located approximately 5.2 km southeast and 6.9 km southwest of the Project Site respectively (see **Figure 4**). Brief comments on these stations are provided below:

- The Rozelle AQMS was commissioned in 1978 and is located in the grounds of Rozelle Hospital, off Balmain Road, Rozelle. It is situated in a residential area in the Parramatta River valley and is at an elevation of 22 m.
- The Randwick AQMS was commissioned in 1995 and is located in the grounds of the Randwick Army Barracks, on the corner of Avoca and Bundock Streets, Randwick. It is situated in the eastern suburbs of Sydney in a residential area and is at an elevation of 28 m.
- The Earlwood AQMS was commissioned in 1978 and is located in Beaman Park, off Riverview Road, Earlwood. It is situated in a residential area in the Cook's River valley at an elevation of 6 m.

Due to the presence of trees within 20 m of the Rozelle AQMS, the clear sky angle is less than 120° which means this station does not currently comply with Australian Standard AS/NZS 3580.1.1:2007 - *Methods for sampling and analysis of ambient air - Guide to siting air monitoring equipment*. Earlwood AQMS does not currently comply with the Australian Standard due to the same reason. Therefore, data from the Randwick AQMS have been used for the contemporaneous cumulative impact assessment, which is required for a Level 2 AQA (as per the Approved Methods). Data from the Randwick AQMS have been supplemented by data from the Earlwood and Rozelle AQMSs to address $PM_{2.5}$ and CO data gaps. The air pollutants currently measured by the Randwick, Earlwood and Rozelle AQMSs are presented in **Table 8**.

Table 8 Air Pollutants Measured by Nearby Monitoring Stations

Air Quality Indicator	Rozelle AQMS	Randwick AQMS	Earlwood AQMS
Ozone (O_3)	✓	✓	✓
Oxides of nitrogen (NO, NO_2 & NO_X)	✓	✓	✓
Sulphur dioxide (SO_2)	✓^	✓	×
Fine particles less than 10 microns (PM_{10})	✓	✓	✓
Fine particles less than 2.5 microns ($PM_{2.5}$)	✓^	✓*	✓
Carbon monoxide (CO)	✓	×	✓^

^ 2015 onwards

* 2017 onwards

Air quality monitoring data recorded by the Randwick AQMS were obtained for the calendar years 2014 - 2018 and are summarised in **Table 9**. To be consistent with the NSW ESS monitoring reports, the data for gaseous pollutants are presented in parts per hundred million (pphm) or parts per million (ppm), rather than $\mu g/m^3$ and mg/m^3 as used in **Section 5**.

A review of the data shows that exceedances of the 24-hour average PM_{10} criterion were recorded by the Randwick AQMS in 2015, 2017 and 2018. A review of the exceedances recorded during 2015 (NSW OEH, 2017),2017 (NSW OEH, 2017b) and 2018 (NSW OEH, 2019)indicates that they were due to natural events such as bushfires or dust storms, or hazard reduction burns.

Exceedances of the 24-hour average $PM_{2.5}$ criterion were also recorded by the Randwick AQMS in 2017 and 2018 (the only years for which $PM_{2.5}$ monitoring data was available from the Randwick AQMS at the time of retrieving the data). Ambient $PM_{2.5}$ concentrations often exceed the 24-hour and annual average criteria set out in the Approved Methods across the Sydney Greater Metropolitan Area.

Ambient concentrations of the gaseous pollutants SO_2 and NO_2 were below the relevant criteria for all years that data are available. In 2015, 2017 and 2018 maximum 1-hour average O_3 concentrations exceeding the criterion of 10 pphm were recorded. The 4-hour average O_3 concentrations exceeded the 8 pphm criterion in 2015, 2016 and 2017.

Table 9 Summary of Randwick AQMS Data (2014 – 2018)

Pollutant	Averaging Period	Criteria	Year	Randwick AQMS		Units
				Maximum Concentration	Number of Exceedances	
SO_2	1-hour	20 pphm	2014	2.6	0	pphm
			2015	3.1	0	pphm
			2016	3.4	0	pphm
			2017	2.9	0	pphm
			2018	2.1	0	pphm
	24-hour	8 pphm	2014	0.4	0	pphm
			2015	0.4	0	pphm
			2016	0.3	0	pphm
			2017	0.8	0	pphm
			2018	0.4	0	pphm
	Annual	2 pphm	2014	0.09	0	pphm
			2015	0.08	0	pphm
			2016	0.09	0	pphm
			2017	0.10	0	pphm
			2018	0.10	0	pphm
NO_2	1-hour	12 pphm	2014	4.7	0	pphm
			2015	4.3	0	pphm
			2016	4.4	0	pphm
			2017	4.1	0	pphm
			2018	4.0	0	pphm
	Annual	3 pphm	2014	0.6	0	pphm
			2015	0.8	0	pphm
			2016	0.8	0	pphm
			2017	0.7	0	pphm
			2018	0.7	0	pphm
Ozone	1-hour	10 pphm	2014	6.6	0	pphm
			2015	11.3	1	pphm
			2016	9.9	0	pphm
			2017	11.6	3	pphm
			2018	7.3	0	pphm
	4-hour	8 pphm	2014	6.1	0	pphm
			2015	8.5	2	pphm
			2016	9.0	2	pphm
			2017	10.2	12	pphm
			2018	6.9	0	pphm
PM_{10}	24-hour	50 µg/m³	2014	46	0	µg/m³
			2015	77	1	µg/m³
			2016	44	0	µg/m³

Pollutant	Averaging Period	Criteria	Year	Randwick AQMS		Units
				Maximum Concentration	Number of Exceedances	
			2017	56	1	µg/m³
			2018	96	5	µg/m³
	Annual	25 µg/m³	2014	18	0	µg/m³
			2015	19	0	µg/m³
			2016	18	0	µg/m³
			2017	19	0	µg/m³
			2018	21	0	µg/m³
$PM_{2.5}$	24-hour	25 µg/m³	2014	ND	ND	µg/m³
			2015	ND	ND	µg/m³
			2016	ND	ND	µg/m³
			2017	45	1	µg/m³
			2018	31	1	µg/m³
	Annual	8 µg/m³	2014	ND	ND	µg/m³
			2015	ND	ND	µg/m³
			2016	ND	ND	µg/m³
			2017	7.0*	0	µg/m³
			2018	7.6	0	µg/m³

Notes:
ND- No data
* Based on approximately 9 months of data as $PM_{2.5}$ monitoring commenced end of March 2017

As outlined above, limited $PM_{2.5}$ data and no CO data are available from the Randwick AQMS. In order to characterise background $PM_{2.5}$ concentrations for 2014 (concurrent with the meteorological modelling period), data from the next nearest ESS AQMSs with a full set of data, (Earlwood AQMS for $PM_{2.5}$ and Rozelle AQMS for CO) were used.

A comparison of the $PM_{2.5}$ data available from the Earlwood AQMS during 2017 with that recorded by the Randwick AQMS during the same period shows that on average, the 24-hour average $PM_{2.5}$ concentration was approximately 11% higher than that recorded by the Randwick Station. Therefore, the use of Earlwood data is considered conservative.

$PM_{2.5}$ data recorded by the Earlwood AQMS was obtained for the calendar years 2014 - 2018 and is summarised in **Table 10**. Exceedances of the 24-hour average $PM_{2.5}$ criterion were recorded by the Earlwood AQMS in all years except 2014. As noted above, ambient $PM_{2.5}$ concentrations often exceed the 24-hour and annual average criterion set out in the Approved Methods across the Sydney Greater Metropolitan Area.

CO data recorded by the Rozelle AQMS was obtained for the calendar years 2014 - 2018 and is summarised in **Table 11**. No exceedances of the 1-hour average and 8-hour average CO criteria were recorded by the Rozelle AQMS over this period.

Table 10 Summary of Earlwood $PM_{2.5}$ Data (2014 – 2018)

Pollutant	Averaging Period	Criteria	Year	Earlwood AQMS		Units
				Maximum Concentration	Number of Exceedances	
$PM_{2.5}$	24-hour	25 µg/m³	2014	23	0	µg/m³
			2015	28	2	µg/m³
			2016	33	5	µg/m³
			2017	51	2	µg/m³
			2018	29	1	µg/m³
	Annual	8 µg/m³	2014	7.8	0	µg/m³
			2015	8.5	1	µg/m³
			2016	8.1	1	µg/m³
			2017	7.3	0	µg/m³
			2018	7.8	0	µg/m³

Table 11 Summary of Rozelle AQMS CO Data (2014 – 2018)

Pollutant	Averaging Period	Criteria	Year	Rozelle AQMS		Units
				Maximum Concentration	Number of Exceedances	
CO	1-hour	25 ppm	2013	1.4	0	ppm
			2014	1.6	0	ppm
			2015	1.7	0	ppm
			2016	1.2	0	ppm
			2017	1.0	0	ppm
	8-hour	9 ppm	2013	1.1	0	ppm
			2014	1.1	0	ppm
			2015	1.2	0	ppm
			2016	0.9	0	ppm
			2017	0.7	0	ppm

7 Assessment Methodology

The key issues identified for air quality at the Project Site are emissions of combustion products and particulate matter from the surrounding road network. Emissions from the closest surrounding roads were modelled using the GRAMM/GRAL modelling system to predict the incremental impact of these emissions across the Project Site. Regional monitoring data available from the NSW ESS ambient monitoring networks (see **Section 6.1**) were then used to assess the potential cumulative concentrations of these pollutants that future residents of the Project Site would potentially be exposed to, and to assess compliance against relevant air quality guidelines.

As outlined in **Section 4.1**, atmospheric pollutants emitted from road traffic include NO_x, $PM_{2.5}$, PM_{10}, SO_2 and TVOCs. Given the low level of CO and SO_2 emissions from vehicles and the low ambient concentrations recorded in Sydney (see **Section 6.1**), it is reasonable to assume that CO and SO_2 emissions from road traffic are highly unlikely to result in any exceedances of the relevant criteria (see **Section 5**) at the Project Site. SLR's experience in modelling VOC emissions from roads, has shown that kerbside concentrations of VOCs are typically well below the relevant air quality guidelines. Moreover, a review of the Air Quality Impact Assessment prepared for M4 East (Pacific Environment, 2015), which will have significantly higher traffic volumes than the roads surrounding the Project Site, shows that the ground level VOC concentrations at receptors are well below the relevant assessment criteria. Hence, CO, SO_2 and TVOC traffic emissions have not been considered further in this assessment and only emissions of NO_X, PM_{10} and $PM_{2.5}$ have been modelled.

No other sources of air pollutants were identified in the local area with the potential to have any significant impacts on air quality at the Project Site.

In addition to the above, emission sources within the Project Site (e.g. food outlets) could potentially lead to amenity/nuisance impacts at surrounding sensitive receptors or at residential locations within the Project Site itself. As detailed information on the type and scale of these facilities is not available at this stage, impacts from these potential sources have not been assessed further in this AQA. However, it is recommended that assessment of any potentially air polluting activities proposed within the Project Site be carried out during the detailed design stage so that appropriate mitigation measures are adopted to reduce the risk of any exceedances of the relevant air quality criteria.

7.1 Estimation of Traffic Emissions

Individual vehicle emissions are a combination of emissions produced by:

- the engine;
- the fuel system;
- the braking system; and
- materials from the road surface disturbed by the wheels and by air movement around the vehicle.

The principal factors that influence the generation of traffic air pollution, and thus the potential for air quality impacts, are:

- Traffic volume – the total numbers of cars on the road and diurnal pattern of traffic numbers throughout the day.
- Vehicle type – pollutant emission rates are different for different vehicle types (e.g. passenger cars versus heavy duty vehicles).

- Vehicle age – older vehicles will tend to produce higher emission rates than newer vehicles. Newer vehicles are subject to more stringent emission standards, and also vehicles will tend to become less efficient as they age and engine components wear.
- Fuel type – the combustion of petrol, diesel, ethanol-blends, natural gas fuels emit the various constituent pollutants at different rates, and therefore the rate of emissions will vary by the fleet engine composition.
- Road gradient – driving uphill results in a greater load on the engine and thus higher pollutant emission rates. If the average road gradient is larger than a value of about 2%, the emissions of ascending and descending vehicles do not balance each other, even if the traffic is the same in the two directions. That is, the lower emissions in the downhill direction do not balance the higher emissions of the uphill direction.
- Driving conditions and average traffic speed – vehicle speed is normally assumed to be represented by the posted speed limit. Emissions from congested traffic are greater than for free-flowing traffic.
- Other driver behaviour and vehicle operating conditions, such as:
  - air conditioner use;
  - braking and acceleration patterns;
  - gear operations;
  - maintenance;
  - engine temperature; and
  - ambient temperature.

A spatial emissions inventory was developed for the emissions of NO_X, PM_{10} and $PM_{2.5}$ from vehicles travelling on the main roads surrounding the Project Site using the 'Computer Programme to calculate Emissions from Road Transport' (COPERT) Australia software. The most important input to COPERT Australia is a detailed breakdown of the total number of on-road vehicles for 226 vehicle classes (Uniquest, 2014). The vehicle classifications used in COPERT Australia are presented in **Table 12**. Multiplying the hourly traffic volumes by the length of the road segment gives an estimate of the hourly vehicle kilometres travelled (VKT). The information on VKT is then used to estimate emission levels by the COPERT software using emission factors in g/km or g/VKT. Information on the parameters used as input to COPERT Australia is presented in detail in **Appendix A**.

Table 12 COPERT Australia Vehicle Classifications

Main Category	Sub Category	Fuel Type	Emission Control Standard
Passenger car	Small (<2.0 litre) Medium (2.0-3.0 litre) Large (>3.0 litre)	Petrol Diesel LPG E10	Uncontrolled ADR27 ADR37/00-01 ADR79/00-05
SUV	Compact (< 4.0 litre) Large (>4.0 litre)	Petrol Diesel E10	Similar to PC +ADR36 (SUV-L) +ADR30 (SUV-Diesel)
Light Commercial Vehicle	Gross Vehicle Mass < 3.5 tonnes	Petrol Diesel	Uncontrolled ADR36 (P) ADR30(D) ADR37/00-01 ADR79/00-05
Heavy Duty Truck	Medium (MCV 3.5-12.0 tonnes) Heavy (HCV 12.0-25.0 tonnes) Articulated (AT >25 tonnes)	Petrol Diesel LPG	Uncontrolled ADR30 ADR70 ADR80/00 ADR80/02-05
Bus	Light bus (<8.5 tonnes) Heavy bus (>8.5 tonnes)	Diesel	
Moped	2-Stroke 4 Stroke	Petrol	Conventional; Euro 1-3
Motorcycle	2-Stroke; 4-Stroke <250 cm^3 4-Stroke 250-750 cm^3 4-Stroke >750 cm^3		

7.1.1 Assumptions Used to Compile COPERT Input Parameters

The COPERT Australia input data file requires detailed information on vehicle counts within each vehicle sub-category, fuel type and emission control standard listed in **Table 12**. However such detailed information on the distribution of vehicles is not publicly available for the roads surrounding the Project Site. Therefore, in order to compile the COPERT Australia input files, the following assumptions were applied:

- The annual vehicle counts were subdivided into each sub category, fuel type and emission control standard using statistical data compiled for NSW by the National Pollutant Inventory (NPI) team of the Australian Government Department of the Environment (DSITIA, 2014), for use in preparing the Australian Motor Vehicle Emission Inventory for the NPI (see **Appendix A**).
- The emissions were estimated for a nominal 1 km length of road based on a low vehicle speed of 10 km/hr (potential worst case emission rate that would be representative of congested traffic conditions).
- Meteorological conditions, including maximum and minimum temperature and relative humidity were estimated based on available long term average data for the Sydney region (see **Appendix A**).

7.1.2 Peak Traffic Volumes

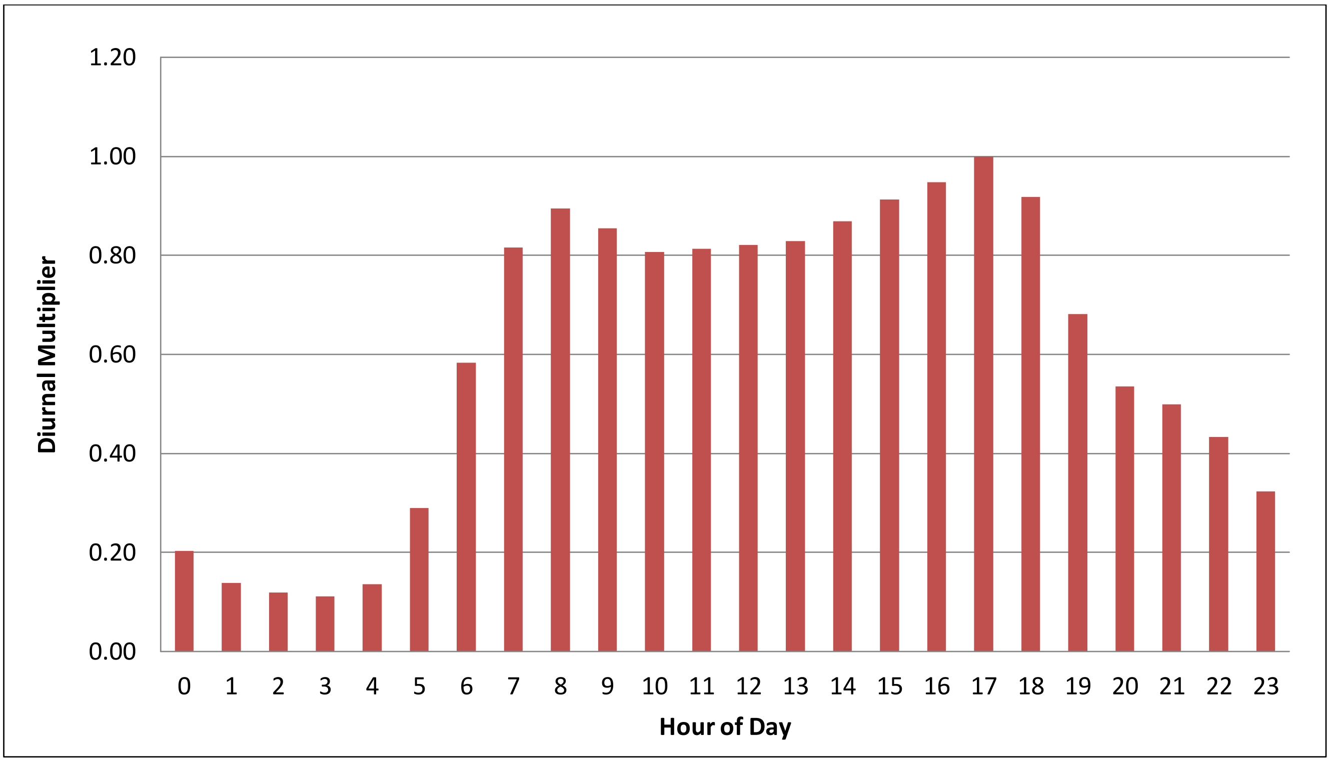
Predicted peak 1-hour traffic volumes with the Project Site in place were provided by Jacobs for use in this assessment. Afternoon peak (5 – 6 pm) traffic volume data for the surrounding roads is presented in **Table 13**.

Traffic surveys performed by Jacobs to establish the baseline traffic volumes mainly covered the morning and afternoon peak periods, information on the diurnal variation in traffic flows for the roads surrounding the Project Site was not obtained during these surveys. Therefore, information on the diurnal variation of traffic on Regent Street (Station ID: 02385 – 10 m north of James Street, Redfern) was obtained from the RMS Traffic Volume Viewer and used to estimate a 'diurnal multiplier' for the roads assessed in this study. As illustrated in **Figure 10**, the diurnal multiplier for each hour of day is the ratio of the reported traffic volume for that hour to the afternoon peak hour (5 – 6 pm) traffic volume.

Table 13 Peak Traffic Volumes – Road Network Surrounding the Project Site

ID	Road Link Name	Peak Volume (vehicles/hour)
1111	Elizabeth Street Northbound - Phillip Street to Redfern Street	677
1112	Elizabeth Street Southbound - Redfern Street to Phillip Street	973
1113	Phillip Street Eastbound - Elizabeth Street to Walker Street	378
1114	Phillip Street Westbound - Walker Street to Elizabeth Street	300
1115	Phillip Street Eastbound - Walker Street to Morehead Street	365
1116	Phillip Street Westbound - Morehead Street to Walker Street	283
1117	Redfern Street Eastbound - Elizabeth Street to Walker Street	215
1118	Redfern Street Eastbound - Walker Street to Morehead Street	148
1119	Walker Street Southbound - Redfern Street to Kettle Street	78
1120	Walker Street Southbound - Kettle Street to Phillip Street	71
1121	Kettle Street Eastbound - Walker Street to Morehead Street	24
1122	Kettle Street Eastbound - Elizabeth Street to Walker Street	2
1123	Redfern Street Westbound - Walker Street to Elizabeth Street	242
1124	Redfern Street Westbound - Morehead Street to Walker Street	231
1125	Walker Street Northbound - Kettle Street to Redfern Street	80
1126	Walker Street Northbound - Phillip Street to Kettle Street	20
1127	Kettle Street Westbound - Morehead Street to Walker Street	56
1128	Kettle Street Westbound - Walker Street to Elizabeth Street	2

Figure 10 Diurnal Variation of Traffic on O'Riordan Street



7.1.3 Road Gradients and Lengths

The average gradient of each road link was estimated using high-resolution terrain data obtained from the Foundation Spatial Data Framework website. Elevation above sea level of the start and end points for each road link was determined and the average gradient was estimated based on the difference in the height of the start and end points (road link rise) and the approximate length of the road link. Estimated road link length, height and gradients are presented in **Table 14.**

Emission factors prepared using COPERT are not gradient dependent. Therefore, correction factors derived from emission factors published by PIARC (PIARC, 2012) were applied to the COPERT emission factors. These are presented in **Table 15**.

Table 14 Estimated Road Link Length, Height and Gradient

ID	Road Link Name	Road Link Length (m)	Road Link Rise (m)	Road Link Gradient (%)
1111	Elizabeth Street Northbound - Phillip Street to Redfern Street	330	2.1	1%
1112	Elizabeth Street Southbound - Redfern Street to Phillip Street	330	-2.1	-1%
1113	Phillip Street Eastbound - Elizabeth Street to Walker Street	100	-0.8	-1%
1114	Phillip Street Westbound - Walker Street to Elizabeth Street	100	0.8	1%
1115	Phillip Street Eastbound - Walker Street to Morehead Street	90	3.9	4%
1116	Phillip Street Westbound - Morehead Street to Walker Street	90	-3.9	-4%
1117	Redfern Street Eastbound - Elizabeth Street to Walker Street	100	6.3	6%
1118	Redfern Street Eastbound - Walker Street to Morehead Street	90	-1.3	-1%
1119	Walker Street Southbound - Redfern Street to Kettle Street	160	-8.1	-5%
1120	Walker Street Southbound - Kettle Street to Phillip Street	140	-1.0	-1%
1121	Kettle Street Eastbound - Walker Street to Morehead Street	90	6.1	7%
1122	Kettle Street Eastbound - Elizabeth Street to Walker Street	60	0.0	0%
1123	Redfern Street Westbound - Walker Street to Elizabeth Street	100	-6.3	-6%
1124	Redfern Street Westbound - Morehead Street to Walker Street	90	1.3	1%
1125	Walker Street Northbound - Kettle Street to Redfern Street	160	8.1	5%
1126	Walker Street Northbound - Phillip Street to Kettle Street	140	1.0	1%
1127	Kettle Street Westbound - Morehead Street to Walker Street	90	-6.1	-7%
1128	Kettle Street Westbound - Walker Street to Elizabeth Street	60	0.0	0%

Table 15 Gradient Correction Factors for COPERT Emission Factors for Vehicles Travelling at 10 km/hr

Road Gradient	Particulate Matter Correction Factor	NO_2 Correction Factor
-8 %	45%	51%
-6 %	45%	51%
-4 %	46%	53%
-2 %	54%	63%
0 %	100%	100%
2 %	142%	130%
4 %	182%	160%
6 %	225%	175%
8 %	225%	175%

7.1.4 Estimated Emission Rates

The peak hourly NO_X, PM_{10} and $PM_{2.5}$ emission rates estimated using COPERT Australia for the road sections modelled in this assessment using the methodology outlined above are presented in **Table 16**.

Table 16 Estimated Emission Rates - Traffic

ID	Road Link Name	Emission Rates (kg/km/h)		
		NO_X	PM_{10}	$PM_{2.5}$
1111	Elizabeth Street Northbound - Phillip Street to Redfern Street	0.847	0.050	0.042
1112	Elizabeth Street Southbound - Redfern Street to Phillip Street	1.217	0.072	0.060
1113	Phillip Street Eastbound - Elizabeth Street to Walker Street	0.473	0.028	0.023
1114	Phillip Street Westbound - Walker Street to Elizabeth Street	0.375	0.022	0.019
1115	Phillip Street Eastbound - Walker Street to Morehead Street	0.732	0.049	0.041
1116	Phillip Street Westbound - Morehead Street to Walker Street	0.188	0.010	0.008
1117	Redfern Street Eastbound - Elizabeth Street to Walker Street	0.471	0.036	0.030
1118	Redfern Street Eastbound - Walker Street to Morehead Street	0.117	0.006	0.005
1119	Walker Street Southbound - Redfern Street to Kettle Street	0.050	0.003	0.002
1120	Walker Street Southbound - Kettle Street to Phillip Street	0.089	0.005	0.004
1121	Kettle Street Eastbound - Walker Street to Morehead Street	0.053	0.004	0.003
1122	Kettle Street Eastbound - Elizabeth Street to Walker Street	0.003	0.000	0.000
1123	Redfern Street Westbound - Walker Street to Elizabeth Street	0.155	0.008	0.007
1124	Redfern Street Westbound - Morehead Street to Walker Street	0.377	0.024	0.020
1125	Walker Street Northbound - Kettle Street to Redfern Street	0.175	0.013	0.011
1126	Walker Street Northbound - Phillip Street to Kettle Street	0.025	0.001	0.001
1127	Kettle Street Westbound - Morehead Street to Walker Street	0.036	0.002	0.002
1128	Kettle Street Westbound - Walker Street to Elizabeth Street	0.003	0.000	0.000

7.2 Dispersion Modelling

7.2.1 Model Selection

The GRAL modelling system was selected for the dispersion modelling of traffic emissions from roads surrounding the Project Site primarily due to its ability to take account of the localised effects of buildings and obstacles. Like the US-EPA CALPUFF model, GRAL is suitable for regulatory applications, it can utilise a full year of meteorological data and has the ability to handle low-wind-speed conditions.

GRAMM/GRAL is a coupled Eulerian (GRAMM, Graz Mesoscale Model wind fields) and Lagrangian (microphysics Graz Lagrangian Model) model, developed by the Graz University of Technology, Austria. It is designed to solve the sources accurately and to compute concentrations with a very high resolution in complex topographic and building configurations.

The Eulerian model GRAMM solves the conservation equations for mass, enthalpy, momentum and humidity. The surface energy balance is calculated in a surface module of GRAMM, where several different land use categories are used to define the surface roughness, the albedo, the emissivity, the soil moisture content, the specific heat capacity of the soil and the heat transfer coefficient.

The Lagrangian model GRAL uses 3D meteorological data generated by GRAMM and computes steady state concentration fields for classified meteorological conditions using 3-7 stability classes, 36 wind direction classes and several wind speed classes to reduce the computational time. Typically, 500-600 bins of meteorological scenarios are required to characterise the dispersion situations that may occur at a given site within a year. Each of the steady-state concentration fields is stored as a separate file. Based on these results, the concentration fields for the annual mean value, maximum daily mean value and maximum value are calculated using a post-processing routine. In this way, the annual average, maximum daily mean, or maximum concentration for defined periods can be computed rapidly. The pseudo time series of concentration field can be obtained by taking the corresponding time series of classified meteorological situations of a certain period and multiplying each concentration field corresponding to certain hours of that period with some emission modulation factors.

7.2.2 Accuracy of Modelling

All atmospheric dispersion models, including GRAL, represent a simplification of the many complex processes involved in the dispersion of pollutants in the atmosphere. To obtain good quality results it is important that the most appropriate model is used and the quality of the input data (meteorological, terrain, source characteristics) is adequate.

The main sources of uncertainty in dispersion models, and their effects, are discussed below.

- **Oversimplification of physics:** This can lead to both under-prediction and over-prediction of ground level pollutant concentrations. Errors are greater in Gaussian plume models as they do not include the effects of non-steady-state meteorology (i.e., spatially- and temporally-varying meteorology).
- **Errors in emission rates:** Ground level concentrations are proportional to the pollutant emission rate. In addition, most modelling studies assume constant worst case emission levels or are based on the results of a small number of stack tests, however operations (and thus emissions) are often quite variable. Accurate measurement of emission rates and source parameters requires continuous monitoring.
- **Errors in source parameters:** Plume rise is affected by source dimensions, temperature and exit velocity. Inaccuracies in these values will contribute to errors in the predicted height of the plume centreline and thus ground level pollutant concentrations.
- **Errors in wind direction and wind speed**: Wind direction affects the direction of plume travel, while wind speed affects plume rise and dilution of plume. Errors in these parameters can result in errors in the predicted distance from the source of the plume impact, and magnitude of that impact. In addition, aloft wind directions commonly differ from surface wind directions. The preference to use rugged meteorological instruments to reduce maintenance requirements also means that light winds are often not well characterised.
- **Errors in mixing height:** If the plume elevation reaches 80% or more of the mixing height, more interaction will occur, and it becomes increasingly important to properly characterise the depth of the mixed layer as well as the strength of the upper air inversion.
- **Errors in temperature:** Ambient temperature affects plume buoyancy, so inaccuracies in the temperature data can result in potential errors in the predicted distance from the source of the plume impact, and magnitude of that impact.
- **Errors in stability estimates:** Gaussian plume models use estimates of stability class, and 3D models use explicit vertical profiles of temperature and wind (which are used directly or indirectly to estimate stability class for Gaussian models). In either case, errors in these parameters can cause either under-prediction or over-prediction of ground level concentrations.

The US EPA makes the following statement in its Modelling Guideline (US EPA, 2005) on the relative accuracy of models:

> "Models are more reliable for estimating longer time-averaged concentrations than for estimating short-term concentrations at specific locations; and the models are reasonably reliable in estimating the magnitude of highest concentrations occurring sometime, somewhere within an area. For example, errors in highest estimated concentrations of ± 10 to 40% are found to be typical, i.e., certainly well within the often quoted factor-of-two accuracy that has long been recognised for these models. However estimates of concentrations that occur at a specific time and site, are poorly correlated with actually observed concentrations and are much less reliable."

To maximise the accuracy of the model predictions, this AQA utilises the GRAL dispersion model in prognostic mode, enabling the representation of dynamic effects due to local topography such as obstacle-influenced air flows, and accommodating complex topography with high a horizontal resolution. The meteorological dataset was compiled using observations from nearby automatic weather stations and a five year period of meteorological data was reviewed to ensure that the year selected for use in the modelling is representative of long-term meteorological conditions.

7.2.3 Dispersion Model Configuration

Emissions from the vehicles travelling on the surrounding road network with available traffic volume data were represented by a series of line sources. **Figure 11** illustrates the roads modelled as part of this study.

The proposed Project Site buildings as well as existing buildings and structures that may affect the dispersion of pollutants through channelling and blocking effects were included in the modelling. These buildings were taken into account using the advanced prognostic microscale wind field option and a 1.0 m horizontal grid resolution. Outlines of these building are illustrated in **Figure 11**. The heights for all buildings were determined using high resolution LIDAR data.

A total of 2,746 discrete receptors were distributed across the Project Site to predict the incremental impact of these surrounding roads on pollutant concentrations at potential residential areas (see **Figure 11**). The time series of hourly average pollutant concentrations predicted by GRAL for these discrete receptor locations were then added to contemporaneous background time series data for the same period as the meteorological data used in the modelling to allow an assessment of potential cumulative impacts.

In addition to the discrete receptors discussed above, the GRAL model was set up to predict concentrations across the modelling domain based on a Cartesian grid of points with an equal spacing of 1 m in the x and y directions. This results in 267,285 grid locations across the domain, which were used to produce contour plots.

In order to assess pollutant concentrations at various elevations, gridded receptors were located at 3 m, 6 m, 9 m and 12 m in addition to those located at 1 m above ground level (i.e. ground level receptors). Discrete receptors were located at 3 m intervals on building facades for all proposed buildings (see **Figure 12**).

The Ozone Limiting Method (OLM) was used for the conversion of modelled NO_X to NO_2 using contemporaneous hourly-varying 1-hour average ozone concentration data from the Randwick AQMS. This method assumes that all available ambient ozone will react instantaneously with the emitted NO to form NO_2. This is a conservative approach for near-source receptor locations as assessed in this study.

Figure 11 Modelled Road Sources, Buildings and Receptors

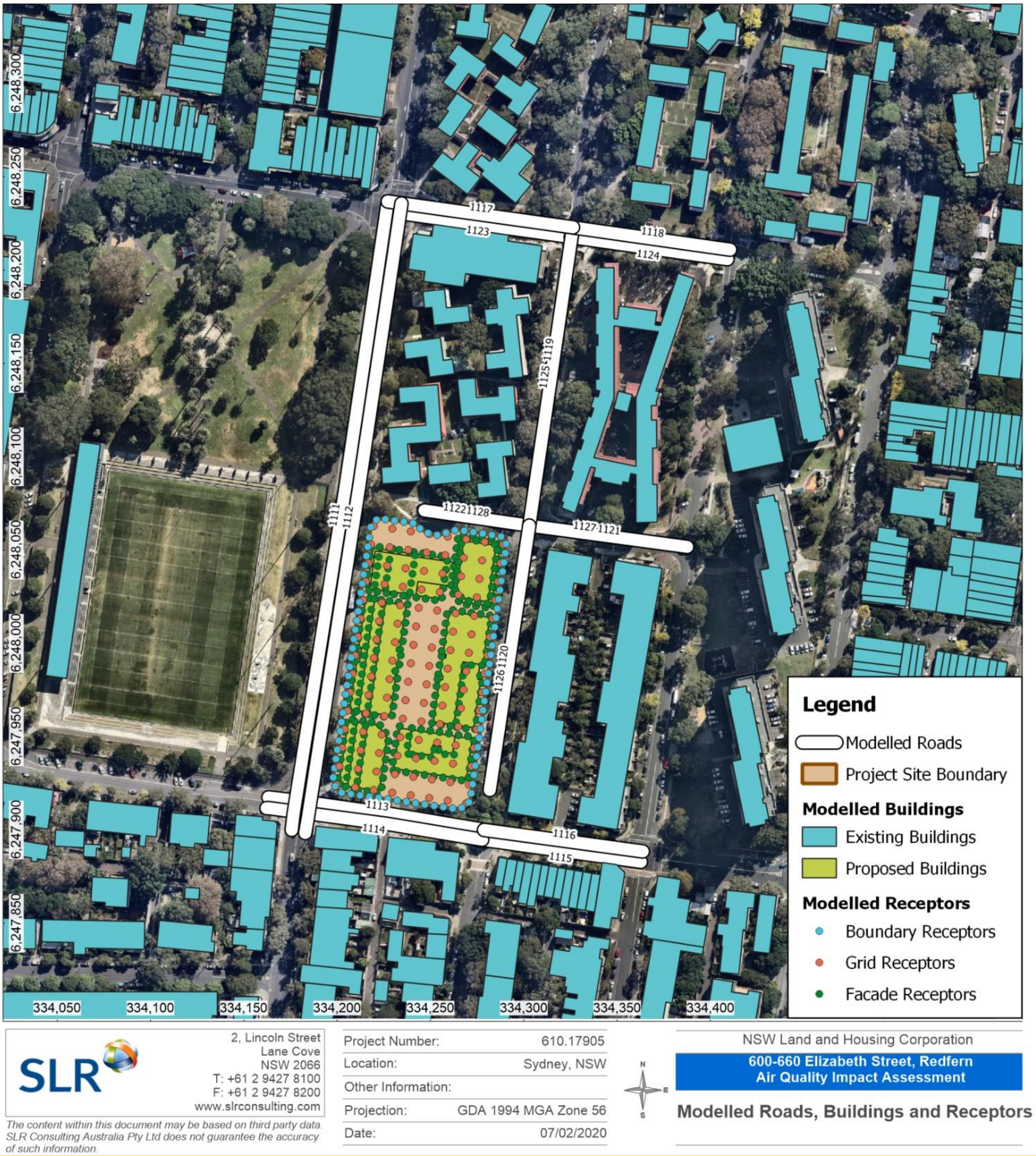
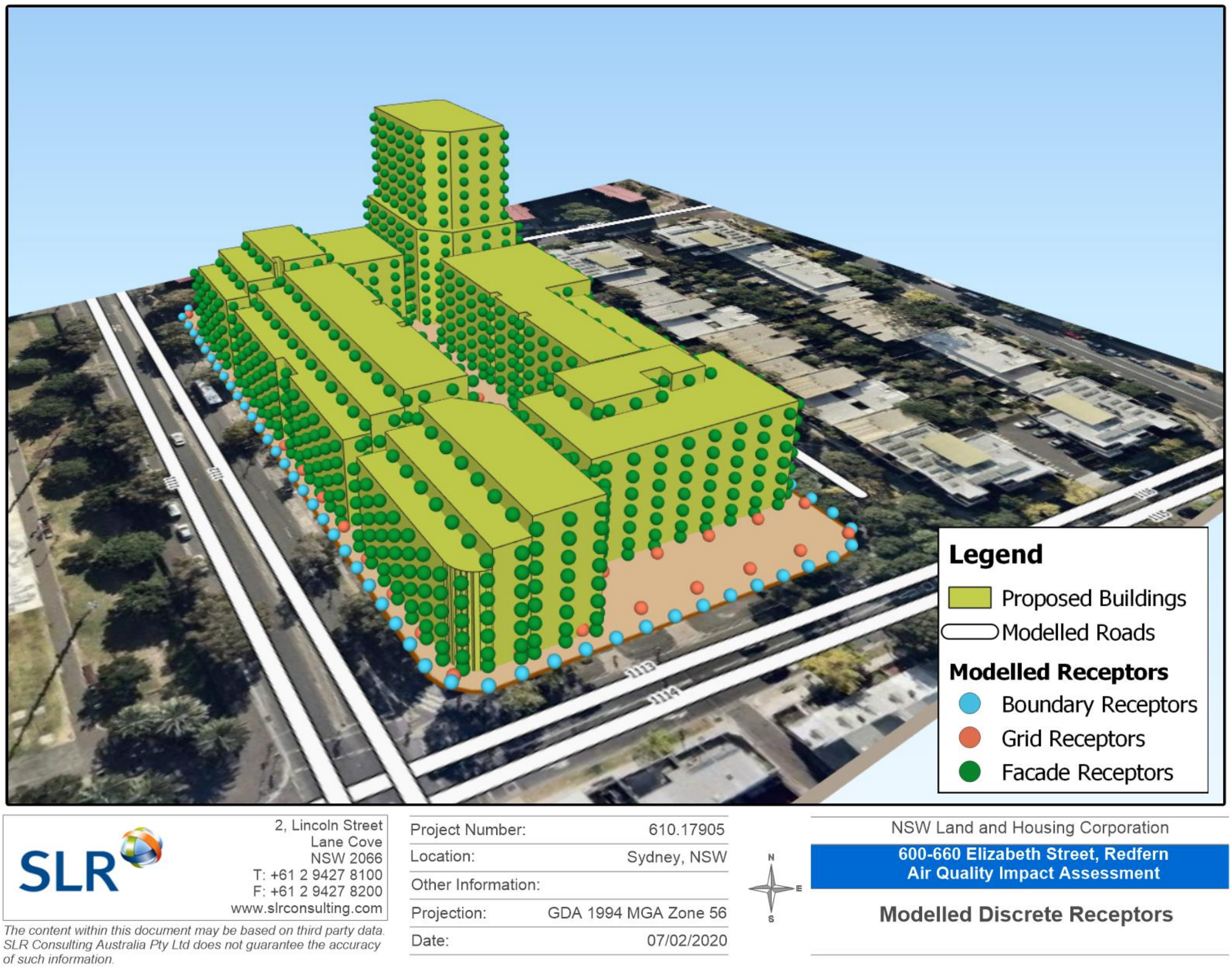


Figure 12 Modelled Discrete Receptors



7.3 Meteorological Modelling

To provide the meteorological data required by GRAMM, information is needed on the prevailing wind regime, mixing depth and atmospheric stability and other parameters such as ambient temperature and relative humidity. In absence of any site-specific observed meteorological data, a site-representative meteorological dataset was compiled using the CSIRO model TAPM, the US EPA's CALMET model and the GRAMM meteorological processor.

7.3.1 Selection of the Meteorological Year

In order to determine a representative meteorological year for use in the dispersion modelling, five years of meteorological data (2014-2018) from the Sydney Airport AWS and the Canterbury Racecourse AWS were analysed against the 5-year average meteorological conditions. Specifically, the following parameters were analysed:

- Percentage of calm wind speed events (wind speed <0.5 m/s): Calm wind conditions are conducive to higher concentrations of air pollutants due to poor dispersion of the plume.
- Wind speeds: Monthly average as well as hourly average observed at 9:00 am and 3:00 pm.

- Temperature: Monthly average as well as hourly average at 9:00 am and 3:00 pm.

Figure 13 presents the annual wind roses for the two BoM stations, which show relatively similar wind roses for all five years analysed. **Figure 14** illustrates average monthly wind speeds for the two stations and compares them against the 5-year average.

While the temperatures and average wind direction and wind speed frequencies for the years analysed were generally similar for each BoM station, the analysis showed a relatively higher frequency of calms and lower than average wind speeds for the year 2014. Using this year as the representative year would therefore be a conservative approach because low wind speeds are associated with less effective plume dispersion. No other parameters significantly deter the use of this year's data. Consequently, 2014 was selected as the representative year of meteorology.

As noted in **Section 6.1**, the ESS maintains a network of AQMSs across NSW that record wind speed and wind direction as well as air quality data. The nearest such ESS stations are located at Rozelle (approximately 5 km to the northeast of the Project Site), Randwick (approximately 5.2 km southeast of the Project Site) and Earlwood approximately 6.9 km southwest of the Project Site) (refer **Figure 4**).

As noted on the ESS website, the Rozelle and Earlwood monitoring stations do not currently comply with the relevant siting standards as the clear sky angle for both sites is < 120° due to trees within 20 m of the monitoring site. The data from the Randwick AQMS was reviewed to confirm it agreed with the BoM data summarised above.

Figure 13 Sydney Airport AWS and Canterbury Racecourse AWS Annual Wind Roses, 2014-2018

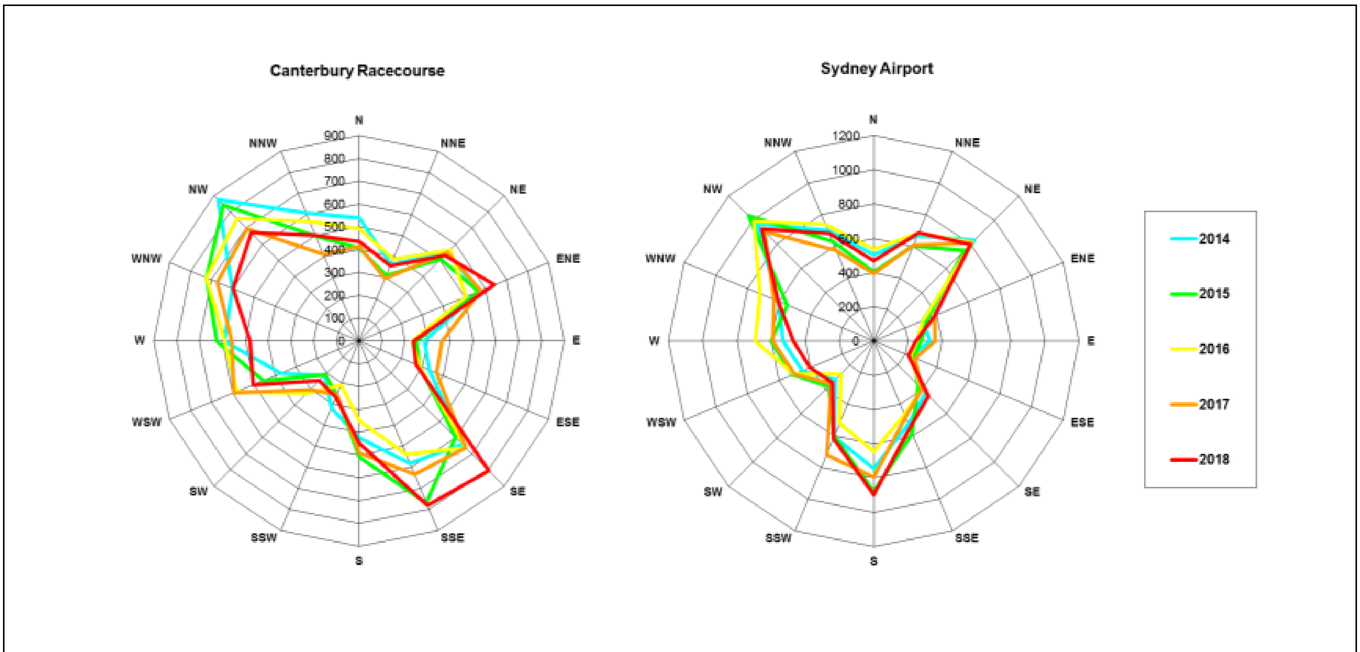
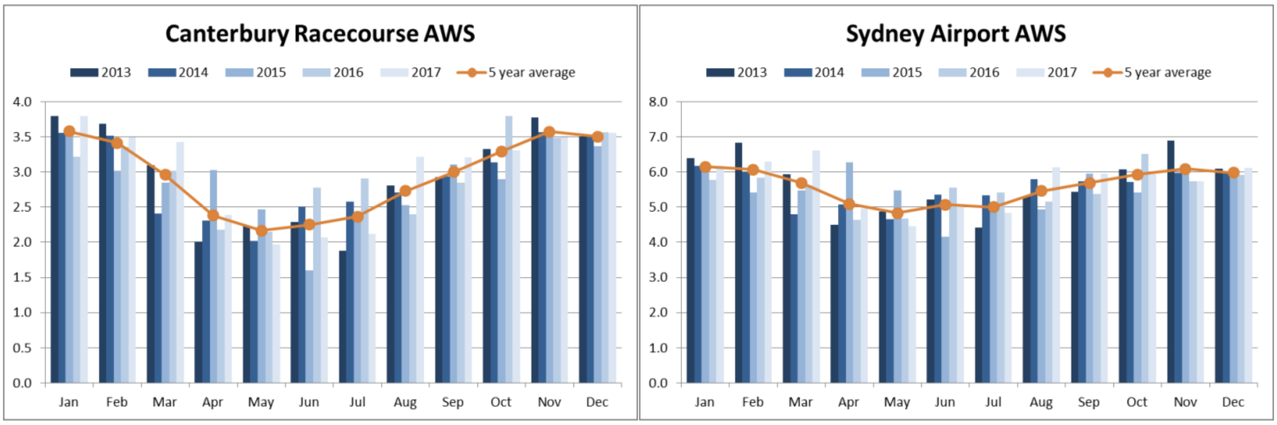


Figure 14 Sydney Airport and Canterbury Racecourse Monthly Average Wind Speeds, 2014-2018



7.3.2 TAPM

The TAPM prognostic model, developed by the Commonwealth Scientific and Industrial Research Organisation (CSIRO) was used to generate the three dimensional upper air data required for CALMET modelling (**Section 7.3.3**).

TAPM predicts wind speed and direction, temperature, pressure, water vapour, cloud, rain water and turbulence. The program allows the user to generate synthetic observations by referencing databases (covering terrain, vegetation and soil type, sea surface temperature and synoptic scale meteorological analyses) which are subsequently used in the model input to generate one full year of hourly meteorological observations at user-defined levels within the atmosphere.

Additionally, TAPM may assimilate actual local wind observations so that they can optionally be included in a model solution. The wind speed and direction observations are used to realign the predicted solution towards the observation values. Available observed meteorological data from the nearby BoM stations were incorporated into the TAPM setup. **Table 17** details the parameters used in the TAPM meteorological modelling for this assessment.

Table 17 Meteorological Parameters used for the AQA – TAPM

Parameter	Value
Modelling Period	1 January 2014 to 31 December 2014
Centre of analysis	332750 mE 6250232 mN (UTM Coordinates)
Number of grid points	35 × 35 × 35
Number of grids (spacing)	4 (30 km, 10 km, 3 km, 1 km)
Data assimilation	Sydney Airport AWS (Station # 66037) Canterbury Racecourse AWS (Station # 66194)
Terrain	AUSLIG 9 second DEM

7.3.3 CALMET

In order to further refine TAPM outputs, the CALMET model was used. In the simplest terms, CALMET is a meteorological model that develops hourly wind and other meteorological fields on a three-dimensional gridded modelling domain. Associated two dimensional fields such as mixing height, surface characteristics and dispersion properties are also included in the file produced by CALMET. The interpolated wind field is then modified within the model to account for the influences of topography, sea breeze, as well as differential heating and surface roughness associated with different land uses across the modelling domain. These modifications are applied to the winds at each grid point to develop a final wind field. The final hourly varying wind field thus reflects the influences of local topography and land uses.

CALMET modelling was conducted using the nested CALMET approach, where the final results from a coarse-grid run were used as the initial guess of a fine-grid run. This has the advantage that off-domain terrain features including slope flows, blocking effect can be allowed to take effect and the larger-scale wind flow provides a better start in the fine-grid run.

The outer domain was modelled with a resolution of 0.3 km. The TAPM-generated 3-dimensional meteorological data was used as the 'initial guess' wind field and the local topography and available surface weather observations in the area were used to refine the wind field predetermined by TAPM. Hourly surface meteorological data from BoM stations located at Sydney Airport and Canterbury Racecourse were incorporated in the outer domain modelling.

The output from the outer domain CALMET modelling was then used as the initial guess field for the inner domain CALMET modelling. A horizontal grid spacing of 0.1 km was used in the inner domain to adequately represent the important local terrain features and land use. Finer scale land use data were used in the inner domain run to refine the wind field parameters given by the coarse CALMET run. **Table 18** details the parameters used in the meteorological modelling to drive the CALMET model.

Table 18 Meteorological Parameters used for this Study – CALMET (v 6.42)

Outer Domain	
Meteorological grid	15 km × 15 km
Meteorological grid resolution	0.3 km
Surface station data	Sydney Airport AWS (Station # 66037) Canterbury Racecourse AWS (Station # 66194)
Initial guess filed	3D output from TAPM modelling
Inner Domain	
Meteorological grid	5 km × 5 km
Meteorological grid resolution	0.1 km
Initial guess field	3D output from outer domain modelling

7.3.4 GRAMM

The GRAMM domain was defined so that it covered the whole extent of the Project Site as well as the surrounding road network, with a sufficient buffer zone. The model was run with 100 m horizontal resolution and 15 vertical layers to adequately resolve surrounding topography and land use.

Topographical data used in GRAMM were sourced from the Geoscience Australia database that has corrected Shuttle Radar Topography Mission (SRTM) topography data for Australia with a 1 arc second (approximately 30 m) spacing. The land use data for the modelling domain was defined by CORINE land use categories using values specified for urban land use.

The site-representative predicted meteorological data extracted from the inner domain output from the CALMET model was used as input to the GRAMM model.

7.3.5 Meteorological Data Used in Modelling

7.3.5.1 Wind Speed and Direction

A summary of the annual wind behaviour predicted by CALMET, extracted at a location within the Project Site is presented as wind roses in **Figure 15**.

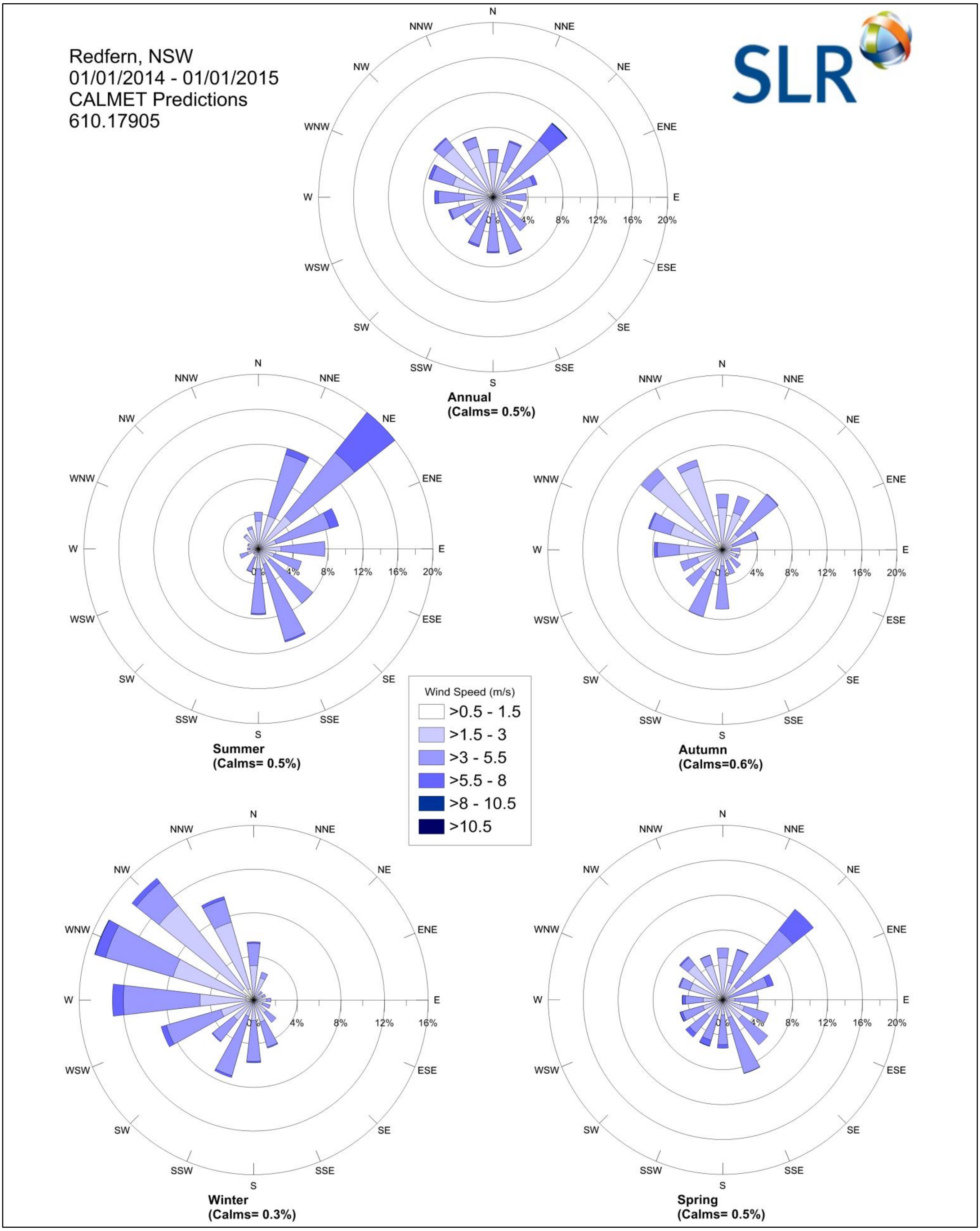
Figure 15 indicates that winds predicted at the Project Site are predominantly light to moderate (between 1.5 m/s and 8 m/s). Calm wind conditions (wind speed less than 0.5 m/s) were predicted to occur approximately 0.5% of the time throughout the modelling period.

The seasonal wind roses indicate that:

- In summer, winds are predicted to be light to moderate, occurring predominantly from the northeast, with the smallest percentage of winds blowing from the western quadrant. Calm winds were predicted 0.5% of the time during summer.
- In autumn, winds are predicted to be light to moderate and predominantly from the northwest quadrant, with the smallest percentage of winds blowing from the southeastern quadrant. Calm winds were predicted 0.6% of the time during autumn.
- In winter, winds are predicted to be light to moderate and predominantly from the west-northwestern quadrant, with very few winds from the eastern quadrant. Calm winds were predicted 0.3% of the time during winter.
- In spring, winds are predicted to be light to moderate, predominantly from the northeast. Calm winds were predicted 0.5% of the time during spring.

It is noted that the wind conditions predicted by the model at other areas within the modelling domain may vary from the wind roses presented in **Figure 15** for one point within the Project Site, and within GRAL the dispersion of pollutants from each source within the models will reflect the local conditions.

Figure 15 Predicted Seasonal Wind Roses for the Project Site (CALMET predictions, 2014)



7.3.5.2 Atmospheric Stability

Atmospheric stability refers to the tendency of the atmosphere to resist or enhance vertical motion. The Pasquill-Gifford-Turner (PGT) assignment scheme identifies six stability classes, A to F, to categorise the degree of atmospheric stability as follows:

- A = Extremely unstable conditions
- B = Moderately unstable conditions
- C = Slightly unstable conditions
- D = Neutral conditions
- E = Slightly stable conditions
- F = Moderately stable conditions

The meteorological conditions defining each PGT stability class are shown in **Table 19**.

Table 19 Meteorological Conditions Defining PGT Stability Classes

Surface wind speed (m/s)	Daytime insolation			Night-time conditions	
	Strong	Moderate		Strong	Moderate
< 2	A	A - B	< 2	A	A - B
2 - 3	A - B	B	2 - 3	A - B	B
3 - 5	B	B - C	3 - 5	B	B - C
5 - 6	C	C - D	5 - 6	C	C - D
> 6	C	D	> 6	C	D

Source: (NOAA, 2018)

Notes:

1. Strong insolation corresponds to sunny midday in midsummer in England; slight insolation to similar conditions in midwinter.
2. Night refers to the period from 1 hour before sunset to 1 hour after sunrise.
3. The neutral category D should also be used, regardless of wind speed, for overcast conditions during day or night and for any sky conditions during the hour preceding or following night as defined above.

The frequency of each stability class predicted by CALMET during the modelling period, extracted at a location within the Project Site is presented in **Figure 16**. The results indicate a high frequency of conditions typical to Stability Classes D and F. Stability Class D is indicative of neutral conditions, conducive to a moderate level of pollutant dispersion due to mechanical mixing. Stability Class F is indicative of stable night time conditions, which will inhibit pollutant dispersion resulting in higher pollutant concentrations at ground level at surrounding areas.

7.3.5.3 Mixing Heights

Diurnal variations in maximum and average mixing heights predicted by CALMET at the Project Site during the 2014 modelling period are illustrated in **Figure 17**.

As would be expected, an increase in mixing depth during the morning is apparent, arising due to the onset of vertical mixing following sunrise. Maximum mixing heights occur in the mid to late afternoon, due to the dissipation of ground based temperature inversions and growth of the convective mixing layer.

7.3.5.4 Temperature

The modelled temperature variations as predicted at the Project Site during the year 2014 are illustrated in **Figure 18**. The maximum temperature (36.9°C) was predicted on 14 November 2014 and the minimum temperature 3.4°C) was predicted on 12 July 2014.

Figure 16 Predicted Stability Class Frequencies at the Project Site (CALMET predictions, 2014)

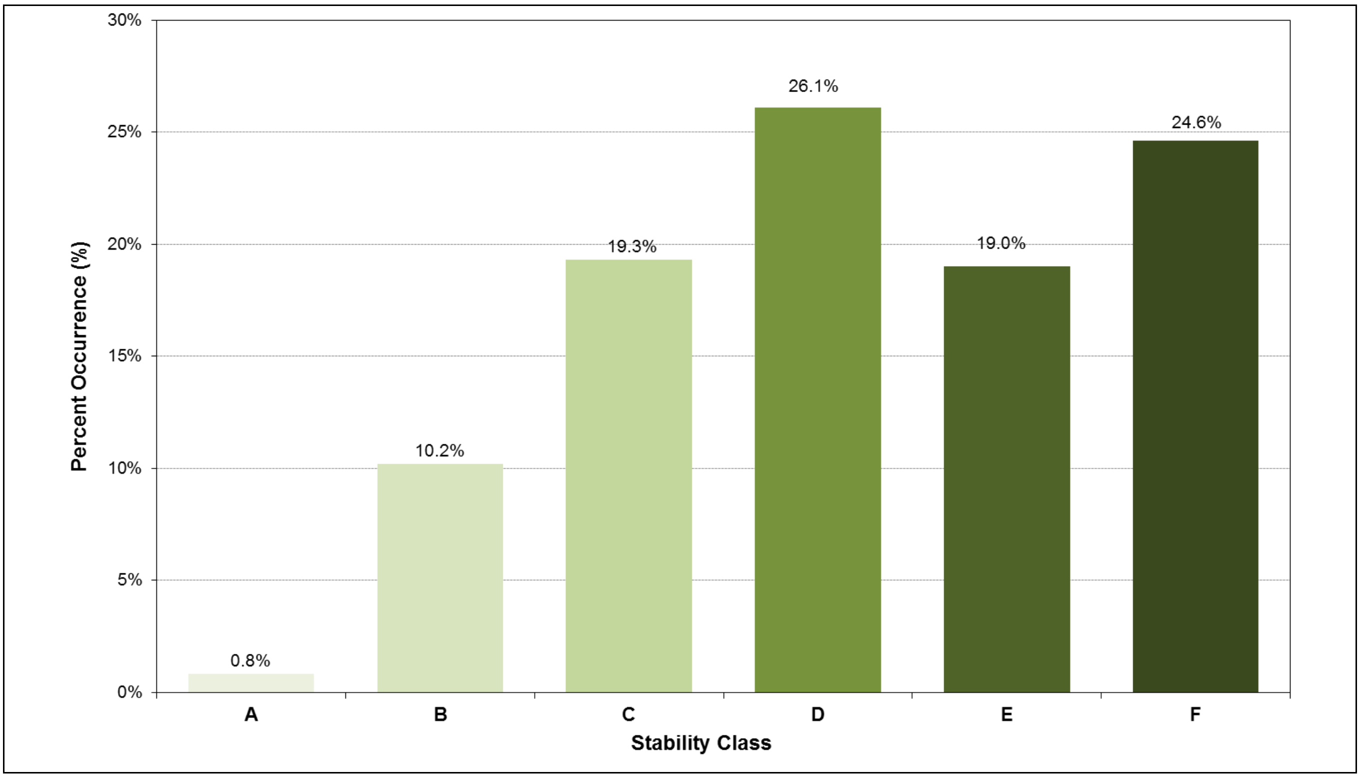


Figure 17 Predicted Mixing Heights at the Project Site (CALMET predictions, 2014)

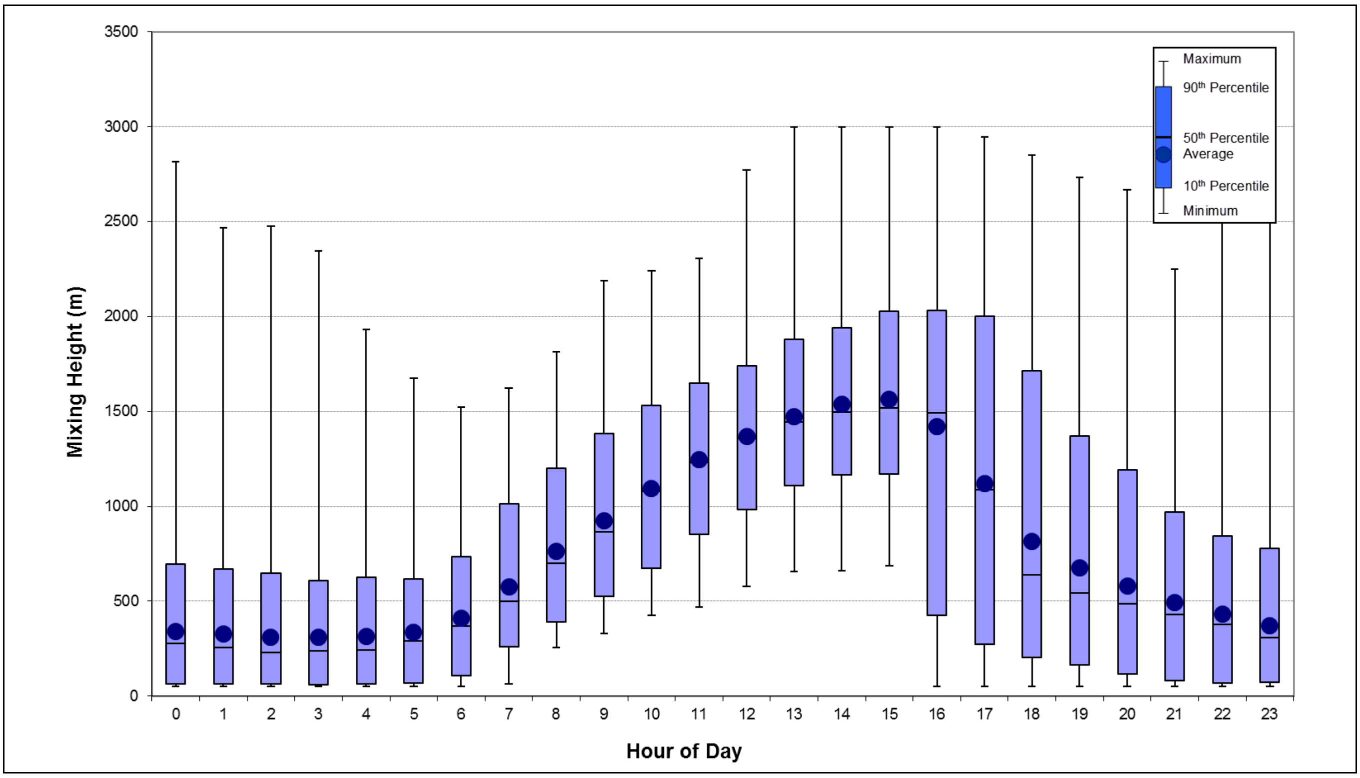
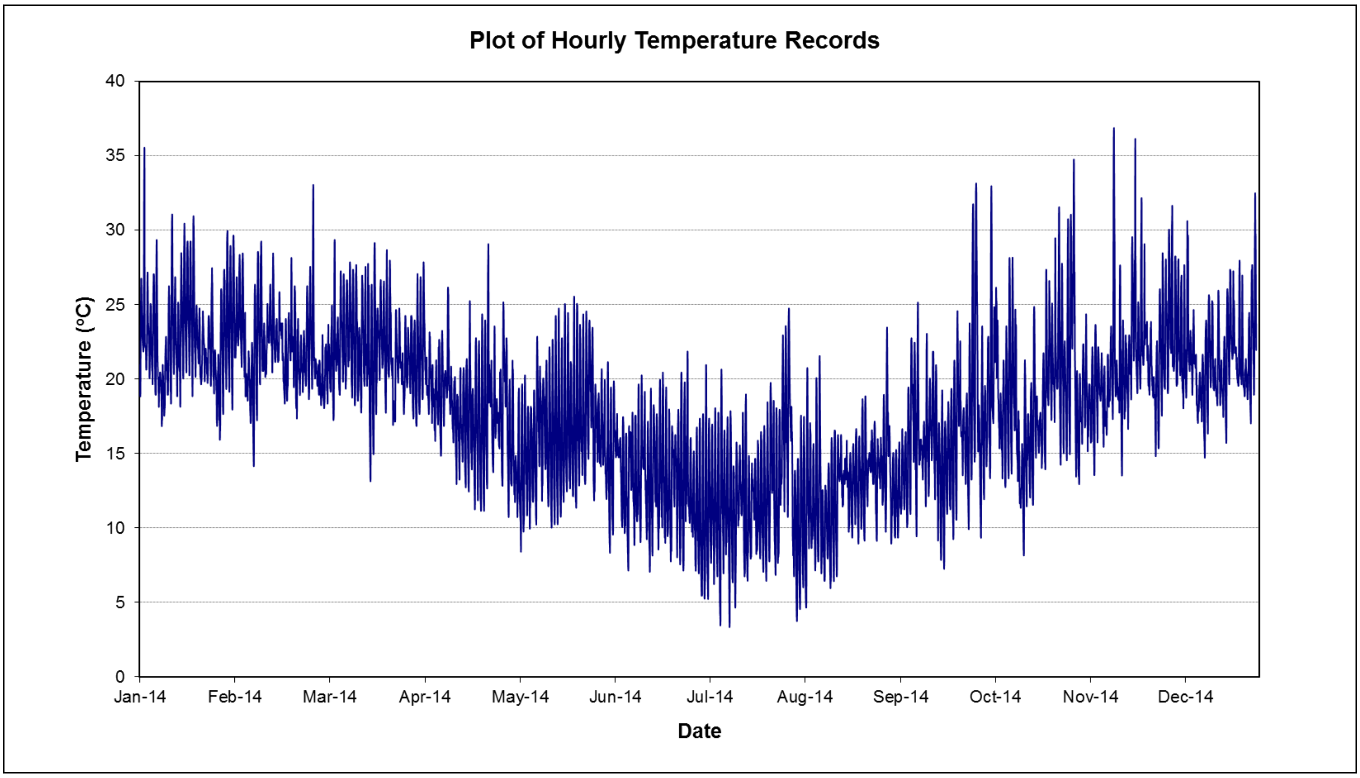


Figure 18 Predicted Temperatures at Project Site (CALMET predictions, 2014)



8 Assessment of Air Quality at the Project Site

Ambient air quality monitoring performed in the Sydney area over the last few decades has shown that the city's air quality has improved and is continuing to improve. A major driver of this improvement in urban air quality is the fact that newer vehicles produce significantly less emissions than older vehicles. This is in part as a result of improvements in the quality and composition of fuels as well as improved engine designs and fuel efficiency. According to Trends in Motor Vehicles and their Emissions (NSW EPA, 2014), cars built from 2013 onwards emit only 3% of the NO_X emissions compared to vehicles built in 1976, and diesel trucks built from 2011 onwards emit just 8% of the particles emitted by vehicles built in 1996. Thus even as Sydney's population and total vehicle kilometres travelled each year have increased (NSW EPA, 2014), key measures of air pollution have dropped significantly and this trend is expected to continue.

This section presents a summary of the air quality impacts predicted by the modelling of vehicle emissions from the main roads surrounding the Project Site, based on current vehicle numbers and emission factors representative of the current Sydney fleet. Future impacts can be expected to be lower than those predicted for current conditions, due to improved vehicle emissions performance as outlined above.

8.1 $PM_{2.5}$

The maximum incremental and cumulative 24-hour and annual average $PM_{2.5}$ concentrations predicted at the worst impacted building facade receptors (for ground level, 3 m elevation, 6 m elevation, 9 m elevation and 12 m elevation) as well as the worst impacted boundary receptors are presented in **Table 20.**

Figure 19 illustrates the cumulative ground level 24-hour average $PM_{2.5}$ concentrations predicted within the Project Site, while **Figure 20** illustrates the cumulative ground level annual average concentrations. It should be noted that contour plots do not represent the dispersion pattern for any individual time period, but rather illustrate the maximum 24-hour average or annual average concentration that was predicted to occur at each model calculation point over the range of meteorological conditions occurring during the 2014 modelling period.

Table 20 Predicted $PM_{2.5}$ Concentrations

Elevation [1]	Location	Maximum Incremental Concentrations (µg/m³)		Maximum Cumulative Concentrations (µg/m³)	
		24-Hour Average	Annual Average	24-Hour Average	Annual Average
Ground Level	Maximum at boundary receptor	4.3	1.7	24.6	9.5
	Maximum at building facade	2.7	1.1	24.3	8.9
3 m Elevation	Maximum at building facade receptors	4.6	2.1	24.9	9.9
6 m Elevation	Maximum at building facade receptors	3.7	1.8	24.6	9.6
9 m Elevation	Maximum at building facade receptors	3.1	1.4	24.3	9.2
12 m Elevation	Maximum at building facade receptors	2.7	1.1	24.0	8.9
			CRITERIA	**25**	**8**

Note 1: Concentrations at elevations above 12 m are predicted to be lower than the maximum concentrations presented in the table.

Note 2: Red text indicates exceedance of relevant ambient air quality criteria

The modelling results presented in **Table 20** show that while no exceedances of the 24-hour $PM_{2.5}$ criteria are predicted, the cumulative annual $PM_{2.5}$ concentrations predicted for the Project Site do not comply with the relevant ambient air quality criterion outlined in **Section 5**. As illustrated in **Figure 19** and **Figure 20**, the highest $PM_{2.5}$ concentrations are predicted to occur within close proximity of Elizabeth Street and Phillip Street.

Exceedances of the annual average $PM_{2.5}$ criterion were predicted at 60% of the discrete receptor locations modelled within the Project Site (see **Figure 20**). This is primarily due to high background concentrations of $PM_{2.5}$ within the local airshed. As outlined in **Section 6.1**, exceedances of the annual average $PM_{2.5}$ criterion were recorded by the Earlwood AQMS in two of the last five years and the annual average background $PM_{2.5}$ concentration used in this assessment of 7.8 µg/m³ is already only fractionally below the criterion of 8 µg/m³. It is noted that the annual average criterion for $PM_{2.5}$ adopted by the NSW EPA is more stringent than those set by the European Union, the United States and the WHO.

The NSW EPA has a number of programmes in place (refer **Section 6**) through which sources of $PM_{2.5}$ in NSW are being studied and managed to ensure that the regional background concentrations that residents within Sydney, including the Project Site, are exposed to are minimised as much as practicable.

8.2 PM_{10}

The maximum incremental and cumulative 24-hour and annual average PM_{10}concentrations predicted at the worst impacted building facade receptors (for ground level, 3 m elevation, 6 m elevation, 9 m elevation and 12 m elevation) as well as the worst impacted boundary receptors are presented in **Table 21**.

Figure 21 illustrates the cumulative 24-hour average PM_{10} concentrations predicted within the Project Site, while **Figure 22** illustrates the cumulative annual average concentrations.

Table 21 Predicted PM_{10} Concentrations

Elevation [1]	Location	Maximum Incremental Concentrations (µg/m³)		Maximum Cumulative Concentrations (µg/m³)	
		24-Hour Average	Annual Average	24-Hour Average	Annual Average
Ground Level	Maximum at boundary receptor	4.9	2.0	48.8	20.3
	Maximum at building facade	3.2	1.4	47.9	19.6
3 m Elevation	Maximum at building facade receptors	5.5	2.5	49.5	20.7
6 m Elevation	Maximum at building facade receptors	4.4	2.1	49.0	20.4
9 m Elevation	Maximum at building facade receptors	3.6	1.7	48.6	19.9
12 m Elevation	Maximum at building facade receptors	3.2	1.3	48.0	19.6
			CRITERIA	**50**	**25**

Note 1: Concentrations at elevations above 12 m are predicted to be lower than the maximum concentrations presented in the table.

The modelling results presented in **Table 21** show that no exceedances of the 24-hour and annual PM_{10} criteria are predicted for the Project Site.

8.3 NO_2

The maximum incremental and cumulative 1-hour and annual average NO_2 concentrations predicted at the worst impacted building facade receptors (for ground level, 3 m elevation, 6 m elevation, 9 m elevation and 12 m elevation) as well as the worst impacted boundary receptors are presented in **Table 22**. These NO_2 concentrations were derived from the ground level NO_X concentrations predicted by the modelling using the Ozone Limiting Method and contemporaneous hourly-varying 1-hour average ozone concentration data from the Randwick AQMS, as described in **Section 7.2.3**

Figure 23 and **Figure 24** illustrate the cumulative maximum 1-hour average and annual average ground level NO_2 concentrations predicted across the Project Site.

Table 22 Predicted NO_2 Concentrations

Elevation	Location	Maximum Incremental Concentrations (µg/m³)		Maximum Cumulative Concentrations (µg/m³)	
		1-Hour Average	Annual Average	1-Hour Average	Annual Average
Ground Level	Maximum at boundary receptor	104	22	140	42
	Maximum at building facade	103	17	139	37
3 m Elevation	Maximum at building facade receptors	134	26	172	46
6 m Elevation	Maximum at building facade receptors	138	25	170	45
9 m Elevation	Maximum at building facade receptors	132	22	170	42
12 m Elevation	Maximum at building facade receptors	132	18	170	38
CRITERIA				**246**	**62**

Note 1: Concentrations at elevations above 12 m are predicted to be lower than the maximum concentrations presented in the table.

The modelling results presented in **Table 22** show that no exceedances of the 1-hour or annual NO_2 criteria are predicted.

Figure 19 Maximum Predicted Cumulative 24-Hour Average Ground Level $PM_{2.5}$ Concentrations

Figure 20 Predicted Cumulative Annual Average Ground Level $PM_{2.5}$ Concentrations

Figure 21 Maximum Predicted Cumulative 24-Hour Average Ground Level PM_{10} Concentrations

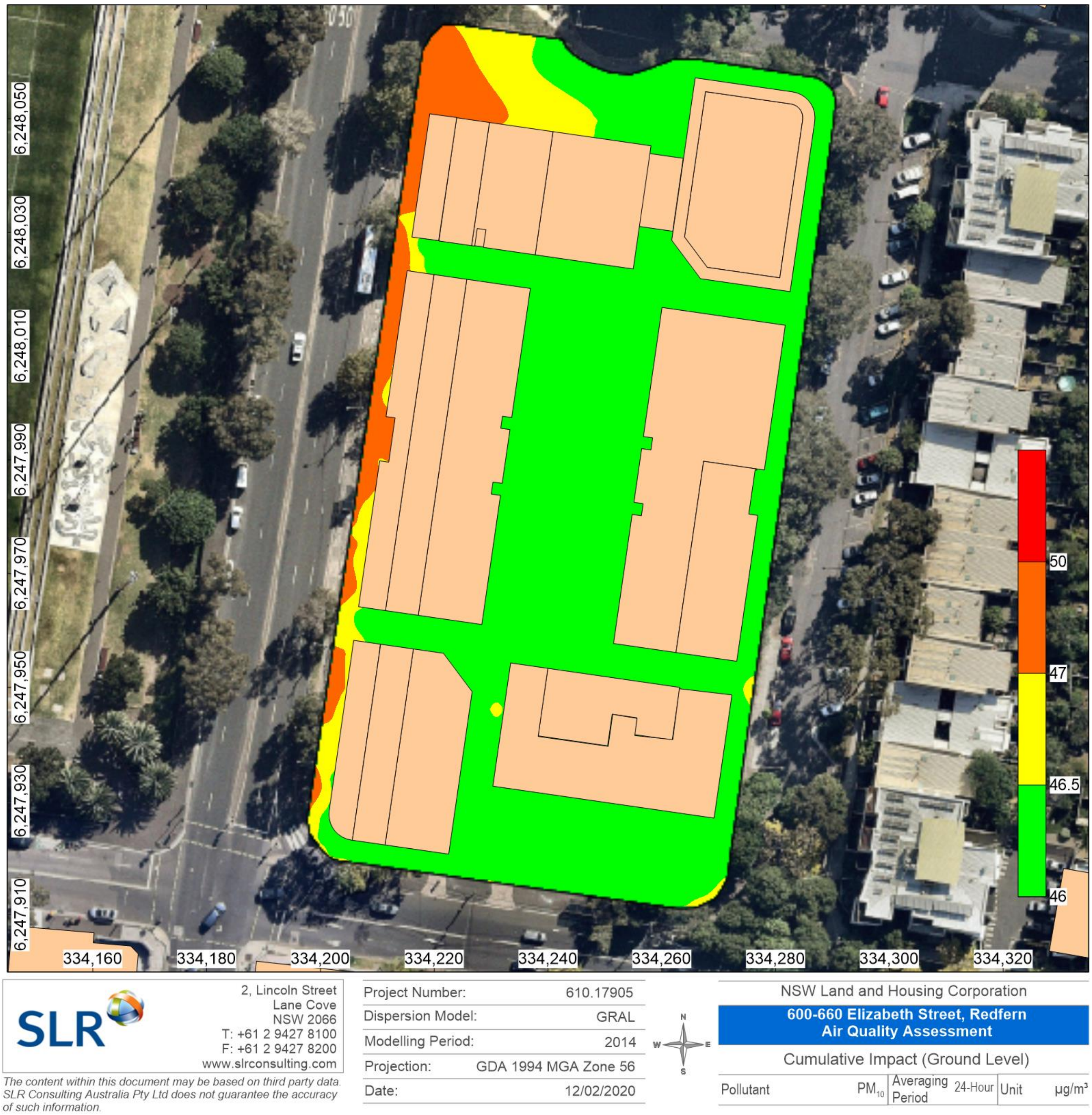


Figure 22 Predicted Cumulative Annual Average Ground Level PM_{10} Concentrations

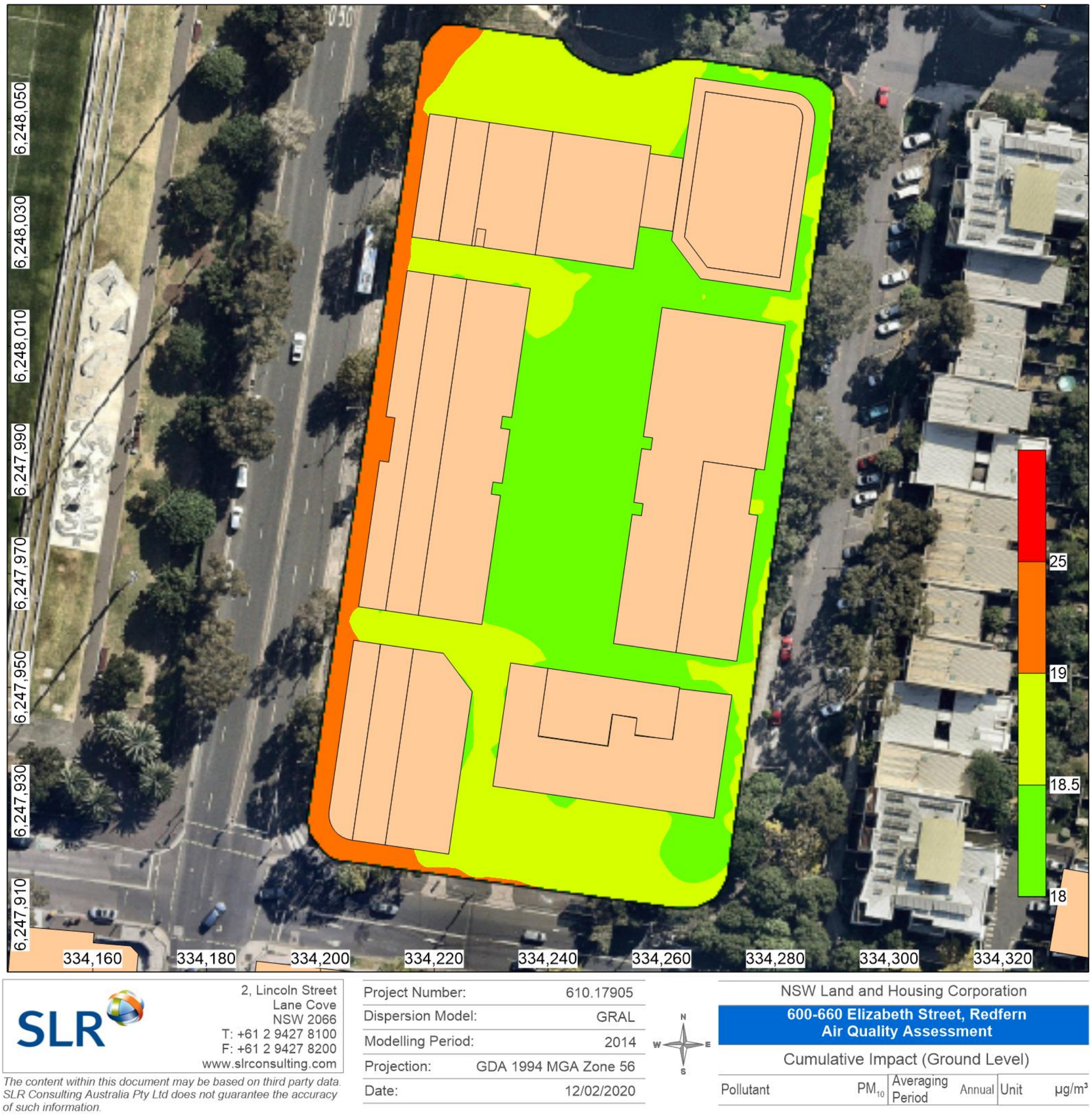


Figure 23 Maximum Predicted Cumulative 1-Hour Average Ground Level NO_2 Concentrations

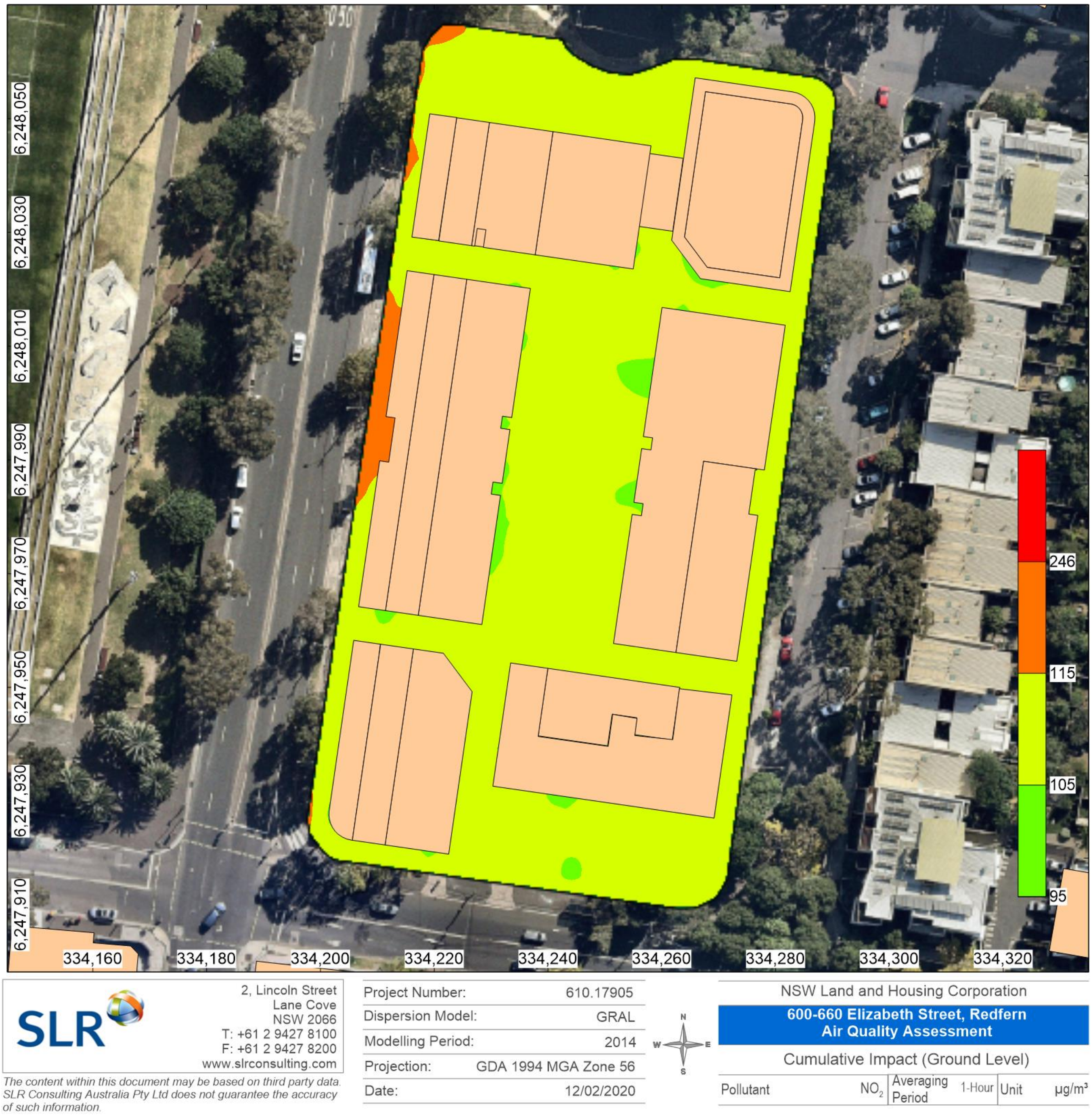


Figure 24 Predicted Cumulative Annual Average Ground Level NO_2 Concentrations

8.4 Summary and Recommendations

The results of the cumulative impact assessment indicate that within the Project Site:

- No exceedances of the PM_{10}, NO_2 and 24-hour $PM_{2.5}$ criteria are predicted.
- Exceedances of the annual $PM_{2.5}$ criterion are predicted for 60% of the discrete receptor locations modelled within the Project Site, especially those close to Elizabeth Street and Phillip Street.

The predicted exceedances of the annual $PM_{2.5}$ criterion are primarily due to high background concentrations of $PM_{2.5}$ within the local airshed; with the annual average background $PM_{2.5}$ concentration used in this assessment of 7.8 µg/m^3 being only fractionally below the criterion of 8 µg/m^3.

It is noted that changes to the reference scheme may affect the dispersion of pollutants from road traffic, it is therefore recommended that further air quality assessment be undertaken during the development application stage to ensure that any such changes do not lead to potential exceedances of the air quality impact assessment criteria, particularly at the lower levels of buildings facing Elizabeth Street.

Other principles that should be considered at the detailed design stage to achieve improved air quality include:

- Minimising the formation of urban canyons by having buildings of different heights interspersed with open areas, and setting back the upper stories of multi-level buildings.
- Locating living areas, outdoor space and bedrooms and other sensitive uses (such as childcare centres) as far as practicable from the major source of air pollution.
- Locating mechanical air intakes and means of natural ventilation as far as practicable from the major source of air pollution.
- Using vegetative screens, to assist in maintaining local ambient air amenity.

9 Recommended Controls

As outlined in **Section 8**, for the majority of the pollutants assessed, compliance with the relevant air quality criteria is achieved at all locations within the reference scheme (with the exception of annual $PM_{2.5}$ concentrations, which exceed the relevant criterion due to high background concentrations). However, if changes are made to the design and layout of the buildings in the detailed design stage, it is possible that exceedances of the ambient air quality criteria could occur at some locations within the project site. Further, the potential air quality impacts during the construction stage have not been assessed at this stage. Therefore, it is recommended that the proposed development be undertaken in accordance with the requirements contained within the following documents and guidelines:

Controlling air quality impacts for future residents of the development:

- *Approved Methods for Modelling and Assessment of Air Pollutants in NSW* (NSW EPA, 2017)
- *The State Environmental Planning Policy (Infrastructure) 2007* (the 'Infrastructure SEPP')
- *Local government air quality toolkit guidance notes for Food Outlets* (NSW EPA, 2007)

Throughout the assessments for future development across the site, particularly those fronting Elizabeth Street, detailed assessments on final building configurations should be undertaken to ensure that as well compliance with the relevant air quality impact assessment criteria, ventilation needs can be met.

Controlling construction air quality impacts of the development on surrounding land uses:

- Approved Methods for Modelling and Assessment of Air Pollutants in NSW (NSW EPA, 2017)
- Approved Methods for the Sampling and Analysis of Air Pollutants in New South Wales (DEC, 2007)
- Local government air quality toolkit guidance notes for Construction Sites (NSW EPA, 2007)

Once details of the proposed construction methodology and equipment are known, a construction air quality impact assessment should be undertaken and a Construction Air Quality Management Plan (CAQMP) developed as part of the approval process.

The CAQMP should incorporate air emissions mitigation and management strategies developed through consultation with the surrounding community and the relevant regulatory authority.

10 Conclusions

SLR Consulting was commissioned by LAHC to conduct an AQA for the proposed development of 600-660 Elizabeth Street, Redfern (the Project Site), which is a part of the Redfern Social Housing Estate. This AQA has been prepared in general accordance with The Approved Methods (NSW EPA, 2017) with reference to the Infrastructure SEPP and the NSW Department of Planning document "*Development near Rail Corridors and Busy Roads – Interim Guideline*" (DoP, 2008) (the Guideline).

The primary source of air emissions in the area immediately surrounding the Project Site was identified as vehicles travelling along Elizabeth Street and Phillip Street. In order to gain a better understanding of the potential worst case air pollutant concentrations within the Project Site, detailed meteorological and air quality dispersion modelling of these emissions was carried out. Emissions of NO_2 and particulate matter (as PM_{10} and $PM_{2.5}$) from the surrounding road network were estimated using the COPERT Australia software package. The calculated emissions from the surrounding road network were then modelled using the GRAMM/GRAL modelling system.

The results of the cumulative impact assessment indicated that while exceedances of the annual $PM_{2.5}$ criterion were predicted to occur at 60% of the discrete receptor locations modelled within the Project Site, especially those close to Elizabeth Street and Phillip Street, exceedances of PM_{10} criteria, NO_2 criteria and the 24-hour $PM_{2.5}$ criterion are not predicted. It is noted that the predicted exceedances of the annual $PM_{2.5}$ criterion are primarily due to high background concentrations of $PM_{2.5}$ within the local airshed; with the annual average background $PM_{2.5}$ concentration used in this assessment of 7.8 $\mu g/m^3$ being only fractionally below the criterion of 8 $\mu g/m^3$.

Based on the modelling results, SLR concludes that the Project Site is suitable for the intended mixed-use development, providing that throughout the assessments for future development on the Project Site, a detailed assessment on final building configurations be undertaken to ensure that potential air quality impacts at future sensitive receptors are not exacerbated by the building design.

11 References

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APPENDIX A

COPERT Australia Input Parameters

Table A-1 Long Term Average Ambient Temperature and Relative Humidity – Sydney Area

Month	Minimum Temperature (°C)	Maximum Temperature (°C)	Relative Humidity (%)
January	19.8	27.1	71.3
February	20.0	27.4	73.1
March	18.7	25.7	71.5
April	16.2	23.9	71.9
May	11.5	20.9	61.6
June	9.9	19.6	58.4
July	9.1	17.6	66.8
August	10.4	19.2	63.1
September	11.9	21.1	67.9
October	14.6	22.7	67.5
November	16.3	24.9	65.9
December	17.9	25.2	71.1

Table A-2 Estimated Distribution of Vehicles – Based on NSW Fleet Average

Vehicle Type	Percentage
Cars and motorcycles	82.9%
Light commercial vehicles	13.6%
Heavy vehicles	3.5%

Table A-3 Distribution of Vehicles – Sectors and Subsectors

Sector	Subsector	Technology	Population (Annual)	Percentage
Passenger Cars	PC-S-petrol	ADR00-UNC	0	0.0%
Passenger Cars	PC-S-petrol	ADR27	35,732	0.7%
Passenger Cars	PC-S-petrol	ADR37-00	240,222	5.0%
Passenger Cars	PC-S-petrol	ADR37-01	242,850	5.1%
Passenger Cars	PC-S-petrol	ADR79-00	106,648	2.2%
Passenger Cars	PC-S-petrol	ADR79-01	244,203	5.1%
Passenger Cars	PC-S-petrol	ADR79-02	60,297	1.3%
Passenger Cars	PC-S-petrol	ADR79-03	0	0.0%

Sector	Subsector	Technology	Population (Annual)	Percentage
Passenger Cars	PC-S-petrol	ADR79-04	0	0.0%
Passenger Cars	PC-S-petrol	ADR79-05	0	0.0%
Passenger Cars	PC-M-petrol	ADR00-UNC	0	0.0%
Passenger Cars	PC-M-petrol	ADR27	50,017	1.0%
Passenger Cars	PC-M-petrol	ADR37-00	145,356	3.0%
Passenger Cars	PC-M-petrol	ADR37-01	97,929	2.0%
Passenger Cars	PC-M-petrol	ADR79-00	43,833	0.9%
Passenger Cars	PC-M-petrol	ADR79-01	77,585	1.6%
Passenger Cars	PC-M-petrol	ADR79-02	16,603	0.3%
Passenger Cars	PC-M-petrol	ADR79-03	0	0.0%
Passenger Cars	PC-M-petrol	ADR79-04	0	0.0%
Passenger Cars	PC-M-petrol	ADR79-05	0	0.0%
Passenger Cars	PC-L-petrol	ADR00-UNC	0	0.0%
Passenger Cars	PC-L-petrol	ADR27	56,971	1.2%
Passenger Cars	PC-L-petrol	ADR37-00	264,980	5.5%
Passenger Cars	PC-L-petrol	ADR37-01	210,427	4.4%
Passenger Cars	PC-L-petrol	ADR79-00	65,009	1.4%
Passenger Cars	PC-L-petrol	ADR79-01	73,277	1.5%
Passenger Cars	PC-L-petrol	ADR79-02	14,985	0.3%
Passenger Cars	PC-L-petrol	ADR79-03	0	0.0%
Passenger Cars	PC-L-petrol	ADR79-04	0	0.0%
Passenger Cars	PC-L-petrol	ADR79-05	0	0.0%
Passenger Cars	PC-S-diesel	ADR00-UNC	0	0.0%
Passenger Cars	PC-S-diesel	ADR30	32	0.0%
Passenger Cars	PC-S-diesel	ADR70-00	178	0.0%
Passenger Cars	PC-S-diesel	ADR79-00	3,769	0.1%
Passenger Cars	PC-S-diesel	ADR79-01	12,612	0.3%
Passenger Cars	PC-S-diesel	ADR79-02	5,803	0.1%
Passenger Cars	PC-S-diesel	ADR79-03	0	0.0%
Passenger Cars	PC-S-diesel	ADR79-04	0	0.0%
Passenger Cars	PC-S-diesel	ADR79-05	0	0.0%
Passenger Cars	PC-ML-diesel	ADR00-UNC	0	0.0%
Passenger Cars	PC-ML-diesel	ADR30	215	0.0%
Passenger Cars	PC-ML-diesel	ADR70-00	396	0.0%
Passenger Cars	PC-ML-diesel	ADR79-00	2,395	0.1%
Passenger Cars	PC-ML-diesel	ADR79-01	11,557	0.2%
Passenger Cars	PC-ML-diesel	ADR79-02	4,423	0.1%
Passenger Cars	PC-ML-diesel	ADR79-03	0	0.0%
Passenger Cars	PC-ML-diesel	ADR79-04	0	0.0%

Sector	Subsector	Technology	Population (Annual)	Percentage
Passenger Cars	PC-ML-diesel	ADR79-05	0	0.0%
Passenger Cars	PC-S-E10	ADR00-UNC	0	0.0%
Passenger Cars	PC-S-E10	ADR27	0	0.0%
Passenger Cars	PC-S-E10	ADR37-00	78,212	1.6%
Passenger Cars	PC-S-E10	ADR37-01	106,426	2.2%
Passenger Cars	PC-S-E10	ADR79-00	66,758	1.4%
Passenger Cars	PC-S-E10	ADR79-01	166,391	3.5%
Passenger Cars	PC-S-E10	ADR79-02	41,084	0.9%
Passenger Cars	PC-S-E10	ADR79-03	0	0.0%
Passenger Cars	PC-S-E10	ADR79-04	0	0.0%
Passenger Cars	PC-S-E10	ADR79-05	0	0.0%
Passenger Cars	PC-M-E10	ADR00-UNC	0	0.0%
Passenger Cars	PC-M-E10	ADR27	0	0.0%
Passenger Cars	PC-M-E10	ADR37-00	43,101	0.9%
Passenger Cars	PC-M-E10	ADR37-01	43,046	0.9%
Passenger Cars	PC-M-E10	ADR79-00	27,438	0.6%
Passenger Cars	PC-M-E10	ADR79-01	52,864	1.1%
Passenger Cars	PC-M-E10	ADR79-02	11,313	0.2%
Passenger Cars	PC-M-E10	ADR79-03	0	0.0%
Passenger Cars	PC-M-E10	ADR79-04	0	0.0%
Passenger Cars	PC-M-E10	ADR79-05	0	0.0%
Passenger Cars	PC-L-E10	ADR00-UNC	0	0.0%
Passenger Cars	PC-L-E10	ADR27	0	0.0%
Passenger Cars	PC-L-E10	ADR37-00	84,509	1.8%
Passenger Cars	PC-L-E10	ADR37-01	92,093	1.9%
Passenger Cars	PC-L-E10	ADR79-00	40,693	0.9%
Passenger Cars	PC-L-E10	ADR79-01	49,928	1.0%
Passenger Cars	PC-L-E10	ADR79-02	10,211	0.2%
Passenger Cars	PC-L-E10	ADR79-03	0	0.0%
Passenger Cars	PC-L-E10	ADR79-04	0	0.0%
Passenger Cars	PC-L-E10	ADR79-05	0	0.0%
Passenger Cars	PC-LPG	ADR00-UNC	0	0.0%
Passenger Cars	PC-LPG	ADR27	7,152	0.1%
Passenger Cars	PC-LPG	ADR37-00	13,465	0.3%
Passenger Cars	PC-LPG	ADR37-01	25,951	0.5%
Passenger Cars	PC-LPG	ADR79-00	17,528	0.4%
Passenger Cars	PC-LPG	ADR79-01	86,947	1.8%
Passenger Cars	PC-LPG	ADR79-02	8,935	0.2%
Passenger Cars	PC-LPG	ADR79-03	0	0.0%

Sector	Subsector	Technology	Population (Annual)	Percentage
Passenger Cars	PC-LPG	ADR79-04	0	0.0%
Passenger Cars	PC-LPG	ADR79-05	0	0.0%
SUV	SUV-C-petrol	ADR00-UNC	1,529	0.0%
SUV	SUV-C-petrol	ADR37-00	22,064	0.5%
SUV	SUV-C-petrol	ADR37-01	48,013	1.0%
SUV	SUV-C-petrol	ADR79-00	26,171	0.5%
SUV	SUV-C-petrol	ADR79-01	47,376	1.0%
SUV	SUV-C-petrol	ADR79-02	17,394	0.4%
SUV	SUV-C-petrol	ADR79-03	0	0.0%
SUV	SUV-C-petrol	ADR79-04	0	0.0%
SUV	SUV-C-petrol	ADR79-05	0	0.0%
SUV	SUV-L-petrol	ADR00-UNC	1,561	0.0%
SUV	SUV-L-petrol	ADR36	41,700	0.9%
SUV	SUV-L-petrol	ADR37-00	14,309	0.3%
SUV	SUV-L-petrol	ADR37-01	27,391	0.6%
SUV	SUV-L-petrol	ADR79-00	26,603	0.6%
SUV	SUV-L-petrol	ADR79-01	38,774	0.8%
SUV	SUV-L-petrol	ADR79-02	9,264	0.2%
SUV	SUV-L-petrol	ADR79-03	0	0.0%
SUV	SUV-L-petrol	ADR79-04	0	0.0%
SUV	SUV-L-petrol	ADR79-05	0	0.0%
SUV	SUV-diesel	ADR00-UNC	2,205	0.0%
SUV	SUV-diesel	ADR30	9,727	0.2%
SUV	SUV-diesel	ADR70-00	26,202	0.5%
SUV	SUV-diesel	ADR79-00	31,054	0.6%
SUV	SUV-diesel	ADR79-01	36,982	0.8%
SUV	SUV-diesel	ADR79-02	17,519	0.4%
SUV	SUV-diesel	ADR79-03	0	0.0%
SUV	SUV-diesel	ADR79-04	0	0.0%
SUV	SUV-diesel	ADR79-05	0	0.0%
SUV	SUV-C-E10	ADR00-UNC	0	0.0%
SUV	SUV-C-E10	ADR37-00	7,458	0.2%
SUV	SUV-C-E10	ADR37-01	21,355	0.4%
SUV	SUV-C-E10	ADR79-00	16,383	0.3%
SUV	SUV-C-E10	ADR79-01	32,280	0.7%
SUV	SUV-C-E10	ADR79-02	11,851	0.2%
SUV	SUV-C-E10	ADR79-03	0	0.0%
SUV	SUV-C-E10	ADR79-04	0	0.0%
SUV	SUV-C-E10	ADR79-05	0	0.0%

Sector	Subsector	Technology	Population (Annual)	Percentage
SUV	SUV-L-E10	ADR00-UNC	0	0.0%
SUV	SUV-L-E10	ADR36	16,919	0.4%
SUV	SUV-L-E10	ADR37-00	4,926	0.1%
SUV	SUV-L-E10	ADR37-01	11,993	0.3%
SUV	SUV-L-E10	ADR79-00	16,652	0.3%
SUV	SUV-L-E10	ADR79-01	26,419	0.6%
SUV	SUV-L-E10	ADR79-02	6,312	0.1%
SUV	SUV-L-E10	ADR79-03	0	0.0%
SUV	SUV-L-E10	ADR79-04	0	0.0%
SUV	SUV-L-E10	ADR79-05	0	0.0%
Light Commercial Vehicles	LCV-petrol	ADR00-UNC	29,241	0.6%
Light Commercial Vehicles	LCV-petrol	ADR36	123,715	2.6%
Light Commercial Vehicles	LCV-petrol	ADR37-00	43,792	0.9%
Light Commercial Vehicles	LCV-petrol	ADR37-01	38,684	0.8%
Light Commercial Vehicles	LCV-petrol	ADR79-00	47,219	1.0%
Light Commercial Vehicles	LCV-petrol	ADR79-01	44,034	0.9%
Light Commercial Vehicles	LCV-petrol	ADR79-02	9,447	0.2%
Light Commercial Vehicles	LCV-petrol	ADR79-03	0	0.0%
Light Commercial Vehicles	LCV-petrol	ADR79-04	0	0.0%
Light Commercial Vehicles	LCV-petrol	ADR79-05	0	0.0%
Light Commercial Vehicles	LCV-diesel	ADR00-UNC	28,825	0.6%
Light Commercial Vehicles	LCV-diesel	ADR30	36,092	0.8%
Light Commercial Vehicles	LCV-diesel	ADR70-00	60,452	1.3%
Light Commercial Vehicles	LCV-diesel	ADR79-00	68,553	1.4%
Light Commercial Vehicles	LCV-diesel	ADR79-01	88,557	1.9%
Light Commercial Vehicles	LCV-diesel	ADR79-02	32,648	0.7%
Light Commercial Vehicles	LCV-diesel	ADR79-03	0	0.0%
Light Commercial Vehicles	LCV-diesel	ADR79-04	0	0.0%
Light Commercial Vehicles	LCV-diesel	ADR79-05	0	0.0%
Heavy Duty Trucks	MCV-petrol	ADR00-UNC	10,603	0.2%
Heavy Duty Trucks	MCV-diesel	ADR00-UNC	20,660	0.4%
Heavy Duty Trucks	MCV-diesel	ADR30	11,700	0.2%
Heavy Duty Trucks	MCV-diesel	ADR70-00	20,969	0.4%
Heavy Duty Trucks	MCV-diesel	ADR80-00	23,569	0.5%
Heavy Duty Trucks	MCV-diesel	ADR80-02	12,869	0.3%
Heavy Duty Trucks	MCV-diesel	ADR80-03	0	0.0%
Heavy Duty Trucks	MCV-diesel	ADR80-04	0	0.0%
Heavy Duty Trucks	MCV-diesel	ADR80-05	0	0.0%
Heavy Duty Trucks	HCV-diesel	ADR00-UNC	8,264	0.2%

Sector	Subsector	Technology	Population (Annual)	Percentage
Heavy Duty Trucks	HCV-diesel	ADR30	3,948	0.1%
Heavy Duty Trucks	HCV-diesel	ADR70-00	6,540	0.1%
Heavy Duty Trucks	HCV-diesel	ADR80-00	7,411	0.2%
Heavy Duty Trucks	HCV-diesel	ADR80-02	3,420	0.1%
Heavy Duty Trucks	HCV-diesel	ADR80-03	0	0.0%
Heavy Duty Trucks	HCV-diesel	ADR80-04	0	0.0%
Heavy Duty Trucks	HCV-diesel	ADR80-05	0	0.0%
Heavy Duty Trucks	AT-diesel	ADR00-UNC	3,142	0.1%
Heavy Duty Trucks	AT-diesel	ADR30	1,918	0.0%
Heavy Duty Trucks	AT-diesel	ADR70-00	4,115	0.1%
Heavy Duty Trucks	AT-diesel	ADR80-00	6,450	0.1%
Heavy Duty Trucks	AT-diesel	ADR80-02	2,803	0.1%
Heavy Duty Trucks	AT-diesel	ADR80-03	0	0.0%
Heavy Duty Trucks	AT-diesel	ADR80-04	0	0.0%
Heavy Duty Trucks	AT-diesel	ADR80-05	0	0.0%
Heavy Duty Trucks	Autogas Trucks	ADR30	643	0.0%
Heavy Duty Trucks	Autogas Trucks	ADR70-00	455	0.0%
Heavy Duty Trucks	Autogas Trucks	ADR80-00	461	0.0%
Heavy Duty Trucks	Autogas Trucks	ADR80-02	282	0.0%
Heavy Duty Trucks	Autogas Trucks	ADR80-03	0	0.0%
Heavy Duty Trucks	Autogas Trucks	ADR80-04	0	0.0%
Heavy Duty Trucks	Autogas Trucks	ADR80-05	0	0.0%
Buses	BUS-L-diesel	ADR00-UNC	1,961	0.0%
Buses	BUS-L-diesel	ADR30	2,065	0.0%
Buses	BUS-L-diesel	ADR70-00	3,352	0.1%
Buses	BUS-L-diesel	ADR80-00	2,582	0.1%
Buses	BUS-L-diesel	ADR80-02	2,126	0.0%
Buses	BUS-L-diesel	ADR80-03	0	0.0%
Buses	BUS-L-diesel	ADR80-04	0	0.0%
Buses	BUS-L-diesel	ADR80-05	0	0.0%
Buses	BUS-H-diesel	ADR00-UNC	527	0.0%
Buses	BUS-H-diesel	ADR30	708	0.0%
Buses	BUS-H-diesel	ADR70-00	1,095	0.0%
Buses	BUS-H-diesel	ADR80-00	852	0.0%
Buses	BUS-H-diesel	ADR80-02	746	0.0%
Buses	BUS-H-diesel	ADR80-03	0	0.0%
Buses	BUS-H-diesel	ADR80-04	0	0.0%
Buses	BUS-H-diesel	ADR80-05	0	0.0%
Mopeds	2-stroke <50 cm^3	Conventional	0	0.0%

Sector	Subsector	Technology	Population (Annual)	Percentage
Mopeds	2-stroke <50 cm^3	Mop - Euro I	0	0.0%
Mopeds	2-stroke <50 cm^3	Mop - Euro II	0	0.0%
Mopeds	2-stroke <50 cm^3	Mop - Euro III	0	0.0%
Mopeds	4-stroke <50 cm^3	Conventional	0	0.0%
Mopeds	4-stroke <50 cm^3	Mop - Euro I	0	0.0%
Mopeds	4-stroke <50 cm^3	Mop - Euro II	0	0.0%
Mopeds	4-stroke <50 cm^3	Mop - Euro III	0	0.0%
Motorcycles	2-stroke >50 cm^3	Conventional	0	0.0%
Motorcycles	2-stroke >50 cm^3	Mot - Euro I	0	0.0%
Motorcycles	2-stroke >50 cm^3	Mot - Euro II	0	0.0%
Motorcycles	2-stroke >50 cm^3	Mot - Euro III	0	0.0%
Motorcycles	4-stroke <250 cm^3	Conventional	0	0.0%
Motorcycles	4-stroke <250 cm^3	Mot - Euro I	0	0.0%
Motorcycles	4-stroke <250 cm^3	Mot - Euro II	0	0.0%
Motorcycles	4-stroke <250 cm^3	Mot - Euro III	0	0.0%
Motorcycles	4-stroke 250 - 750 cm^3	Conventional	180,979	3.8%
Motorcycles	4-stroke 250 - 750 cm^3	Mot - Euro I	0	0.0%
Motorcycles	4-stroke 250 - 750 cm^3	Mot - Euro II	0	0.0%
Motorcycles	4-stroke 250 - 750 cm^3	Mot - Euro III	0	0.0%
Motorcycles	4-stroke >750 cm^3	Conventional	0	0.0%
Motorcycles	4-stroke >750 cm^3	Mot - Euro I	0	0.0%
Motorcycles	4-stroke >750 cm^3	Mot - Euro II	0	0.0%
Motorcycles	4-stroke >750 cm^3	Mot - Euro III	0	0.0%

Table A-4 Other Parameters

Parameter	Input
Road share percentage	100% urban
Canister size	(DSITIA, 2014)
Fuel tank size	
Fuel injection percentage	
RVP	
Sulphur and metal content in fuel	

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